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RESEARCH ARTICLE

Impact of green knowledge management and green technology innovation on circular economy practices with social psychology driven sustainability metrics as a mediating factor

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ABSTRACT

India envisions 2047 as a sustainable, inclusive, and technologically advanced nation, it is crucial to implement circular economy practices. With a population of over 1.4 billion, focusing on circular economy practices can help to enhance resource efficiency, economic growth, and cost savings, while promoting innovation, sustainability, and resilience. For an economically viable future, now is the right time to think innovatively and develop new strategies to enhance circular economy practices. Considering the current scenario, this study investigates the impact of green knowledge management (GKM) and green technology innovation (GTI) on circular economic practices (CEP) and also examines the mediating effect of social psychology-driven sustainability metrics (SPSM) between these factors. Structured questionnaires were distributed to 313 Indian manufacturers, and the collected data were tested using SPSS and AMOS software. The statistical analysis shows that two elements, green knowledge and technology, have a significant impact on circular economy practices and that social psychology-driven sustainability metrics partially and fully mediate between these factors. This study is one of the pioneering studies on the concept of circular economy practices, and this research adds value by demonstrating how green knowledge and technology help manufacturing firms develop more efficient processes, make clear decisions, and analyze how sustainability metrics provide a quantifiable assessment and growth.

Keywords: Social psychology; sustainability metrics; circular economy practices; green knowledge management; green technology

1. Introduction

Nowadays, the manufacturing sector in India is seen transforming to technological advancement, shifting to consumer preferences, supply chain resilience, government policies, and environmental concerns

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[1]. To thrive, the manufacturer adapts the eco-friendly practices in the product with technological advancement and creates value for customers. The improving interest in using digital technology to change the circular economy practices in the manufacturing industry reflects the global efforts for Industry 5.0 and sustainable development [2]. A circular economic practice is an economic model that promotes the sustainable development of the organization. As a traditional way of approach, manufacturing industries usually followed the linear model of disposing of materials. Later, they shifted towards circular economic practices. To reuse the main resources, the 3R strategies were effectively used [3]. These strategies enhance the brand reputation, reduce waste, increase cost efficiency, and increase sustainability and competitiveness.

The major outcomes of this strategy are achieving brand reputation, reducing major costs, minimizing waste, and, most importantly, achieving sustainability and worldwide competitiveness.

The UN's Sustainable Development Goals (SDGs) strongly advocate for circular economic practices, especially in the digital transformation era, as a pathway to enhance organizations' overall economic growth and play a significant role in global development by 2030 [4]. By implementing new factors related to green concepts, such as Green Knowledge Management (GKM) - acquiring knowledge based on green categories and Green Technology Innovation(GTI), which adds new technological concepts to existing ones, manufacturing industries can reduce environmental impact and increase sustainability [5].

These factors need to be implemented in Indian Manufacturing sectors as they continuously focus on automation, Industry 5.0, digitalization, and, most importantly, staying competitive worldwide.

This not only helps individuals and organizations but also plays a major role in economic development by increasing productivity, creating jobs, and reducing unemployment, GDP, and exports in the Indian manufacturing sector [6,8]. The Indian manufacturing sector is influenced by various factors such as technological advancements, government policies and practices, global competition, demand for skilled labor, lean manufacturing, and sustainability processes.

However, there are some specific research gaps in the current literature, particularly where we have focused on circular economic practices in the Indian manufacturing industry, and only a few studies have been carried out in this sector [9]. In the previous research, focus was given to different aspects of sustainability models like waste management, energy efficiency, and environmental sustainability. There is limited research on these two green elements in the Indian scenario. Similarly, few studies have explored the mediating role of sustainability metrics, as the combination of variables such as circular economic practices, green knowledge management, and green technology innovation has not yet been studied among manufacturers [10]. From the above analysis, this research is concerned with addressing these gaps specifically in automotive and textile manufacturing units. Since the Indian manufacturing sector size value will reach US$1 trillion by 2025- 2026 [11], FY 2023-24, India's manufacturing sector production increase remained at 1.4 percent, compared to 4.7 percent in FY 2022-23. As per the estimated predictions, the manufacturing sector will contribute around 13-14 percent of GDP in 2025. Circular economic practices in the previous industrial revolution 4.0 were mainly concerned with automotive, IOT, reducing waste, and energy efficiency. Currently, we are towards the fifth industrial revolution 5.0, where the manufacturers integrate green production and smart manufacturing along with a human-centric workforce [12]. However, most of the companies have not yet implemented Industry 5.0 practices. To address this gap, the study aims to explore key factors essential for India's economic development, focusing on green knowledge management and green technology innovation as potential drivers of circular economy practices.

The impact of Green Knowledge Management (GKM) and Green Technology Innovation (GTI) on Circular Economy (CE) practices will be the major analysis of this study, as both are crucial to advancing

sustainable development. The direct relationship between GKM and GTI in circular economy practices provides only the outer-layered concepts. To make it broader, additional factors related to this concept are highly needed to address more complicated relationships around the circular economy. Social Psychology-driven Sustainability Metrics (SPSM) play a vital role alongside these relationships, providing a broader outline for green and circular practices.

To understand the most critical part i.e, how human behaviour influences sustainability outcomes, the role of social psychology, along with sustainability metrics, provides a novel way to prove this relationship [13]; [14]. To clearly understand how organizations adopt and sustain circular economy practices, there is s huge need to examine the role of psychological drivers such as attitudes, motivation, and behavioral intentions. The introduction of socio-psychological drivers is crucial for the implementation of CE practices because technological changes alone won't bring any impact on sustainability; a deeper change in mindset and behavior at both the organizational and societal levels also needed.

