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Barriers to Green Manufacturing Implementation: A Systematic Literature Review of Organizational and Institutional Challenges

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ABSTRACT

Green manufacturing (GM) implementation remains limited despite its proven environmental and economic benefits, particularly in developing economies and SMEs. This systematic literature review (SLR) synthesizes high-quality studies from 2020–2025 to identify and analyze barriers hindering GM adoption. Employing PRISMA and Tranfield protocols, the review analyzed 45 peer-reviewed articles from top-tier journals (SJR ≥1.0), revealing ten interconnected barriers classified into organizational (e.g., weak sustainability culture, high costs, skill shortages, limited RD) and institutional (e.g., inadequate government support, poor supply chain coordination, low customer demand) categories. A novel conceptual model maps their systemic interdependencies, positioning managerial commitment as a pivotal mediator that amplifies or mitigates external pressures on internal capabilities. This study contributes to the advancement prior SLRs by integrating post-pandemic evidence, refining barrier taxonomies, and visualizing causal feedback loops, offering a systems perspective absent in earlier fragmented listings. Theoretically, it contributes an actionable framework for understanding GM resistance in resource-constrained contexts. Practically, it provides managers with prioritized interventions (e.g., leadership training, supply chain partnerships) and policymakers with targeted recommendations (e.g., incentives, awareness campaigns) to accelerate green transitions. These insights bridge the gap between sustainability rhetoric and industrial reality, equipping stakeholders to dismantle barrier networks and foster resilient GM adoption.

1. Introduction

In the era of rapid globalization and industrialization, the manufacturing sector faces a dual challenge: maintaining economic growth while simultaneously mitigating its environmental impacts. Industrial activities have caused severe global environmental degradation and significant harm to human life (Gupta et al., 2020). Generally, the manufacturing industry accounts for about 36% of carbon dioxide emissions and consumes 33% of the world's energy resources (Sarker & Bartok, 2024). The rapid depletion of natural resources and the increasing CO_2 emissions have made the adoption of environmentally friendly manufacturing practices essential for industries worldwide

(Karuppiah et al., 2020). In response to these challenges, the concept of green manufacturing (GM) has emerged as a critical paradigm for sustainable development (Huiling & Dan, 2020).

Green manufacturing is commonly defined as a set of approaches that focus not only on waste and pollution reduction but also on energy efficiency and the use of ecofriendly materials throughout the product life cycle (Prakash et al., 2022). In general, GM represents an environmentally conscious production approach that aims to minimize negative environmental impacts (Karuppiah et al., 2020), from the design stage to the end of the product's life cycle (cradle to grave) (Prakash et al., 2022). GM has become an industrial paradigm in response to increasing global concern over the environmental consequences (Sarker & Bartok, 2024). Research consistently shows that GM practices, such as green procurement, green product innovation, and green process innovation, can improve environmental, social, and economic performance, including cost reduction, enhanced reputation, and better compliance with environmental regulations (Abdillah & Chang, 2022; Acquah et al., 2021; Al-Hakimi et al., 2022; Hassan & Jaaron, 2021; Nyakudya et al., 2022; Pathak et al., 2021; Yadegaridehkordi et al., 2020).

Despite these proven benefits, the implementation of GM is far from widespread. In practice, manufacturing firms, especially in developing countries and among small and medium sized enterprises, encounter substantial financial, organizational, and technological constraints that hinder the transition toward green production (Afum, Agyabeng-Mensah, et al., 2020; Afum, Osei-Ahenkan, et al., 2020; Andaregie & Astatkie, 2022; Bui et al., 2024; Ghadimi et al., 2020; Guo, 2023). The literature highlights numerous internal and external barriers, including limited knowledge and training, high initial and operational costs, insufficient R&D and technology, lack of skilled human resources, weak managerial commitment, inadequate government support, ineffective supply chain management, and low customer awareness and demand (Bendig et al., 2023; D'Angelo et al., 2023; Hariadi et al., 2023; Hong et al., 2021; Kannan et al., 2022; Mishra et al., 2022; Mungai & Ndiritu, 2023). These interacting barriers create a complex system of constraints that slows the broader diffusion of GM, particularly in contexts with limited resources and regulatory uncertainties (Bendig et al., 2023; Machingura et al., 2024; Mandal et al., 2025).

