Linking Innovative and Analytical Reasoning to Sustainable Manufacturing: The Mediating Role of Strategic Thinking

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ABSTRACT

This study investigates the mediating role of managers' strategic thinking in the relationship between innovative thinking, analytical reasoning, and sustainable manufacturing. A total of 150 managers from manufacturing firms were invited via email to participate in the study, with data collected through structured surveys. The analysis revealed that both analytical reasoning and innovative thinking had significant positive effects on strategic thinking, supporting the proposed relationships. However, neither analytical reasoning nor innovative thinking showed a direct significant effect on sustainable manufacturing, leading to the rejection of their direct influence. In contrast, strategic thinking was found to have a significant and positive impact on sustainable manufacturing, indicating its critical role in driving sustainability outcomes. Further, mediation analysis confirmed that strategic thinking significantly mediated the effects of both analytical reasoning and innovative thinking on sustainable manufacturing. These findings underscore the importance of strategic thinking as a conduit through which cognitive capabilities translate into effective sustainability practices. The study supports the theoretical assertion that reasoning and innovation must be strategically oriented to produce meaningful sustainability outcomes in the manufacturing sector. Overall, the results highlight the necessity of embedding strategic thinking within organizational processes to maximize the impact of analytical and innovative competencies on sustainable development.

Keywords: Innovative Thinking, Analytical Reasoning, Strategic Thinking, Sustainable Manufacturing

INTRODUCTION

In the era of Industry 4.0 and rapid global transformation, innovation and sustainability have emerged as strategic imperatives for manufacturing firms. The integration of innovative thinking, analytical reasoning, and sustainable manufacturing is critical to remaining competitive and resilient in uncertain business environments. However, the actualization of these elements into coherent strategic action often hinges on the cognitive capacity of managers, particularly their strategic thinking abilities. Strategic thinking serves as a vital enabler that allows managers to synthesize innovative insights, apply analytical reasoning, and align operational decisions with long-term sustainability goals. In the context of sustainable manufacturing, this capability is crucial for identifying ways to optimize resource use, reduce waste, and implement environmentally responsible production practices without compromising efficiency or profitability. By adopting a strategic mindset, manufacturing leaders can evaluate the lifecycle impact of materials, embrace circular economy principles, and invest in cleaner technologies that support environmental, economic, and social objectives. Ultimately, strategic thinking ensures that sustainability is not treated as a separate initiative but is embedded into the core decision-making processes across the entire manufacturing value chain.

This study views sustainable manufacturing as the creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources. [1] associate it with green production models that integrate eco-design and user-centered innovation. [2] systematically review Industry 5.0 practices, defining sustainable manufacturing as the combination of advanced technologies with environmentally responsible production. [3] highlight its relevance in the Indian

textile industry, where ecological and societal impacts, along with technological innovations, drive adoption. [4] discuss the role of additive manufacturing in achieving sustainability, emphasizing both opportunities and challenges.

Strategic thinking serves as a vital enabler that allows managers to synthesize innovative insights, apply analytical reasoning, and align operational decisions with long-term sustainability goals. Nevertheless, the lack of integration between innovation thinking and strategic thinking frameworks ([5], [6]) limits the development of comprehensive models that can inform managerial decision-making in real-world contexts. Furthermore, the empirical validation of models linking innovation and strategic thinking within sustainability frameworks remains limited [7], undermining our understanding of how these constructs interact in practice. While [8] propose innovation ecosystems for Industry 4.0 adoption, their frameworks overlook strategic thinking as a mediating or enabling construct. This oversight is particularly critical, given that the successful alignment of technology adoption with sustainable outcomes requires a deliberate and future-oriented mindset at the managerial level.

Despite growing interest in innovation and sustainability, the integration of innovative thinking, analytical reasoning, and sustainable manufacturing within strategic decision-making remains underexplored. Existing frameworks often treat these elements in isolation, lacking a coherent model that captures how managers mediate and align them through strategic thinking. The absence of strategic thinking as a mediating construct in innovation and sustainability models [8] raises questions about how effectively manufacturing firms can embed sustainability into their core strategies. Moreover, limited empirical studies have examined this relationship in a manufacturing context [7], contributing to a significant theoretical and practical gap in the literature. The primary objective of this study is to examine the mediating role of managers' strategic thinking in the relationship between innovative thinking, analytical reasoning, and sustainable manufacturing.