The linkage between the study variables, such as green knowledge, technology, and circular economy practices, has been examined by many researchers [15] using varying factors like green supply chain management, environmental innovation, and eco-efficiency. However, a gap remains in exploring how human behaviour, specifically social psychology-driven sustainability, which is a crucial factor in the current organizational context, can enhance the concept of the circular economy.

Behaviorally informed policies and practices, emphasizing social psychology-driven sustainability metrics based on the current global context, are the need of the hour. Due to the emergence of new and fast-evolving business practices, organizations must enhance not only their technological aspects but also, and more importantly, their behavioral aspects [17-19]. By analyzing the mediating effect of SPSM, the current study provides new insights into how socio-psychological aspects drive sustainable practices and tests how they enhance the circular economy practices. Therefore, the major objectives of this study are to analyze the impact of green knowledge management and green technology innovation on circular economy practices, with social psychology-driven sustainability metrics as a mediating factor.

The theoretical contributions of this study are as follows: As a primary impact, the present study examines the key antecedents of circular economy practices, namely green knowledge management and green technology innovation, particularly in Indian practices for outcome-based transformations in the manufacturing sector. Second, this study is one of the few to integrate social psychology-driven sustainability metrics into these relationships, offering a fresh perspective on the intersection of green technologies, knowledge management, and social psychology. Third, the study fills a significant gap in the existing literature, which remains limited in its exploration of the interplay between green concepts, circular economy practices, and social psychology, particularly within the Indian context.

Definitions

Green Knowledge Management

"Green Knowledge Management uses knowledge management models and methods to implement and promote environmental sustainability. Its integration and interaction with existing environmental management and green approaches, as well as the networking of environmental information into environmental knowledge" – [Dornhofer, 2017]

Green Technology Innovation

"Green Technology Innovation refers to the development of new and improved techniques and methods that promote the use of environmentally friendly materials and processes to reduce the negative impact on the planet" – [Sustainable Production and Consumption, 2019]

Circular Economy

"The circular economy is an economic model that aims to eliminate waste and promote sustainability through reuse and resource efficiency. Through sharing, repairing, refurbishment, remanufacturing, and recycling, this model creates a closed-loop system that minimizes the amount of resources used. It also reduces the creation of waste, pollution, and carbon emissions – a leading cause of climate change" – [Amanda McGrath, Alexandra Jonker, IBM]

Social Psychology and Sustainability Metrics

"The study of how an individual's thoughts, feelings, and actions are affected by other people, whether actual, imagined, or symbolically represented. In essence, even just imagining another person watching you influences how you will process information, behave, and react – and this is something social psychologists strive to understand" – [American Psychological Association (APA)]

"Sustainability metrics and indices are measures of sustainability, using numbers to quantify environmental, social, and economic aspects of the world. There are multiple perspectives on how to measure sustainability, as there is no universal standard. Instead, different disciplines and international organizations have offered measures or indicators of how to measure the concept" – [Wikipedia]

2. Theoretical backgrounds and related literature

Most of the researchers have investigated knowledge sharing in circular economic practices. Only very few studies suggest the effect of two green elements – GKM and GTI on circular economy (CE) practices. However, very few studies have considered these two green elements with sustainability metrics performance monitoring in the manufacturing sector [20]; [21]. In this study, the researcher applied various methodologies, approaches, and instruments to evaluate the different factors.

Resource-Based View Theory

This theory plays an important role in enhancing circular economic practices with special reference to the employees working in the Indian manufacturing sector [22]. Penrose (2009) proposed this theory of how the organization is based on the resources used to generate new products with sustainability and competitive advantage. This RBV theory proposed that organizations must be scarce, unique, and rare to enhance their circular economy inventiveness program [23]. In this study, the application of Natural resource-based view (NRBV) and Knowledge-based view (KBV) theories, an extension to RBV theory, has been included. Hart (1995), NRBV significantly contributes to the developing topic of competitive social sustainability, which still lags behind environmental sustainability. This theory comprises four resources concerned with the optimization of sustainability and competitiveness, which tend to address both ecological and societal sustainability in the company's operations. Robert M. Grant (1996), KBV theory helps companies in a socially embedded dynamic nature tof knowledge to produce socially responsible products, processes. Through which knowledge gets disseminated throughout the organization by involving not only an individual but the whole organization in terms of culture.

In this study, a combination of three theories links the impact of green elements on circular economic practices, highlighting the usage of organizational resources, knowledge sharing, and technology with social sustainability. This theory explains how organizations impact their capacities to achieve long-term environmental and economic sustainability.

2.1. Green knowledge management, green technology innovation on circular economy practices

Environmental challenges like polluted air, industrial waste, and soil degradation urge the automotive and textile industries to incorporate ecologically friendly knowledge and processes in terms of GKM and

GTI. Particularly, eco-friendly knowledge formed if used effectively, improves the environmental sustainability in these sectors, also found to enhance the circular economy significantly [24]. Previous research emphasized a strong association of green product innovation on CE by supporting a resilient and sustainable economy by incorporating best sustainable product development practices, with a positive impact on corporate social performance [25]. On the other hand, both GKM and GTI were found to have a significant impact on the transition from a linear economy and leveraging organizations' sustainability, which leads to social sustainability [26]. The best use of resources and waste generation reduction, the circular economy model offers a solution to these resource and environmental challenges through product reuse, recycling, remanufacturing, and refurbishment, a good alternative approach to a linear model of 'take, make, dispose of' [27]. This approach increases economic opportunities mainly for fast-growing and industrializing countries like India, where there exists an implementation challenge. This can be overcome through digital technology usage, which results in green innovation and positive organizational development, corporate environmental responsibilities, thus enhancing circular economy practices [28];[29].