Previous studies and reviews have discussed GM barriers and related sustainability challenges; however, many of them focus on specific regions, sectors, or technologies and predominantly rely on literature published before 2020. Earlier reviews also tend to apply less stringent journal quality criteria and provide limited synthesis of how internal and external barriers interact across different organizational contexts (Bendig et al., 2023). Since 2020, there has been a significant increase in high quality publications on GM barriers in leading journals such as Journal of Cleaner Production, Journal of Manufacturing Technology Management, and Sustainability, reflecting new policy developments, technological advances, and post pandemic supply chain dynamics that have not yet been fully integrated into a focused and updated synthesis (Bui et al., 2024; Ganschinietz, 2021; Liu et al., 2025; Long & Wang, 2025; Rejeb et al., 2022). Consequently, there remain at least three important gaps: (1) the absence of a recent systematic literature review (SLR) that concentrates on the 2020–2025 period, (2) the lack of a structured mapping of GM barriers into organizational (internal) and institutional (external) categories based on strict journal quality standards, and (3) the limited discussion of managerial and policy implications derived from these latest findings, particularly for developing countries and SMEs.

To address these gaps, this study conducts a SLR of GM barriers using research articles published between January 2020 and October 2025. The review applies a three-phase procedure comprising database searching and screening, quality-based selection using the SCImago Journal and Country Rank as a threshold, and content analysis that combines qualitative interpretation with simple quantitative aggregation (Ganschinietz, 2021; Rejeb et al., 2022; Zhang et al., 2019). Conceptually, this article contributes by (1) synthesizing key barriers to GM and classifying them into organizational and institutional categories, (2) explaining how these barriers jointly constrain GM adoption, especially in resource constrained environments, and (3) providing a structured basis for designing managerial and policy interventions to overcome these obstacles (Bendig et al., 2023; Hariadi et al., 2023; Mungai & Ndiritu, 2023). Accordingly, the specific objectives of this paper are to: (1) explain the concept of GM based on recent academic literature published between January 2020 and October 2025, and (2) identify and categorize the main organizational (internal) and institutional (external) barriers to GM implementation, thereby supporting more effective strategies for practitioners and policymakers.

The 2020–2025 timeframe for this SLR was deliberately selected to align with the global industrial transformation spurred by the COVID-19 pandemic, which acted as a pivotal turning point for green manufacturing adoption. In 2020, severe supply chain disruptions and economic instability compelled manufacturers to prioritize crisis response and operational survival, often diverting funds intended for sustainable technologies to immediate recovery needs. Extending the scope to 2025 offers a comprehensive longitudinal view, tracing the progression of distinct barriers from acute pandemic pressures to the 'green recovery' era and evolving post-crisis resilience strategies. Thus, this period captures the most relevant socio-economic dynamics and technological hurdles currently confronting the manufacturing sector.

2. Method

This study adopts a systematic literature review (SLR) approach that is conceptually aligned with established international frameworks such as PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) in Page et al. (2021) and the evidence-based management review protocol (Tranfield et al., 2003). PRISMA provides updated guidance on how to transparently report the identification, screening, eligibility assessment, and inclusion of studies in systematic reviews. The three-phase procedure used in this paper, (1) literature search, (2) article selection and quality evaluation, and (3) data extraction and content analysis mirror the key stages recommended in management SLRs based on Tranfield's evidence-based approach, namely planning the review, conducting the review, and reporting the results (Sauer & Seuring, 2023). This staged process of identification, screening, eligibility assessment, and inclusion is summarized in a PRISMA like flowchart in Fig. 1.