LITERATURE REVIEW

Innovative Thinking and Its Influence on Sustainable Manufacturing

Innovative thinking, often operationalized through frameworks like design thinking and systems thinking, plays a crucial role in advancing sustainable manufacturing practices. Innovation thinking strategies such as protecting the environment and reducing toxic emissions are considered as one of the strategies aimed at competing and gaining a sustainable competitive advantage. Through innovative thinking, manufacturers can discover novel ways to optimize resource use and minimize waste. The application of this concept in manufacturing processes can lead to significant reductions in material consumption and waste production ([9], [1] demonstrate how design thinking fosters the development of green production models by aligning product development with environmental priorities. Similarly, [10], identifies innovation as a driver of competitive advantage in SMEs, with design thinking promoting eco-efficient processes and sustainability. [11] highlight how socio-technical systems design encourages holistic thinking that bridges technology and sustainability goals. Moreover, the integration of Industry 4.0 technologies, as discussed by [8], creates an innovation ecosystem that supports sustainable outcomes. These findings are reinforced by [2], who frame Industry 5.0 as a transformative paradigm incorporating human-centric innovation to further enhance sustainable manufacturing.

Analytical Reasoning and Its Influence on Sustainable Manufacturing

Analytical reasoning is essential in optimizing and implementing sustainable manufacturing systems. Analytical Reasoning is crucial in sustainable manufacturing as it enables organizations to systematically evaluate environmental impacts, optimize processes, and make informed decisions that promote sustainability. By adopting sustainability principles, businesses can become more profitable and sustain their activities over the long term [12]. This cognitive skill involves assessing data, identifying patterns, and applying logical methods to solve complex problems, which are essential for advancing sustainable manufacturing practices. The technologies development provides enormous opportunities for realizing sustainable manufacturing via information and communication technology infrastructure [13]. According to [3], analytical approaches are critical in assessing ecological and societal impacts during the adoption of sustainable manufacturing in textile

industries. [14] illustrate how analytical models support de-manufacturing processes to enhance circular economy practices. [4] similarly emphasize the role of data-driven analysis in addressing additive manufacturing challenges for sustainability. [15] explore how analytical thinking through green knowledge management enhances corporate environmental performance, providing empirical support for integrating analytics into sustainability strategies. Thus, the literature underscores analytical reasoning as a foundation for informed decision-making in sustainable manufacturing.

Innovative Thinking and Its Influence on Strategic Thinking

The nexus between innovative thinking and strategic thinking is well-documented, with innovation serving as a catalyst for strategic transformation. Innovative thinking is a key driver of strategic thinking, as it fosters the generation of new ideas and approaches that can transform an organization's strategy. By encouraging creativity and challenging conventional assumptions, innovative thinking enables organizations to develop forward-looking strategies that address emerging trends and capitalize on new opportunities. In business, innovation thinking is expanding beyond product innovation, and it is being marketed as a catalyst for unique user experiences, businesses, and organizational and cultural change. Innovative thinking facilitates the identification and exploration of new strategic opportunities by encouraging leaders to think beyond traditional boundaries [16]. This approach helps organizations uncover untapped markets, develop novel products, and create disruptive business models. This ability to envision and pursue new opportunities is essential for maintaining competitive advantage and driving economic growth. [17] and [18] explore how creative and systems thinking frameworks empower leaders to reconfigure strategic directions. [19] present a framework for design-driven external analysis, enabling enterprises to adapt strategically to digital disruptions. [20] argue that entrepreneurial innovation, facilitated by forward-thinking mindsets, mediates competitive advantage through strategic foresight. Similarly, [21] note that agile innovation, informed by human factors and ergonomics, supports dynamic strategic adaptability. These insights collectively suggest that innovative thinking is instrumental in shaping proactive and resilient strategic thinking.

Analytical Reasoning and Its Influence on Strategic Thinking

Analytical reasoning is a fundamental component of strategic thinking, as it enables leaders to systematically evaluate complex data, assess potential outcomes, and make informed decisions. By applying analytical reasoning, organizations can enhance their strategic planning processes, anticipate future challenges, and develop robust strategies that align with their long-term goals. Strategic thinking is significantly strengthened by analytical reasoning capabilities, which allow for the systematic evaluation of complex business environments. [22] highlight how AI-driven analytics influence strategic decision-making, showcasing the importance of data interpretation in shaping strategic choices. [5] provide evidence from Volkswagen's Zero Impact Factories, where science-based analytical reasoning integrates into strategic management for sustainability. [23] demonstrate how generative AI applications in design thinking are guided by analytical frameworks that support long-term planning and adaptation. [24] underscore the importance of long-range planning as a form of analytical reasoning that enhances project sustainability. These works confirm that analytical reasoning enhances strategic insight by grounding strategic planning in evidence-based analysis. Analytical reasoning significantly enhances strategic thinking by enabling systematic data evaluation, risk assessment, opportunity identification, and resource optimization. By applying analytical methods, leaders can develop well-informed strategies that address complex challenges and position their organizations for long-term success.