H1: Green knowledge management positively affects the circular economy practices

H2: Green technology innovation positively affects the circular economy practices

2.2. Green knowledge management with social psychology driven sustainability metrics

According to [30], GKM and its outcomes remain an understudied topic, and he undertook a study with GKM. In this study, to address this literature gap and to support the theories, GKM's direct relationship with SPSM has been studied. The enhancement in the healthy economic and social environmental dimensions helps manufacturing units improve their performance through an environmentally responsible, friendly knowledge system by incorporating social psychology-driven sustainability metrics [31]; [32]. Besides its potential benefits, a set of challenges can be overcome by factors such as stakeholder pressure, allocation of resources, a supportive organizational culture, and practices combined with a balanced scorecard approach in facilitating sustainable indices or frameworks to attain desired outcomes closer to sustainability [33]. Particularly, green knowledge acquisition and stakeholders' pressure seem to have a significant result in improving manufacturing unit's performance in the environmental context, through effective green knowledge management, which in turn has a strong positive association and positive impact on the overall sustainable performance of Indian manufacturing units from the previous study [34]; [35]. Similarly, organizational culture concerning social well-being seems to positively moderate between the environment and employee behavioral context. On the other hand, environmental knowledge management practices, especially knowledge sharing and application, were found to have a positive effect on employees' green behavior and intention [36]. Furthermore, utilizing green data analytics along with green knowledge management enables manufacturers to innovate and improve environmental strategies, which is evident from the previous research [37].

H3: Green knowledge management promotes companies' social psychology-driven sustainability metrics

2.3. Green technology innovation with social psychology driven sustainability metrics

The significant rise in sustainability requirements, social well-being, environmental rules, and consumer awareness makes manufacturing units develop ecologically friendly technology and practices, an alternative technique to conventional systems, thus aiming to reduce environmental hazards through green technology innovation and which in turn gives a better social and environmental performance [38]. Previous researchers highlight the importance of implementing green knowledge through which CO2 emission and waste generation can be minimized, and one of the crucial sustainable goals of climate change can be overcome by

producing recyclable products through the application of innovative technologies [39]. The success of green management practices lies in the firm's socially responsible product design and commitment, which are considered important performance measures in terms of psychological aspects among employees in designing such products. By increasing green innovation technology, manufacturers can enhance their environmental and social performance scores by providing their customers with a responsible social image with sustainable products or services, resulting in the way to greater financial benefits [40]. Some of the high-performing sectors identified from previous studies are the chemical, automotive, food, and pharmaceutical industries (India Brand Equity Foundation – Manufacturing industries in India 2025 report). And, these studies highlight that Indian medium-sized enterprises are better performers of green management practices than small-scale enterprises, where large-scale enterprises range in the predominant position [41]. In particular, garment export production firms' environmental and operational performances were significantly influenced by green innovation according to [42]. On the other hand, green innovation is greatly impacted by the digitalization of technology like IoT, AI, and blockchain by enabling real-time monitoring, resource optimization, and transparency in the supply chain particularly in Indian manufacturing units, thus enhancing sustainable performance [43]; [44]. Similarly, previous research suggested that green constructs, especially social influence, have a significant relationship with the adoption of green innovation in manufacturing operations [45].

H4: Green technology innovation promotes companies' social psychology-driven sustainability metrics

2.4. Social psychology driven sustainability metrics on circular economy practices

Each manufacturing sector requires a new sustainability index or indicator classified into the triple bottom line, which needs to be developed to assess social, economic, and environmental sustainability. The social and environmental issues were found to have been well addressed through social psychology, which in turn contributes significantly to the sustainable development goals of an organization [46]. Through SPSM, the key sustainable development goal of a good, healthy, and social environment can be attained [47]. By adopting lean manufacturing, Six Sigma, and green strategies, firms can able to evaluate their sustainability performance and find a notable increase in these indices it as evident from the research [48]. Similarly, the most commonly used performance measure to assess circular economy practices is the balanced scorecard index, which insists that organizations focus on both financial and socio-environmental outcomes [49]. According to Harvard Business School, "The balanced scorecard combines the traditional financial perspective with additional perspectives that focus on customers, internal business processes, and learning and development". These perspectives help organizations to measure all the necessary activities in terms of their own set of metrics by using human, information, and organizational capital to culturally align with the common goal of the company with the perspective of social responsibility [50]. Another vital approach researchers identified for measuring circular economy practices among manufacturing units is the five key performance indicators (KPIs) through social network analysis (SNA). The result found that strategies and initiatives KPI is the foremost important indicator in enhancing circular economy practices, and KPI selection varies among different manufacturers depending upon their objectives, and other characteristics [51].

H5: Social psychology-driven sustainability metrics will enhance circular economy practices.