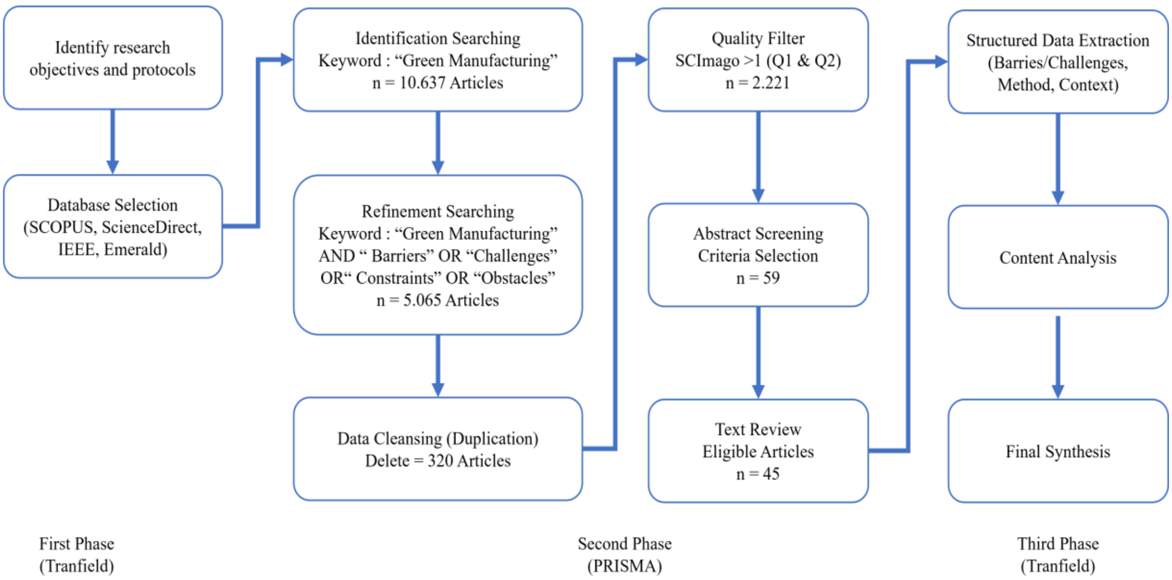

Fig. 1. Article selection and evaluation process

2.1. Search Strategy

Based on the research objectives defined in Section 1, four major databases were selected: ScienceDirect, SCOPUS, IEEE, and Emerald. The initial search used the general keyword "Green Manufacturing" and was restricted to research articles written in English, published between 1 January

2020 and 1 October 2025. To refine the search toward barriers to GM implementation, additional keywords such as "barriers", "challenges", "constraints", and "obstacles" were incorporated into the search strings, which were jointly defined and validated by the authors to ensure domain relevance. This procedure generated approximately 10,637 initial records, which were subsequently reduced to 5,065 records after applying the more specific search terms.

The overall search and screening procedure follows PRISMA type logic, in which records are systematically identified, screened, assessed for eligibility, and included according to explicit criteria, consistent with the PRISMA statement and its revised flow diagrams for systematic reviews (Page et al., 2021). Consistent with the evidence-based management tradition, the review protocol explicitly specifies the review question, search processes, and selection criteria, which is in line with recommendations for SLR in management research that build on Tranfield's original framework (Sauer & Seuring, 2023).

2.2. Inclusion and Exclusion Criteria

The article selection followed predefined inclusion and exclusion criteria. The inclusion criteria required that studies: (1) focus on green manufacturing or closely related sustainable manufacturing practices; (2) explicitly address barriers, challenges, constraints, or obstacles to implementation; (3) are empirical or conceptual research articles (not editorials, notes, or conference abstracts); (4) are written in English; and (5) are published in journals indexed in the selected databases within the 2020–2025 period. Exclusion criteria included publications unrelated to manufacturing sectors, articles that only discuss drivers or enablers without addressing barriers, non-peer reviewed sources, and duplicate records across databases.

A quality filter was then applied using the SCImago Journal and Country Rank (SJR) index, with a threshold of SJR > 1.0 to ensure that only high impact journals in the top 25% were retained (Ganschinietz, 2021). Data cleaning was conducted to remove duplicates, and abstract level screening was performed to assess alignment with the research questions, reducing the dataset to 59 potentially eligible articles. Full text screening based on the same criteria resulted in 45 core articles for in depth analysis, as detailed in Table. 1.

Table 1. Database selection

Database	Identification Searching	Refinement Searching	SCImago >1	Data Cleansing	Abstract Analysis	Content Analysis
IEEE	88	16	11	320	11	2
Emerald	568	26	21		21	12
SCOPUS	3694	573	367		254	6
ScienceDirect	6287	4465	1822		1615	25

2.3. Data Extraction and Analysis

For each included article, a structured data extraction form was used to collect bibliographic information, research context (country, sector, firm size), methodological characteristics, and all identified barriers to GM implementation. Data extraction was carried out by the first author and cross checked by the second and third author to minimize misclassification and ensure the completeness and consistency of the extracted information.

Content analysis was employed as the primary analytical technique to synthesize findings across studies. This method is suitable for systematically interpreting textual data by integrating qualitative interpretation with simple quantitative aggregation, and it has been widely applied in management and sustainability reviews to identify salient themes and patterns (Sauer & Seuring, 2023). In this study, content analysis was used to: (1) categorize reported barriers; (2) group them into organizational (internal) and institutional (external) factors; and (3) count the frequency of each barrier across the sample to highlight dominant challenges. The framework was developed deductively from existing literature and inductively refined during the review process, allowing new barrier categories to emerge when necessary.