Strategic Thinking and Its Influence on Sustainable Manufacturing

Strategic thinking is integral to advancing sustainable manufacturing practices as it enables organizations to align their long-term goals with environmental, social, and economic sustainability objectives. By incorporating strategic thinking into their decision-making processes, manufacturers can effectively integrate sustainability into their core operations, innovate for environmental efficiency, and achieve competitive advantages through responsible practices. [7] provide empirical evidence of strategic thinking’s mediating role between green innovation and business sustainability, highlighting its integrative power. [25] further reinforce the notion that strategic thinking leads to effective prioritization of sustainability initiatives. Sinha et al. (2024)

show that AI-enabled strategic decision-making enhances sustainability impacts in fashion supply chains, while [26] extend this view to smart manufacturing through strategic AI integration. [6] supports embedding innovations into a company's strategy using the sustainable futures design concept, reaffirming strategic thinking's influence on sustainable manufacturing pathways.

Strategic Thinking as a Mediator in the Relationship Between Innovation, Analytical Reasoning, and Sustainable Manufacturing

Strategic thinking is a crucial mediator in the relationship between analytical reasoning, innovative thinking, and sustainable manufacturing. This argument is grounded in the Resource-Based View (RBV) of the firm and the Theory of Dynamic Capabilities. These theories provide a framework for understanding how strategic thinking can bridge the gap between analytical reasoning and innovation, ultimately driving sustainable manufacturing practices. Analytical reasoning involves systematically evaluating data to make informed decisions. According to the RBV, a firm's unique resources and capabilities, such as analytical skills, can provide a competitive advantage [27]. Analytical reasoning enables firms to gather and interpret data related to market trends, environmental impacts, and operational efficiencies. However, without strategic thinking, this data may not translate into effective strategies for sustainable manufacturing. Strategic thinking acts as a mediator by helping organizations synthesize analytical insights into coherent strategies that address both business goals and sustainability objectives [28]. Innovative thinking is essential for developing new solutions and approaches.

The Theory of Dynamic Capabilities emphasizes that firms must develop the ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments [28]. Strategic thinking mediates this relationship by aligning innovative ideas with the firm's strategic goals and long-term vision. It ensures that innovations are not only novel but also strategically relevant, facilitating the implementation of new technologies or processes that enhance sustainable manufacturing [29]. For example, strategic thinking helps in evaluating which innovative technologies, such as energy-efficient systems or waste reduction methods, align with the company's sustainability objectives. [7] specifically identify strategic thinking as a mediator that enhances the impact of green innovation on business sustainability. The interplay between innovative capability and analytical insight, as synthesized by [31], culminates in strategic decisions that are both creative and data-informed. [31] emphasize how Industry 4.0 technologies, when integrated with strategic thought, transform chemical industries into sustainable enterprises. [32] illustrate how digital capabilities, when strategically deployed, promote product and process innovations that reinforce sustainability goals. Thus, strategic thinking serves not only as a conduit but also as a critical enabler for harnessing innovation and analytics in pursuit of sustainable manufacturing.

Based on the arguments of previous studies and guided by the Resource-Based View (RBV) and Theory of Dynamic Capabilities, this study proposes a conceptual framework as shown in Figure 1 and subsequently builds seven hypotheses.

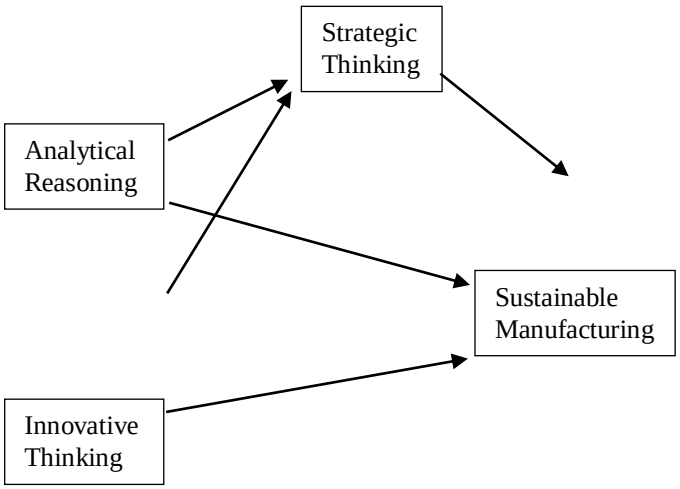

Fig. 1: Conceptual Framework

H1: Analytical reasoning has a significant and positive impact on sustainable manufacturing