2.5. Social psychology driven sustainability metrics as a mediator

Green elements using specific digital technology AI-driven circularity index, lead to the evaluation and improvement of product lifecycle sustainability was found to have an important role in the transition process of organizations towards a circular economy [52]. It was empirically found that there exists a strong relationship between organizations under institutional pressure and a circular economy, suggesting that these

firms have better zero waste management when compared to others. Furthermore, through zero waste practice, firms can significantly enhance the circular economy [53]. To address these hurdles, companies need to provide a sufficient eco-knowledgeable, pro-behavioral environment to their employees and customers, so that through green knowledge along with innovation, sustainable development can be enhanced by effective usage of green knowledge [54]. Previous studies suggest that there exists a strong relation between the links between eco-social behavior and entrepreneurial success, where social and firm innovation seems to have a mediating effect [55]. However, very minimal studies have been carried out on the importance of the sustainability index in the automotive and textile manufacturing sectors. Thus, our conceptual model specifically used SPSM as a mediator between green elements – GKM, GTI, and CE.

H6: Social psychology-driven sustainability metrics mediate between green knowledge management and circular economy.

H7: Social psychology-driven sustainability metrics mediate between green technology innovation and circular economy.

2.6. Conceptual framework

The proposed research model is shown in Figure 1.

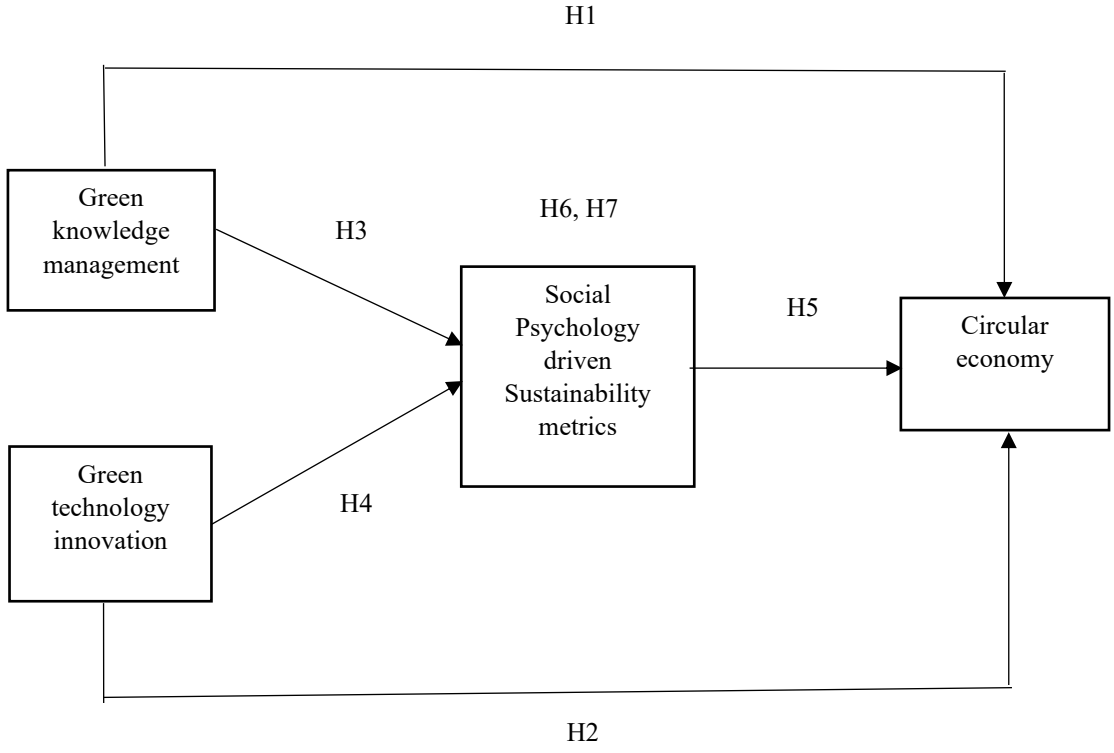

Figure 1. Proposed Research Model

3. Methodology

The conceptual model was proposed to measure how green elements – GKM and GTI have enhanced the circular economy practices among the MSME (Micro, Small, and Medium enterprises) manufacturing, specifically in the automotive and textile industries. According to the Government of India press information (February 2025), there are 5.93 crore registered MSMEs. For our study, we took MSMEs in the automotive and textile industries in India. All the responses were collected through a survey questionnaire using a combination of cluster and multistage random sampling methods of probability sampling technique. We took

a sample of 313 respondents working as middle-level managers in automotive and textile manufacturing units. All the construct scales comprise a total of 22 questions on a five-point Likert scale with 1 as "strongly disagree" and 5 as "strongly agree".

3.1. Respondents' profile

The demographic variables of the employees show that the majority of participants are male (75%), ranging between the age group of 30-39 years (60%), holding an undergraduate degree (55%), and the majority of them have experience more than 3 years (75%) with a monthly income more than 40k (85%). In terms of designation, the majority of the employees fall under middle-level managers (55%), followed by senior-level managers (35%).

3.2. Measurement instruments

Green elements – GKM, and GTI scales have been adopted from [56]; [57]; [58]which comprised five questions each, with a sample item as "Employees and partners at our organization have easy access to information on […]" and "Our organization is actively involved in the redesign and improvement of products or services to […]". For this study, a set of framed questions was drafted for sustainability metrics performance monitoring and circular economy, according to the objectives and variables used in this study. For this purpose, to attain the accuracy and reliability of scale items, all the necessary factors were added. The frame consists of 17 questions on a five-point Likert scale, with 1 as "not suitable" and 5 as "highly suitable", with 10 and 7 questions assigned to sustainability metrics and performance monitoring, respectively. Framed items were then distributed and collected from 30 respondents, where 20 were industrialists and 10 were academicians, and a ten-point rating scale was used to collect responses with ratings from "not suitable" to "highly suitable". Final items on the scale were selected based on the rule of thumb with 70 percent agreement items from the experts included, and the remaining items were excluded from the scale [59]. Then, only 7 questions under sustainability metrics performance monitoring and 5 questions under circular economy were considered for this study. Finally, a questionnaire with both framed and structured scales consisting of a total of 22 questions was drafted. An example of sample items for social psychology-driven sustainability metrics is "SPSM is effective in measuring the long-term impact of Circular Economy practices on organizational culture and behavior […]" and circular economy is "Circular economy principles strongly influence the design and […]". The survey data shows a high-reliability coefficient of greater than 0.70 for all the study variables, and then exploratory factor analysis was performed.