To enhance the reliability of the analysis, three authors independently reviewed a subset of articles; discrepancies were discussed until consensus was reached. This inters reviewer checking procedure helped reduce subjective bias and increased the robustness of the barrier classification. The use of content analysis within this PRISMA inspired and Tranfield based review design allows for a transparent and auditable trail from initial records to synthesized themes, which is considered good practice in contemporary systematic reviews in management and related fields (Sauer & Seuring, 2023).

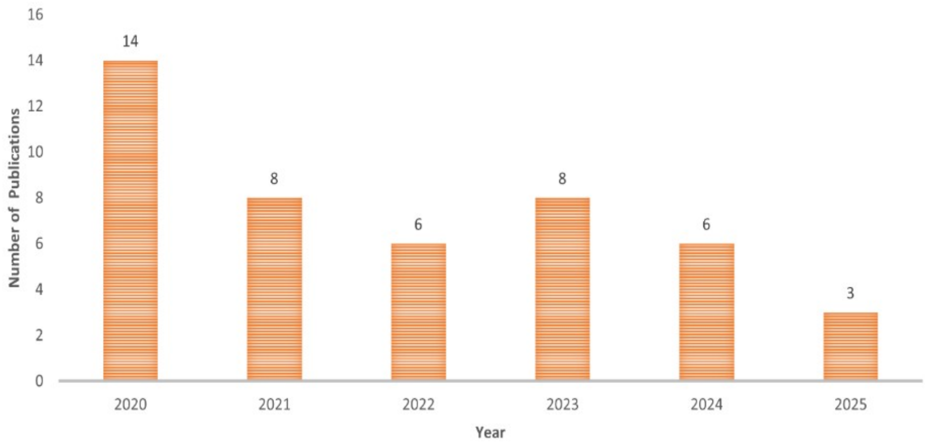

Fig. 2. Number of publications over the years

Building on this methodological rigor, Fig. 2 presents the annual distribution of relevant publications on Green Manufacturing barriers over the period 2020 to 2025. The largest number of publications was recorded in 2020, with a progressive decrease observed in subsequent years. A consistent publication rate was maintained from 2021 to 2023, each yielding 8 articles. The number of publications declined to 6 in 2024, and further to 3 in 2025. This trend may reflect an initial surge of interest in the research topic during the early phase, followed by a stabilization and eventual reduction, possibly due to the maturity of existing studies and saturation of key findings in the field. These results highlight the temporal variation in scholarly attention to Green Manufacturing barriers and suggest shifting research priorities in recent years.