H2: Innovative thinking has a significant and positive impact on sustainable manufacturing

H3: Analytical reasoning has a significant and positive impact on strategic thinking

H4: Innovative thinking has a significant and positive impact on strategic thinking

H5: Strategic Thinking has a significant and positive impact on sustainable manufacturing

METHODOLOGY

Sample and Procedures

We collected data from manufacturing firms in Klang Valley, Malaysia. With the assistance of the human resource departments, 150 managers were invited via e-mail to participate in the study. The email explained the purpose of the research, requested their voluntary participation, and provided a link to an online survey. The survey also included items capturing demographic information. A total of 115 managers completed the online survey, yielding a response rate of 76.7%.

Among the 115 managers who initially responded, 53% were male, and 75.21% were married. The age distribution was as follows: 1.55% were aged 30 years or younger, 23.26% were between 31 and 40 years old, 70.54% were between 41 and 50 years old, and 4.65% were 51 years or older. Most of the managers held a graduate degree (78.91%), while 21.09% possessed a master's degree or higher. Regarding their tenure in their current organizations, 44% had been with the company for three years or less, 32% for 3 to 5 years, 17% for 5 to 7 years, and 6% for more than 7 years.

Measurement

All assessments in this study were conducted using a five-point Likert-type scale, ranging from 1 = "strongly disagree" to 5 = "strongly agree." Each construct was measured using established or adapted instruments validated in prior research to ensure content reliability and conceptual clarity. Innovation Thinking was measured using a structured questionnaire adapted from Torrance's Creative Thinking Scale and other widely used creativity measures. This instrument assessed dimensions such as idea fluency, originality, and flexibility in problem-solving, as applied to innovation contexts. An example item included, "I frequently generate multiple ideas to solve a single problem." This scale was informed by the approach adopted in [18].

Analytical Reasoning was assessed using a researcher-developed scale, based on theoretical models of decision-making drawn from [33] concept of bounded rationality and decision theory. Items were designed to capture logical analysis, evidence-based decision-making, and cognitive structuring. An example item was, "I rely on logical evaluation when comparing alternative solutions." This construct was referenced in [22] and yielded a Cronbach's alpha of 0.85.

Strategic Thinking was evaluated using a validated instrument adapted from the frameworks of [34] and [35], encompassing four key dimensions: systems perspective, intent focus, thinking in time, and hypothesis-driven reasoning. Example items included, "I consider the long-term consequences of today's decisions," and "I integrate information across various departments to make decisions." The Cronbach's alpha for this scale was 0.91, consistent with prior use in [7].

Sustainable Manufacturing was measured using a structured survey instrument based on the Triple Bottom Line (TBL) framework proposed by [36], and adopted in the manufacturing sustainability literature by [4]. The scale captured environmental, economic, and social performance metrics. Example items included, "Our production process prioritizes resource efficiency," and "We regularly evaluate the social impact of our manufacturing practices." The Cronbach's alpha for this scale was 0.88.

ANALYSIS AND FINDING

This research was carried out with the PLS-SEM analysis to investigate the relationship between construct, indicator and item in detail to develop a factor model that test the green behavior.

Factor Loading

Table 1 presents the factor loadings for all items measuring the key constructs: analytical reasoning, innovative thinking, strategic thinking, and sustainable manufacturing. The analysis shows that all retained items meet the accepted factor loading threshold of 0.70 or higher, indicating strong indicator reliability and appropriate representation of the respective constructs. For analytical reasoning, items c1 to c4 demonstrated high factor loadings ranging from 0.886 to 0.941. Innovative thinking was measured with items c12 to c19, all of which loaded strongly, with values between 0.865 and 0.905. Regarding strategic thinking, items d1 to d10 showed solid factor loadings ranging from 0.814 to 0.876, confirming their reliability. Similarly, sustainable manufacturing was well represented by items b1 to b10, all of which had strong loadings between 0.805 and 0.912. All items displayed adequate measurement strength and no item in the table fell below the 0.70 cut-off, hence no item was excluded from the model based on factor loading. These results affirm that the measurement model for all constructs is reliable and valid (refer to Table 1).