3.3. Data Collection and Analysis

A survey method was used to collect primary data through a questionnaire via emails, telephones, and direct communication with the respondents of automotive and textile manufacturing units. For analysis of the data, SPSS software was used to analyze descriptive statistics and reliability. Whereas, AMOS software measures confirmatory factor analysis (CFA) and Structural equation modelling (SEM).

4. Results

For this study, the first confirmatory factor analysis (CFA) identifies whether all the goodness of fit indices have met the threshold limit for the measurement scales of green knowledge management (GKM), green technology innovation (GTI), social psychology-driven sustainability metrics (SPSM), and circular economy (CE). Once the result had a good model fit, all the proposed seven hypotheses were tested using SEM.

4.1. Findings from descriptive statistics and Cronbach's alpha coefficient (Cα)

Table 1, the result suggests that the Cronbach's alpha coefficients (Cα) calculated for all four study variables were found to range between 0.874 to 0.911, which is greater than 0.70. Next, Harman's (1967) single-factor was applied to identify the presence of common method bias (CMB). The findings show that the first factor out of the total variance constitutes 33 percent, which is less than 50 percent, thus indicating no concerns of common method bias. Thus, the sample taken for the study has a favourable impression of all four latent variables among employees at automotive and textile manufacturing units. Since the Kaiser-Meyer-Olkin (KMO) values are calculated to be 0.918, greater than 0.06, and are found to be significant with Barlett's measure ($P < 0.05$), this indicates excellent sampling adequacy, which led the researcher to proceed with factor analysis.

Table 1. Mean, Standard deviation, Cronbach's alpha (Cα)

Variables	Mean	SD	Cα
Green knowledge management	4.21	0.821	0.874
Green technology innovation	3.96	0.733	0.891
Social psychology-driven sustainability metrics	4.33	0.676	0.911
Circular economy	4.67	0.788	0.900

4.2. Findings from confirmatory factor analysis

Confirmatory factor analysis was used to test the model's fitness using AMOS 18.0. The overall model fit denotes the degree to which the indicators represent the respective hypothesized latent constructs, such as GKM, GTI, SPSM, and CE. The parameters used to test model fit are: - GFI – Goodness of the fit index, AGFI – Adjusted goodness of fit index, NFI – Normed fit index, TLI – Tucker-Lewis index, CFI – Comparative fit index, RMSEA – Root mean square error of approximation, and PCLOSE. Table 2 shows the overall fit indices of our proposed measurement model, which were found to be a good model fit as all the parameters met the required threshold limits as given by [60]; [61].

Table 2. Model fit indices

Indices	CMIN	GFI	AGFI	NFI	TLI	CFI	RMSEA	PCLOSE
Threshold limit	<3	>0.90	>0.90	>0.90	>0.90	>0.90	<0.08	>0.05
Observed values	1.652	0.914	0.892	0.935	0.969	0.973	0.046	0.758

Table 3 gives the findings of the measurement model summary. The result suggests that all composite reliability (CR) values exceeded 0.70, with a range of values (0.858 to 0.942). All average variance extracted (AVE) values have met the threshold limit of 0.50. All maximum shared variance (MSV) values are less than corresponding AVE values, and all the values of maximum reliability, MaxR(H), are higher than the CR values of corresponding latent variables of the study. According to [62]; [63]; [64]in our proposed model, all four measurements – CR, AVE, MSV, and MaxR(H) have met the threshold limits, and the constructs factor loadings are displayed in Figure 2.

Table 4 results indicate that our research model has good discriminant validity, as AVE square root values (0.742 to 0.862) are greater than the correlation values of constructs (0.269 to 0.619).

Table 3. Measurement model summary

Construct	Items	Estimate	CR	AVE	MSV	MaxR(H)
Social psychology-driven sustainability metrics (SPSM)			0.942	0.701	0.383	0.947
	SPSM_4	0.882				
	SPSM_3	0.858				
	SPSM_5	0.851				
	SPSM_2	0.887				
	SPSM_6	0.786				
	SPSM_1	0.845				
	SPSM_7	0.742				
Green technology innovation (GTI)			0.935	0.744	0.143	0.940
	GTI_3	0.910				
	GTI_4	0.873				
	GTI_5	0.863				
	GTI_2	0.867				
	GTI_1	0.795				
Green knowledge management (GKM)			0.886	0.610	0.177	0.898
	GKM_2	0.882				
	GKM_3	0.766				
	GKM_4	0.785				
	GKM_5	0.753				
	GKM_1	0.707				
Circular economy (CE)			0.858	0.550	0.383	0.868
	CE_2	0.776				
	CE_1	0.789				
	CE_3	0.780				
	CE_4	0.750				
	CE_5	0.597				