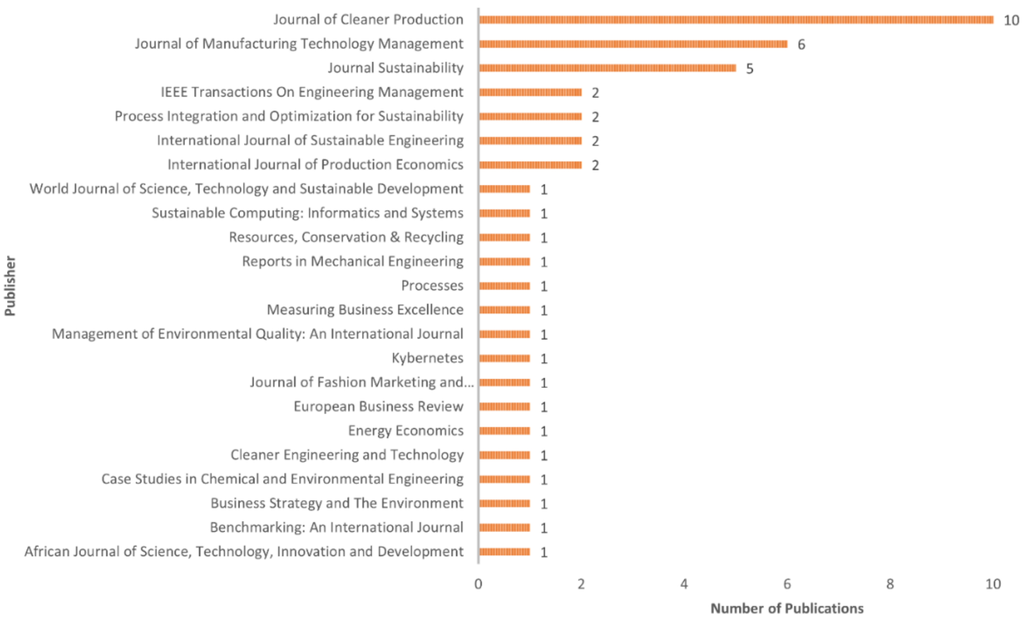

Fig. 3. Number of publish paper per journal

Completing this temporal perspective, Fig. 3 illustrates the distribution of Green Manufacturing barrier publications according to their respective journals. The Journal of Cleaner Production accounted for the highest number of publications (n = 10), followed by the Journal of Manufacturing Technology Management (n = 6) and Sustainability (n = 5). Several other journals contributed two publications each, while the remainder were single-publication outlets. This pattern highlights that Green Manufacturing barrier research is concentrated in a few leading journals, with more limited dissemination across a diverse range of other outlets. The results reflect both the prominence of certain journals in shaping scholarship in this field and the existence of a broad, multidisciplinary interest among specialized publications.

3. Results and Discussion

The literature review identified ten dominant internal and external barriers that form a mutually reinforcing system of constraints rather than isolated obstacles. Organizational barriers such as weak sustainability-oriented culture, limited knowledge, high investment and operating costs, lack of technology and Research & Development, shortage of skilled human resources, and insufficient managerial commitment interact closely with institutional barriers including inadequate government support, ineffective supply chain management, and low customer awareness and demand. This configuration is consistent with recent green manufacturing SLRs, which likewise emphasize that barriers tend to co-occur and amplify each other rather than acting independently. The results of the literature review are comprehensively presented in Table 2 and Table 3, which identifies ten principal barriers to green manufacturing implementation.

3.1. Organizational and Institutional Barriers

The lack of organizational culture and social support often manifests as reluctance among employees and leadership to embrace sustainability as a core value. Companies may emphasize short-term profits and operational efficiency over environmental concerns, resulting in limited initiatives to promote green manufacturing practices (M. Singh et al., 2020b). In some cases, internal communication barriers and resistance to change in Virmani et al. (2021) cause efforts for sustainable transformation to falter, as continual improvement and learning are not prioritized. This is further complicated in organizations where corporate social responsibility is weak, making it difficult to foster an environment conducive to innovation and sustainability. The consequences include delayed transitions to green manufacturing, low employee engagement in environmental initiatives in Omar et al. (2024), and ultimately, a failure to integrate sustainability into the company's strategic vision. This suggests that organizational transformation toward sustainability requires not only structural changes but also a shift in collective mindset and value orientation. Strengthening communication channels and embedding sustainability into corporate culture can therefore play a pivotal role in overcoming resistance and enhancing long-term environmental performance.

Table 2. Organizational Barriers for Green Manufacturing Implementations

Organizational Barriers	References
The organizational culture and social environment do not provide adequate support.	(Abualfaraa et al., 2020; Al-Hakimi et al., 2022; Chen & Cao, 2025; Shokri et al., 2022)
Lack of information, knowledge, and training related to green manufacturing.	(Gupta et al., 2020; Mishra et al., 2022; Pathak et al., 2021)
High Initial Investment (Financial Limitations)	(D'Angelo et al., 2023; Machingura et al., 2024; Sun et al., 2020; Tanco et al., 2021)
Elevated costs associated with manufacturing operations, maintenance, and certification.	(Le & Nguyen, 2024; Liu et al., 2025; Long & Wang, 2025)
Insufficient R&D, innovation, and technological capabilities.	(Hariadi et al., 2023; Sharma et al., 2021)
Lack of qualified, skilled, and professional human resources for the implementation of green manufacturing.	(Leong et al., 2020; Zhu et al., 2023)
Insufficient managerial commitment, support, and competencies in implementing green manufacturing.	(Kannan et al., 2022; Sarker & Bartok, 2024; C. Singh et al., 2020; M. Singh et al., 2020a)

Access to accurate and comprehensive information is a key requirement for successful green manufacturing implementation (Kannan et al., 2022; Kaswan et al., 2023). However, many companies face barriers in obtaining reliable guidance on environmentally friendly practices in Huiling & Dan (2020) and technological advancements (Afum, Osei-Ahenkan, et al., 2020). The absence of specialized training programs prevents employees from developing the expertise necessary for the successful adoption of green methods (Guo, 2023). Furthermore, a lack of awareness among management and staff impedes organizational learning and the dissemination of best practices (Abdillah & Chang, 2022). These constraints indicate that information-related barriers operate not only at a technical level but also at a cognitive and organizational learning level, where firms are unable to systematically acquire, interpret, and apply sustainability knowledge. As a result, companies risk relying on outdated practices, which widens the gap between available green technologies and their actual implementation in daily operations. Addressing these issues therefore requires structured capacity-building initiatives and strategic knowledge management systems that institutionalize continuous learning about green manufacturing across all organizational levels.