TABLE I Summary of Factor Loading for All Items

Item	Variable	Factor Loading	*P* Value
b1	Analytical reasoning	0.834	0
b2	Analytical reasoning	0.812	0
b3	Analytical reasoning	0.887	0
b4	Analytical reasoning	0.859	0
b5	Analytical reasoning	0.912	0
b6	Analytical reasoning	0.876	0
b8	Analytical reasoning	0.904	0
b9	Analytical reasoning	0.847	0
b10	Analytical reasoning	0.805	0
c12	Innovative thinking	0.874	0
c13	Innovative thinking	0.905	0
c14	Innovative thinking	0.904	0
c16	Innovative thinking	0.895	0
c19	Innovative thinking	0.865	0
c1	Strategic Thinking	0.886	0
c2	Strategic Thinking	0.941	0
c3	Strategic Thinking	0.924	0
c4	Strategic Thinking	0.889	0
d1	Sustainable Manufacturing	0.875	0
d2	Sustainable Manufacturing	0.876	0
d3	Sustainable Manufacturing	0.851	0
d4	Sustainable Manufacturing	0.872	0

d5	Sustainable Manufacturing	0.865	0
d6	Sustainable Manufacturing	0.858	0
d7	Sustainable Manufacturing	0.852	0
d8	Sustainable Manufacturing	0.874	0
d9	Sustainable Manufacturing	0.814	0
d10	Sustainable Manufacturing	0.817	0

Figure 2 presents the results of the structural model analysis using Partial Least Squares Structural Equation Modeling (PLS-SEM). The model illustrates the relationships between two main latent constructs, namely, analytical reasoning and innovative thinking, one mediator strategic thinking, and sustainable manufacturing as dependent variable. The R^2 values further support the model's explanatory power. Strategic thinking has an R^2 value of 0.610, meaning that 61% of its variance is explained by analytical reasoning and innovative thinking. Similarly, sustainable manufacturing has an R^2 value of 0.579, indicating that 57.9% of its variance is explained by strategic thinking. These findings collectively demonstrate the central role of strategic thinking as a mediating construct in the relationship between cognitive skills (analytical and innovative thinking) and sustainability performance.

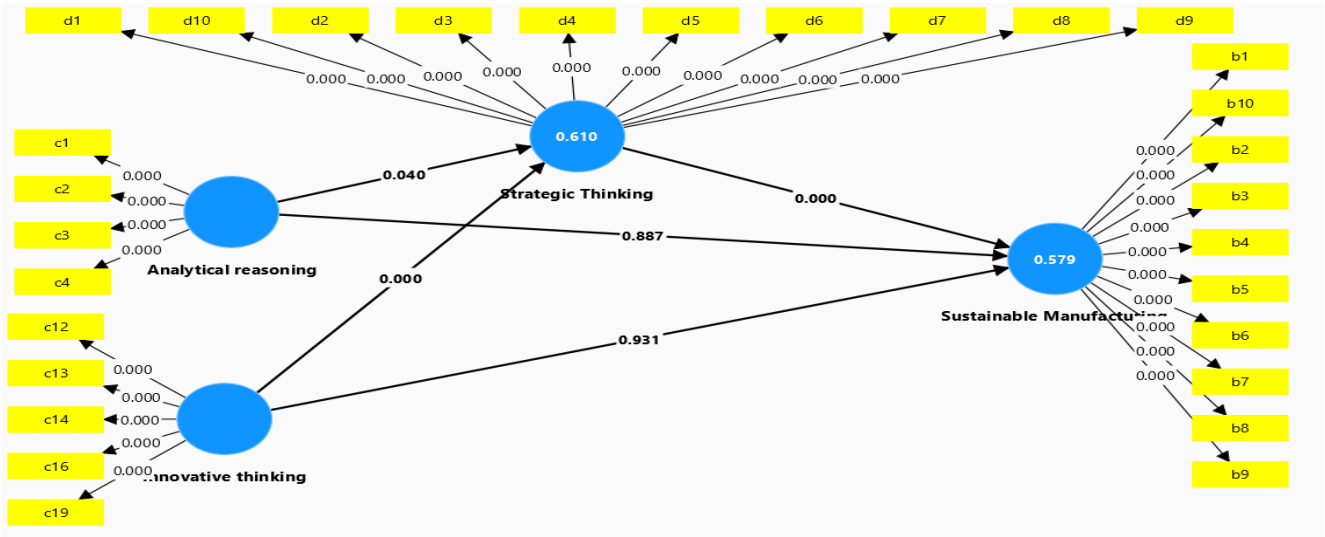

Fig. 2 Structural Model

Consistency Reliability

Table 2 displays the results for internal consistency reliability and convergent validity based on Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) values for each construct. The Cronbach's alpha values range from 0.931 to 0.959, exceeding the recommended threshold of 0.70, indicating excellent internal consistency. Similarly, the composite reliability (CR) values (ρ_a and ρ_c) range from 0.932 to 0.965, further supporting the reliability of the constructs.