Table 4. Discriminant validity

	GKM	SPSM	GTI	CE
GKM	**0.781**			
SPSM	0.346	**0.837**		
GTI	0.378	0.272	**0.862**	
CE	0.421	0.619	0.269	**0.742**

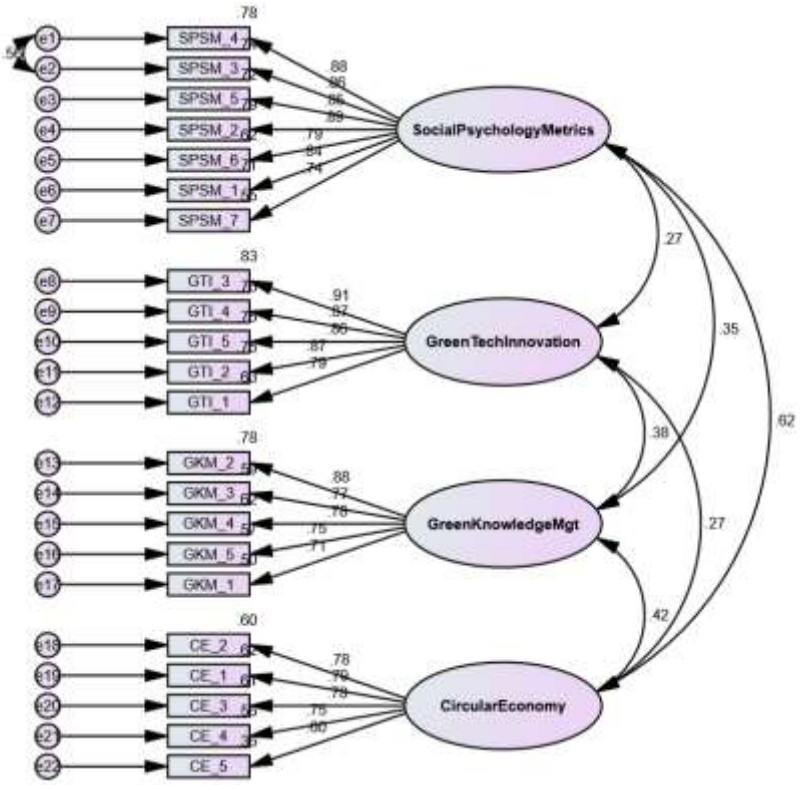

Figure 2. Measurement model summary

4.3. Findings from structural equation modelling – Direct effects

The hypothesis testing and the estimated values are shown in Table 5. As given in the table, green knowledge management is found to have significant effects on circular economy practices ($\beta = 0.376$, $p < 0.05$) and social psychology-driven sustainability metrics ($\beta = 0.287$, $p < 0.05$). Similarly, green technology innovation is found to have significant effects on the circular economy ($\beta = 0.146$, $p < 0.05$) and social psychology sustainability metrics ($\beta = 0.179$, $p < 0.05$). And, social psychology-driven sustainability metrics are found to enhance the circular economy practices ($\beta = 0.531$, $p < 0.05$). Hence, the proposed five hypotheses, H1, H2, H3, H4, and H5, have been supported, and the direct effects of GKM and GTI on CE are shown in Figure 3.

Table 5. Hypothesis test

Hypothesis	Effects	Estimate	P value	Result
H1	GKM – CE	0.376	***	Accept
H2	GTI – CE	0.146	*	Accept
H3	GKM – SPSM	0.287	***	Accept
H4	GTI – SPSM	0.179	*	Accept
H5	SPSM - CE	0.531	***	Accept

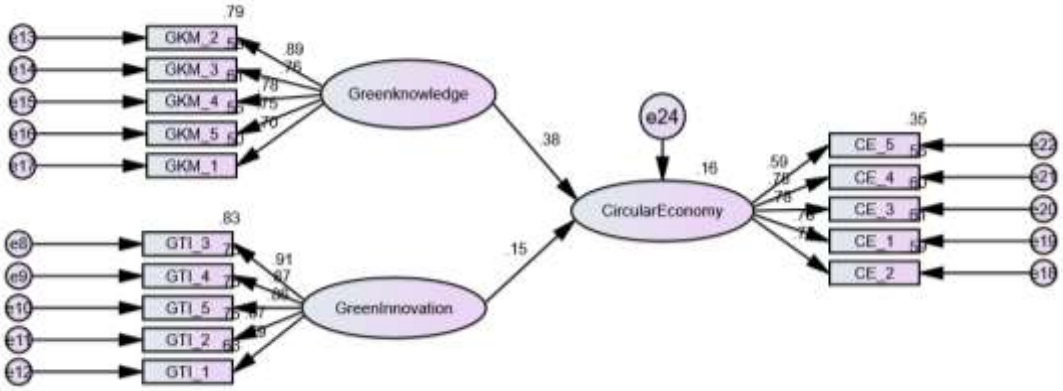

Figure 3. Direct effect of GKM, GTI on CE

4.4. Mediation effect

The bootstrap analysis was performed with 5000 samples and a confidence level of 95% to investigate the mediating effect of social psychology-driven sustainability metrics between green elements and circular economy practices. The indirect effects of green knowledge management (GKM) and green technology innovation (GTI) on the circular economy (CE) were found to be 0.101 and 0.067. To know the significance of the indirect effect and whether it falls within the 95% confidence level as generated by the bootstrap, the lower bound and upper bound confidence intervals are considered. The confidence interval lower and upper limits for green knowledge management are 0.059 and 0.157, and for green technology innovation are 0.026 and 0.125, respectively. There is no zero between the lower bound and upper bound confidence interval; it shows a significant indirect effect. The value (0.000) at the intersection of green knowledge management, green technology innovation, and circular economy shows significance at two-tailed, thus concluding that social psychology-driven sustainability metrics mediate between the two green elements (GKM, GTI) and circular economy.