High upfront financial costs pose one of the most substantial constraints to green manufacturing initiatives. High Investment is needed for new equipment and technologies (Acquah et al., 2021; Afum, Osei-Ahenkan, et al., 2020; Gupta et al., 2020; Shukla & Adil, 2021). For many enterprises, especially SMEs, limited access to capital and uncertainty regarding long-term financial returns make risk evaluation challenging (Mungai & Ndiritu, 2023; Omar et al., 2024). The pre-existing financial constraints are intensified by elevated operational expenditures stemming from the upkeep of eco-friendly systems and mandatory adherence to dynamic regulatory frameworks. Collectively, these factors impair the corporate impetus and capacity to allocate capital toward sustainability initiatives. These financial pressures underscore that economic barrier are not limited to initial investment decisions but extend to firms' broader risk perceptions and strategic prioritization of sustainability over competing short-term demands. In contexts where profit margins are thin and access to external financing is restricted, green manufacturing tends to be framed as a discretionary cost rather than a strategic investment, further delaying technological upgrading and lock-in to conventional processes. Consequently, without supportive financial mechanisms and policy incentives that mitigate perceived risk and enhance returns, firms are likely to underinvest in sustainability despite recognizing its long-term operational and reputational benefits.

Regular costs associated with green manufacturing, such as operational expenses in Ghadimi et al. (2020); Sun et al. (2020), maintenance of specialized equipment and mandatory certification processes in Hong et al. (2021), are significant obstacles. Firms must allocate resources to ensure compliance with evolving regulations and standards, maintain equipment suited for sustainable operation, and adapt to changing market conditions. These expenses, coupled with uncertain returns and high investment risks, place a considerable financial strain on organizations. These ongoing expenditures illustrate that financial barriers to green manufacturing are cumulative and path-dependent, arising not only from initial investment but also from the recurring burden of sustaining compliance and performance over time. As firms continually divert resources to meet operational, maintenance, and certification requirements under regulatory uncertainty, sustainability initiatives may be deprioritized in favors of projects with clearer and more immediate financial payoffs. This dynamic can ultimately discourage long-term commitment to green manufacturing, reinforcing risk-averse behavior and slowing the diffusion of environmentally superior technologies across the industry.

Research and development, together with technological innovation, form the backbone of green manufacturing progress (Gupta et al., 2020; Virmani et al., 2021). Insufficient investment in R&D facilities impairs the sector's ability to discover new sustainable materials, optimize processes, and develop advanced green technologies (Karuppiah et al., 2020). Companies often struggle with technological resistance, primarily due to cost implications or the perception that new solutions are unproven. Without continuous innovation and scientific research, firms are constrained by outdated practices that limit environmental performance and competitiveness (Sharma et al., 2021). These weaknesses indicate that technological barriers are deeply intertwined with firms' strategic choices regarding knowledge creation, where short-term cost concerns systematically crowd out long-term innovation agendas. In the absence of sufficient R&D investment and structured experimentation, organizations tend to overestimate the risks and underestimate the potential efficiency and performance gains of emerging green technologies, reinforcing skepticism toward their adoption. Over time, this dynamic not only entrenches dependency on legacy systems but also widens the technological gap between frontrunners and laggard firms, with significant implications for sector-wide environmental progress and competitive positioning.

The transition to green manufacturing relies on the availability of skilled personnel capable of designing, deploying, and managing sustainable solutions. Many organizations suffer from workforce limitations, including a shortage of trained engineers, environmental experts, and operational staff versed in green practices (Andaregie & Astatkie, 2022; Virmani et al., 2021). The lack of external support for skills development further aggravates this problem (Bui et al., 2024). Over time, this can result in the suboptimal execution of green initiatives, improper handling of advanced technologies, and inability to comply with evolving standards, directly undermining the effectiveness and credibility of sustainability programs.