In terms of convergent validity, all constructs recorded AVE values above the acceptable benchmark of 0.50, specifically ranging from 0.732 to 0.828. These results demonstrate that each construct in this study is both reliable and valid, confirming that the measurement model has adequate consistency and convergent validity (refer to Table 2).

TABLE 2 Summary of Cronbach's Alpha, Composite Reliability

	Cronbach's alpha	CR (rho_a)	CR (rho_c)	AVE
Analytical reasoning	0.931	0.932	0.951	0.828

Innovative thinking	0.934	0.934	0.950	0.790
Strategic Thinking	0.959	0.960	0.965	0.732
Sustainable Manufacturing	0.959	0.960	0.965	0.732

Correlational Analysis

Analyzing the connections between analytical reasoning, innovative thinking, strategic thinking, and sustainable manufacturing revealed strong positive correlations. The relationship between analytical reasoning and innovative thinking was highly significant (r = 0.809), as was the correlation between analytical reasoning and strategic thinking (r = 0.722). Additionally, analytical reasoning was positively associated with sustainable manufacturing (r = 0.541).

Similarly, innovative thinking demonstrated a strong positive relationship with strategic thinking (r = 0.808) and a moderately strong correlation with sustainable manufacturing (r = 0.615). Furthermore, strategic thinking showed a strong and significant positive correlation with sustainable manufacturing (r = 0.791). These findings indicate that higher levels of analytical reasoning and innovative thinking are associated with enhanced strategic thinking and, ultimately, more sustainable manufacturing practices (refer to Table 3).

TABLE 3 CORRELATION BETWEEN STUDY VARIABLES

	Variables	1	2	3	4
1	Analytical reasoning	1			
2	Innovative thinking	0.809	1		
3	Strategic Thinking	0.722	0.808	1	
4	Sustainable Manufacturing	0.541	0.615	0.791	1

Hypotheses Testing

Table 4 presents the path coefficients and significance levels of the hypothesized relationships among the study variables. It was observed that analytical reasoning had a significant positive effect on strategic thinking (β = 0.242, t = 2.058, p = 0.040), thereby supporting H1. However, analytical reasoning did not significantly influence sustainable manufacturing (β = -0.018, t = 0.142, p = 0.887), leading to rejection of H2. With regard to innovative thinking, the results show a strong and significant relationship with strategic thinking (β = 0.582, t = 5.055, p < 0.001), providing support for H3. On the other hand, the relationship between innovative thinking and sustainable manufacturing was not significant (β = 0.011, t = 0.086, p = 0.931), leading to rejection of H4. Finally, strategic thinking exhibited a significant and positive impact on sustainable manufacturing (β = 0.765, t = 6.098, p < 0.001), thus supporting H5.

TABLE 4 HYPOTHESIS TESTING ON DIRECT EFFECT

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics	P Value
AR→ST	0.242	0.235	0.118	2.058	0.040
AR→ SM	-0.018	-0.006	0.127	0.142	0.887
IT→ST	0.582	0.588	0.115	5.055	0.000
IT→SM	0.011	0.020	0.128	0.086	0.931

Note: AR=Analytical reasoning; IT=Innovative thinking; ST=Strategic Thinking; SM=Sustainable Manufacturing

Reporting Mediation Analysis

The bootstrapping analysis revealed that both indirect effects, H6 (AR → ST → SM) and H7 (IT → ST → SM), were statistically significant, thereby supporting the mediation hypotheses. Specifically, the standardized beta values were $\beta = 0.185$ ($t = 1.986$, $p < 0.05$) for H6 and $\beta = 0.445$ ($t = 4.130$, $p < 0.001$) for H7. The 95% Bias-Corrected Confidence Intervals (BC CI) for these indirect effects were [LL = 0.027, UL = 0.404] for H6 and [LL = 0.254, UL = 0.683] for H7. Since neither confidence interval includes zero, the results provide evidence of statistically significant mediation (Preacher & Hayes, 2008).

These findings indicate that Strategic Thinking (ST) significantly mediates the relationship between both Analytical Reasoning (AR) and Sustainable Manufacturing (SM), as well as Innovative Thinking (IT) and Sustainable Manufacturing (SM). This supports the theoretical assertion that cognitive capacities such as reasoning and innovation must be strategically channeled to influence sustainability outcomes effectively. Detailed results of the mediation analysis are presented in Table 5.