4.5. Mediation types

To identify the type of mediation, the C path is examined, which is the direct path from GKM and GTI to a circular economy, and a full structural model is given in Figure 4. The type of mediation shown in Table 6, it was found that there exists a direct effect of green knowledge management, social psychology-driven sustainability metrics on circular economy (0.147, $p < 0.05$), with a significant indirect effect means SPSM partially mediates the effect of GKM on CE. And, there exists an insignificant direct effect of green technology innovation, and social psychology-driven sustainability metrics on circular economy (0.036, $p = 0.330$), with a significant indirect effect means SPSM fully mediates the effect of GTI on CE.

Table 6. Type of mediation

Relationship	Direct effect	Indirect effect	CI Lower Bound	CI Upper Bound	P	Conclusion
GKM → SPSM → CE	0.147 (0.000)	0.101	0.059	0.157	0.000	Partial mediation
GTI → SPSM → CE	0.036 (0.330)	0.067	0.026	0.125	0.000	Full mediation

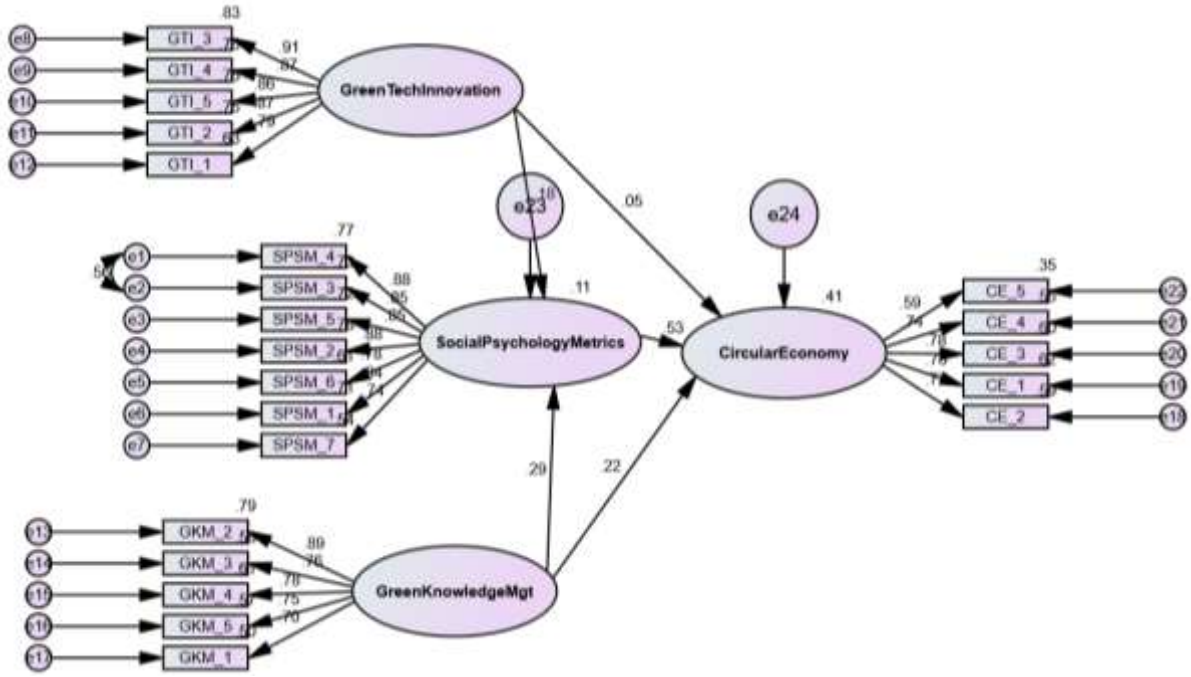

Figure 4. Effect of GKM, GTI on CE through SPSM - SEM

5. Discussion

Impact of green knowledge management and green technology innovation on circular economy practices with social psychology-driven sustainability metrics performance monitoring as a mediating factor

The study found that enhancing circular economy practices, especially in the Indian manufacturing sector, may significantly boost company profits. This can be achieved through an eco-friendly knowledge-sharing system and by designing the product with recyclable materials used in the organization [65]. Adapting sustainable practices not only helps protect the environment but also generates a chance for a reduction in expenses and operational efficiency with long-term profitability [66]. Further, sustainable practices help in the reduction of expenses and achieving operational efficiency, resulting in enhanced long-term profitability of the organization. The organization reuses the material with eco-friendly knowledge sharing and eco-friendly technologies like biodegradable materials, waste-to-energy products, to minimize the environmental impact. The SEM model shows that GKM and GTI positively and significantly influence circular economic practices (H1 and H2). Green knowledge management and green technology innovation positively and significantly influence sustainability metrics performance monitoring (H3 & H4). Sustainability metrics performance monitoring positively and significantly influences circular economy practices (H5). Overall, this study found that for, green knowledge management (0.147, p=0.000), there is a partial mediation effect on circular economy practices, and for green technology innovation (0.036, p = 0.330), there exists a full mediation effect on circular economy practices through sustainability metrics performance monitoring which supports H6 & H7.