These workforce deficiencies reveal a critical skills gap that perpetuates a vicious cycle of underperformance in green manufacturing, where inadequate training hampers both the technical execution of initiatives and the broader organizational capacity to adapt to regulatory and technological shifts. Without targeted upskilling programs and external partnerships for knowledge transfer, firms remain locked into inefficient practices, eroding the potential for scalable sustainability outcomes and competitive differentiation. Ultimately, this human capital constraint not only delays environmental progress but also risks reputational damage, as stakeholders increasingly demand demonstrable expertise in sustainable operations.

Managerial leadership's commitment and capability are pivotal for ensuring the efficacy of green manufacturing implementation (Acquah et al., 2021). Progress toward sustainability is hindered when top management exhibits a preference for short-term profits in Lazarou et al. (2023), or neglects to fully incorporate environmental goals within the core corporate strategy (Pathak et al., 2021). This strategic misalignment inevitably results in stagnation. A lack of accountability within leadership hinders resource mobilization, innovation, and the adoption of systematic approaches needed for successful green transformations. Support from management in Kaswan et al. (2023); Le & Nguyen (2024) is also essential for fostering a culture of learning, experimentation, and adaptation to new regulations, technologies, and market trends.

This leadership shortfall underscores a fundamental governance failure where short-termism at the executive level systematically undermines the strategic embedding of sustainability, diverting resources from transformative initiatives toward incremental gains. Without robust accountability mechanisms and visionary commitment, organizations struggle to cultivate the adaptive cultures necessary for navigating regulatory volatility and technological disruption in green manufacturing. Consequently, this misalignment not only stalls operational progress but also erodes stakeholder trust, positioning firms at a competitive disadvantage in increasingly sustainability-driven markets.

Governmental support in the form of clear regulations, incentives, and standardization is critical for motivating the manufacturing sector to adopt green manufacturing practices. However, rigid policy frameworks and insufficient enforcement of environmental standards often discourage companies from investing in sustainability (Kannan et al., 2022; Mungai & Ndiritu, 2023; C. Singh et al., 2020). The absence of financial incentives in Virmani et al. (2021), industry-specific guidelines in M. Singh et al. (2020a), and government-sponsored training in Pathak et al. (2021) further slowdown the rate at which manufacturers transition to greener models.

If policymakers do not provide specific support measures (e.g., tax incentives, grants, or subsidized training), companies will be forced to absorb the entire cost and risk associated with implementing sustainable production methods. This policy inadequacy reveals a systemic misalignment between regulatory intent and industrial realities, where the absence of tailored incentives and flexible enforcement mechanisms shifts the full burden of sustainability costs onto private actors, stifling proactive adoption. Consequently, firms perceive green manufacturing as a high-risk gamble rather than a supported pathway to compliance and competitiveness, perpetuating reliance on conventional practices amid escalating environmental pressures. Bridging this gap demands policy innovation that integrates financial relief, standardized guidelines, and capacity-building programs to catalyze sector-wide transformation.

Table 3. Institutional Barriers for Green Manufacturing Implementations

Institutional Barriers	References
Lack of government support regarding regulations, standards, and policies related to financial and environmental aspects.	(Bendig et al., 2023;Guo, 2023;Hariadi et al., 2023)
Ineffective Supply Chain Management	(Bui et al., 2024)
Limited customer awareness and insufficient market demand for green products.	(Hong et al., 2021; Sarker & Bartok, 2024; Xu et al., 2024)

Problems in managing the supply chain can strongly hinder the advancement of green manufacturing, since achieving sustainability depends on smooth collaboration between everyone involved in the value chain. If suppliers, manufacturers, and distributors are not well coordinated or fail to communicate effectively, resources may be used inefficiently, more waste can be generated, and organizations may miss key opportunities to adopt environmentally friendly technologies (Karuppiah et al., 2020). Issues can arise in the form of fragmented information exchange, reluctance of supply chain partners to invest in new processes, and lack of standardized approaches toward green procurement and logistics (Hong et al., 2021). These supply chain disruptions highlight a fundamental coordination failure across the value chain, where misaligned incentives and information asymmetries amplify inefficiencies, waste generation, and missed opportunities for collective sustainability gains. Without integrated governance structures that enforce transparency, standardized green procurement, and collaborative investment, individual actors prioritize local optimization over systemic environmental outcomes, perpetuating fragmented progress. Ultimately, this underscores the need for relational contracts and shared platforms to realign partner behaviors, enabling the holistic transformation essential for enduring green manufacturing success.