TABLE 5 HYPOTHESIS TESTING ON MEDIATION

	Std. Beta	Std. Error	t-value	LL (BC)	UL (BC)
AR → ST → SM	0.185	0.093	1.986	0.027	0.404
IT → ST → SM	0.445	0.108	4.130	0.254	0.683

DISCUSSION

Based on the hypothesis testing results, the findings present insightful patterns regarding the role of analytical reasoning, innovative thinking, and strategic thinking in shaping sustainable manufacturing outcomes.

The study revealed that analytical reasoning and innovative thinking do not have a direct significant impact on sustainable manufacturing, suggesting that while these cognitive capabilities are widely recognized as vital enablers of sustainability, their effect is not automatic. This aligns with literature in, where innovative thinking is identified as a catalyst for eco-innovation and resource optimization ([9], [1]) and analytical reasoning as a core skill for environmental impact analysis and process efficiency [15]. However, the study's findings challenge a straightforward interpretation, indicating that these abilities may require a strategic mechanism to be effectively translated into sustainable outcomes. As such, this supports recent work emphasizing that cognitive skills alone are insufficient unless they are channeled through strategic frameworks [13], [2].

Notably, both analytical reasoning and innovative thinking were found to significantly influence strategic thinking, reinforcing evidence from previous studies. Studies such as by [5] confirm that these cognitive faculties are foundational to strategic foresight, long-range planning, and the development of competitive, adaptive strategies. Innovative thinking fosters exploration beyond conventional boundaries, enabling the formulation of novel strategies ([18], [19]), while analytical reasoning enhances the ability to make informed strategic decisions based on robust data interpretation ([23], [24]). These findings collectively validate the idea that organizations benefit most when they harness these cognitive capabilities as inputs to strategic processes.

The study also found that strategic thinking has a significant and positive impact on sustainable manufacturing, echoing the literature, which positions strategic thinking as an integrative force aligning business objectives with sustainability goals ([7], [25]). Strategic thinking enables manufacturers to prioritize sustainability, embed innovation in their core strategy, and adapt to external disruptions through long-term visioning ([6], [26]).

Most importantly, the findings underscore that strategic thinking mediates the relationship between analytical

reasoning and sustainable manufacturing, as well as between innovative thinking and sustainable manufacturing. This supports the arguments, where strategic thinking is portrayed as a bridge that converts cognitive potential into actionable sustainability strategies. Drawing from the Resource-Based View (Barney, 1991) and the Dynamic Capabilities Framework [28], the results affirm that internal cognitive resources must be strategically integrated to yield competitive and sustainable advantages. Without this mediation, the effects of analytical and innovative capacities remain latent. The literature further supports this through empirical cases where strategic thinking facilitates the alignment of green innovation and digital transformation with sustainability goals [32].

In sum, this study confirms that while analytical reasoning and innovative thinking are essential cognitive resources, their direct impact on sustainable manufacturing is limited. Instead, strategic thinking plays a pivotal mediating role, transforming these abilities into effective sustainability practices. These insights carry practical implications for talent development strategies, suggesting that training programs must integrate strategic thinking development alongside analytical and creative skill-building to maximize organizational sustainability performance.

Contribution to Knowledge

This study offers significant contributions to the theoretical understanding of how cognitive capabilities, specifically analytical reasoning and innovative thinking, influence sustainable manufacturing. While previous literature has predominantly emphasized the direct benefits of innovation and analysis on sustainability outcomes (e.g., [9], [15]), this study empirically establishes that such relationships are indirect and mediated by strategic thinking. By positioning strategic thinking as a mediator, the research extends existing frameworks such as the Resource-Based View (RBV) and the Dynamic Capabilities Theory, demonstrating that cognitive competencies must be strategically processed to create tangible sustainability impacts. This offers a more nuanced understanding of capability deployment in manufacturing contexts and enriches the theoretical discourse on capability conversion mechanisms within sustainable organizational practices.

Furthermore, the study bridges distinct but related scholarly domains, cognitive psychology, strategic management, and sustainability studies, into a cohesive model, which is relatively underexplored in prior research. The findings also contribute to the limited empirical literature on how strategic thinking serves as a linchpin that transforms internal intellectual resources into external performance outcomes, particularly in the manufacturing sector.

Contribution to Practice

From a practical standpoint, the study provides actionable insights for manufacturing firms, human resource managers, and organizational development practitioners. First, it warns against over-reliance on cognitive strengths such as creativity or data analysis in isolation, and instead emphasizes the need to develop strategic thinking skills among employees to harness these capabilities effectively. This suggests that training and development programs should be integrative, focusing not only on enhancing analytical and innovative thinking but also on equipping staff with strategic planning, foresight, and systems thinking.