Theoretical and practical implications for business

5.1. Green knowledge management & green technology innovation have a significant positive impact on circular economy practices

Circular economy practices are becoming vital for automotive and textile companies because they help cut waste, use resources more efficiently, and lower costs, all while benefiting the environment. When

companies combine green knowledge management (GKM) with green technology innovation, they bang into a powerful mix of sustainable thinking and practical solutions that drive progress. GKM helps teams share ideas on sustainability and eco-friendly practices, encouraging constant improvement, while green technology innovation introduces advanced tools and methods to reduce the environmental impact even further. Studies by [67]; [68]; [69]; [70] show how combining these two approaches can make a difference in achieving circular economy goals. As consumers become more conscious of sustainability concepts and the government takes several steps toward environmental laws, it has become mandatory for all types of businesses to adopt circular economy practices to stay ahead. All organizations can implement systems that support knowledge sharing, foster a culture of innovation, and motivate their suppliers and partners to also engage in green technologies, ultimately paving the way for a competitive edge and helping the planet.

5.2. Green knowledge management & green technology innovation have a significant positive impact on social psychology-driven sustainability metrics

The sustainable behaviors of employees have become a more important factor in the development of automotive and textile manufacturing organizations, and they can be achieved through social psychology-driven metrics. These metrics are crucial as they reflect employees' values, attitudes, and behaviors towards sustainability goals, along with the environmental impact of the business. To achieve these metrics, the role of green knowledge management and green technology innovation is vital. The main concept of green knowledge management is sharing knowledge among employees, encouraging them to adopt sustainability practices, and fostering environmental responsibility in all their decision-making processes. In addition, to implement sustainable practices more efficiently, the role of green technology innovation is essential, further aligning organizational processes with sustainability objectives. Studies by [71]; [72]; [73]; [74] indicate how sustainable metrics can be achieved by implementing GKM and GTI, as well as improving organizational behavior and decision-making processes. As sustainability becomes the core business strategy, this approach linking GKM, GTI, and SPSM is crucial in today's technology-saturated world. Organizations need to invest more in knowledge-sharing methodologies, an innovation-driven culture, and ensure that their stakeholders integrate green technologies to ensure sustainability in an efficient way.

5.3. Social psychology-driven sustainability metrics have a significant positive impact on circular economy practices

Employee attitudes, behaviours, and commitment towards sustainability are derived through social psychology-driven sustainability metrics. By helping employees understand the need for social dynamics and fostering a culture of eco-consciousness, the adoption of circular practices becomes more flexible. Many researchers [75]; [76]; [77]; [78] highlight the potential linkage between social psychology and circular economy adoption. This mixed approach is crucial for long-term sustainability and achieving environmental goals. To strengthen their circular economy initiatives, organizations need to invest more in cultivating a culture of sustainability among employees and integrating green technology concepts.

5.4. Social psychology-driven sustainability metrics mediate between green knowledge management, green technology innovation, and circular economy practices

The mediating role of social psychology-driven sustainability metrics is crucial and significant between green knowledge management, green technology innovation, and circular economy practices. These psychology-driven metrics partially mediate between GKM and circular economy practices, demonstrating how knowledge-sharing behavior and sustainable practices foster an eco-conscious workforce. Additionally, the psychology-driven metrics fully mediate between GTI and circular economy practices, offering a new way of integrating technology and human nature towards sustainability. If organizations, such as those in

textile and automotive industries, foster sustainability through these metrics, they can easily achieve both their internal practices and environmental goals.

As a final contribution, the present study suggests many initiatives in terms of green technology, like energy-efficient types of machinery, renewable energy resources, to minimize resource consumption. Also, on the other hand, green initiatives such as AI-related real-time dashboards, knowledge-sharing technological platforms, and performance monitoring systems improve the overall organizational performance and sustainability process. The R&D departments of Indian manufacturing units need to focus on critical aspects like recyclable product designs and the usage of eco-friendly products to attain the circular economy and sustainability practices in an effective way. The zero-waste manufacturing system should also be implemented, and efforts to be made to find waste-to-energy within the organization.

6. Conclusion

In conclusion, this study underscores the critical role of green knowledge management and technology innovation in shaping sustainable circular economy practices. By highlighting the mediating influence of social psychology-driven sustainability metrics, it provides a comprehensive framework for manufacturers to enhance efficiency and resilience. The findings emphasize that a shift towards sustainable practices is not only vital for India's future but also offers a path to a globally competitive, resource-efficient economy. Policymakers should prioritize the eco-friendly manufacturing system and invest in R&D for green technology innovation to minimize resource consumption. The Indian manufacturing sector minimizes the linear economy model and strengthens circular economic model practices. This effort will improve the organization as well as environmental conservation and help achieve sustainable goals by 2030 and the vision of sustainability for 2047.

7. Limitatiosns and directions for future research

This study has some limitations and future directions to be addressed. First, though our findings contribute to the particular economic practices concerning automotive and textile manufacturing units, additional research focusing on other manufacturing sectors needs to be conducted. Second, only specific employees working in the selected firms as middle-level managers have been taken for data collection; hence, focusing on another category of workforce is necessary to make better inferences on these units. Third, we sampled 313 respondents from different organizations, which does not represent the entire population of these two manufacturing units. In this same context, the sample size can be increased to help in the generalization of the population with some other combination of sampling methods based on demographic strata. Fourth, this research incorporated two green elements as independent variables, SPSM as a singular mediating variable, so future studies can include other variables like green HRM, green leadership, and sustainable digital transformation to enhance circular economy practices. Finally, the setting up of sustainability indices and performance indicators varies between firms; a deep study into the development of these indices is required in future research models to better investigate the generalizability of these research findings.

Conflict of interest

The authors declare no conflict of interest

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