Second, the research implies that sustainable manufacturing cannot be achieved solely through operational improvements or isolated innovations. Instead, organizations must institutionalize strategic thinking as a core organizational competency. This involves aligning sustainability goals with strategic objectives, fostering a long-term vision across departments, and creating cross-functional teams capable of making informed, future-oriented decisions. Finally, for policymakers and educators, the findings underscore the importance of embedding strategic thinking frameworks into engineering, management, and sustainability curricula. Preparing the future workforce with this triad of competencies—analytical, innovative, and strategic, can substantially enhance national and industry-level sustainability outcomes.

RECOMMENDATION

Based on the findings, several practical recommendations emerge. Organizations, particularly in the manufacturing sector, should focus on developing strategic thinking as a core competency among employees. While analytical reasoning and innovative thinking are valuable, this study confirms that their impact on sustainable manufacturing is mediated through strategic thinking. Therefore, talent development initiatives should integrate strategic planning, systems thinking, and scenario analysis into training programs. Companies are also encouraged to establish cross-functional innovation teams that combine analytical, creative, and strategic expertise, enabling a more seamless transition from ideation to sustainable implementation. Moreover, sustainability goals should be aligned with organizational strategic objectives, ensuring that sustainability is embedded into long-term planning rather than treated as an isolated effort. To support this, training modules should adopt integrative learning models, fostering a culture where employees understand the strategic relevance of their cognitive capabilities. Leadership plays a critical role in this process and should be trained to champion strategic sustainability, guiding their teams to embed long-term environmental goals into everyday decision-making.

To further align cognitive skill development with emerging technological trends in manufacturing, curriculum designers should consider integrating blended learning models. This may include the use of virtual labs, AI-driven simulations, and industry-led modules that bridge theoretical knowledge with real-time industrial challenges. Moreover, fostering partnerships with smart manufacturing firms can facilitate internships, apprenticeships, or live project involvement for students; providing practical exposure to technologies such as AI, IoT, and automation. Parallel to this, faculty upskilling initiatives, through continuous professional development, certifications in digital manufacturing tools, and collaborative teaching with industry experts, are essential to ensure effective delivery of technology-integrated content.

For future research, several avenues are suggested. First, scholars should explore the moderating effects of variables such as organizational culture, leadership style, or digital maturity in shaping the relationship between cognitive capabilities, strategic thinking, and sustainability outcomes. Since this study focused on the manufacturing context, future research could apply the model to other sectors such as services or energy to examine its broader applicability. To understand the evolution of these constructs over time, longitudinal studies are recommended, which can trace how analytical and innovative thinking translate into sustainable outcomes through strategic processes. Additionally, adopting mixed-methods approaches could offer deeper insights into how employees perceive the application of their cognitive skills in strategic contexts. With the rise of digitalization, future studies could also investigate how emerging technologies such as artificial intelligence or big data analytics interact with human cognitive capabilities and strategic thinking to enhance sustainable manufacturing. Lastly, cross-cultural research could reveal how regional or national differences in thinking styles and strategic orientation influence sustainability practices, contributing to a more context-sensitive understanding of the model.

CONCLUSIONS

This study investigated the interplay between analytical reasoning, innovative thinking, strategic thinking, and sustainable manufacturing, offering both theoretical insights and practical implications. The findings revealed that while analytical reasoning and innovative thinking are critical cognitive competencies, they do not directly influence sustainable manufacturing outcomes. Instead, their impact is mediated through strategic thinking, highlighting the pivotal role of strategic orientation in translating cognitive skills into effective sustainability practices.

These results provide a meaningful extension to existing literature by empirically validating the mediating role of strategic thinking, grounded in the Resource-Based View and the Theory of Dynamic Capabilities. They also challenge the assumption that cognitive skills alone can drive sustainability, emphasizing instead the importance of strategic foresight, systems thinking, and long-term planning.

From a practical perspective, organizations must recognize that enhancing sustainability performance requires more than just fostering creativity or analytical capabilities. It demands a deliberate investment in

strategic capacity-building across all organizational levels. Training and development programs should be redesigned to cultivate a synergistic skill set that combines analytical, innovative, and strategic competencies. Leaders, in particular, should be equipped to align sustainability initiatives with overarching strategic goals, enabling firms to respond adaptively to environmental challenges and maintain competitive advantage.

Looking forward, this study opens several pathways for further research, including examining contextual variables, testing the model across industries, and exploring the role of digital technologies in this dynamic. Ultimately, the findings underscore that sustainable manufacturing is not only a product of individual intelligence but also a reflection of how well that intelligence is strategically organized and applied within the enterprise.

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