Consumer knowledge and market demand strongly influence the adoption of green manufacturing strategies. In markets where the benefits of green products are poorly understood or undervalued in Andaregie & Astatkie (2022), manufacturers have little incentive to invest in environmentally friendly processes. This is further compounded by the lack of established demand in Sun et al. (2020), inconsistent purchasing behavior in Chen & Cao (2025), and limited willingness to pay premium prices for green attributes (Lazarou et al., 2023). This market-consumer disconnect reveals a critical feedback loop where weak demand signals reinforce manufacturers' risk aversion, trapping the sector in a low-innovation equilibrium despite potential long-term environmental and economic gains. Without concerted efforts to elevate consumer awareness through education campaigns and transparent labeling, firms lack the commercial justification to scale green processes, perpetuating reliance on conventional products amid rising sustainability expectations. Consequently, this dynamic not only hampers industry-wide adoption but also undermines the transformative potential of green manufacturing as a driver of competitive differentiation.

3.2. Cross Barriers Interactions

Organizational and institutional barriers to green manufacturing implementation do not operate in isolation but form a complex, mutually reinforcing system that amplifies their constraining effects on manufacturing firms. Specifically, external factors such as inadequate government support manifesting in rigid policies, insufficient financial incentives, and weak enforcement, directly undermine internal capabilities by increasing the perceived financial risks of green investments and reducing the strategic priority of sustainability initiatives. For instance, the absence of subsidies or tax breaks for eco-friendly technologies heightens the burden of high initial and operational costs, while unclear regulations discourage managerial commitment, as leaders prioritize short-term profitability over uncertain long-term environmental gains (Kannan et al., 2022).

Managerial commitment emerges as a critical cross-barrier nexus, serving both as an internal barrier and a mediator of external influences. When top management views green practices as peripheral rather than core to corporate strategy, firms underinvest in knowledge dissemination, employee training, and R&D, which in turn limits their ability to capitalize on emerging market demands or collaborate effectively in green supply chains. Conversely strong leadership can buffer external weaknesses: committed managers may proactively seek supply chain partnerships despite low customer awareness or advocate for better policies, thereby fostering a supportive organizational culture and skilled human resources over time. This bidirectional dynamic aligns with findings from Bendig et al. (2023), who frame such interactions within a multi-dimensional green manufacturing structure where leadership bridges institutional pressures and operational enablers.

Financial and technological constraints further illustrate these cross-linkages, particularly for SMEs in developing contexts. Elevated costs and limited R&D capabilities are exacerbated by ineffective supply chain management, where upstream suppliers resist green procurement due to their own regulatory uncertainties, creating a cascade of inefficiencies that strains internal budgets and innovation efforts. Low customer awareness perpetuates this cycle by dampening demand for green products, which discourages investment in skilled personnel or process upgrades yet these internal gaps also hinder firms' capacity to educate markets or meet nascent green standards (Mishra et al., 2022). Ultimately, breaking these loops requires targeted interventions, such as policy reforms to lower entry barriers alongside managerial training to build internal resilience, as evidenced in Table 2. This analytical perspective transforms the descriptive barrier listings into systems view, highlighting leverage points like managerial commitment for more effective green transitions.

These interdependencies are synthesized in the conceptual model presented in Fig. 4, which maps barrier relationships across macro, meso, and micro levels. As depicted, managerial commitment serves as a pivotal node, channeling external policy signals and market demands into internal transformations while mitigating financial and capability constraints. Fig. 4 thus provides a theoretical foundation for prioritizing interventions, such as leadership development programs that simultaneously address cultural, skill, and technological gaps in response to external enablers like regulatory incentives.

A conceptual model in Fig. 4 is proposed to visualize the interrelationships among the identified barriers, positioning managerial commitment as a central mediator between external pressures and internal capabilities. External barriers such as inadequate government support and low customer demand create an unfavorable environment that diminishes the perceived value of green investments, thereby reinforcing internal constraints like financial limitations and cultural resistance. This model draws from systems theory, where barriers form feedback loops: weak external incentives reduce managerial prioritization of sustainability, which in turn limits investments in training, R&D, and skilled human resources, perpetuating a cycle of low green manufacturing adoption.

The model illustrates three interconnected layers, macro (government policies), meso (supply chain and market dynamics), and micro (organizational factors), with bidirectional arrows indicating mutual reinforcement. For instance, insufficient supply chain coordination amplifies internal technology gaps, while strong managerial commitment can partially buffer external regulatory weaknesses by fostering internal innovation. This framework extends prior SLRs from Bendig et al. (2023); Kannan et al. (2022), which noted barrier interactions but did not propose an integrated visual representation of their relative importance and causal pathways.

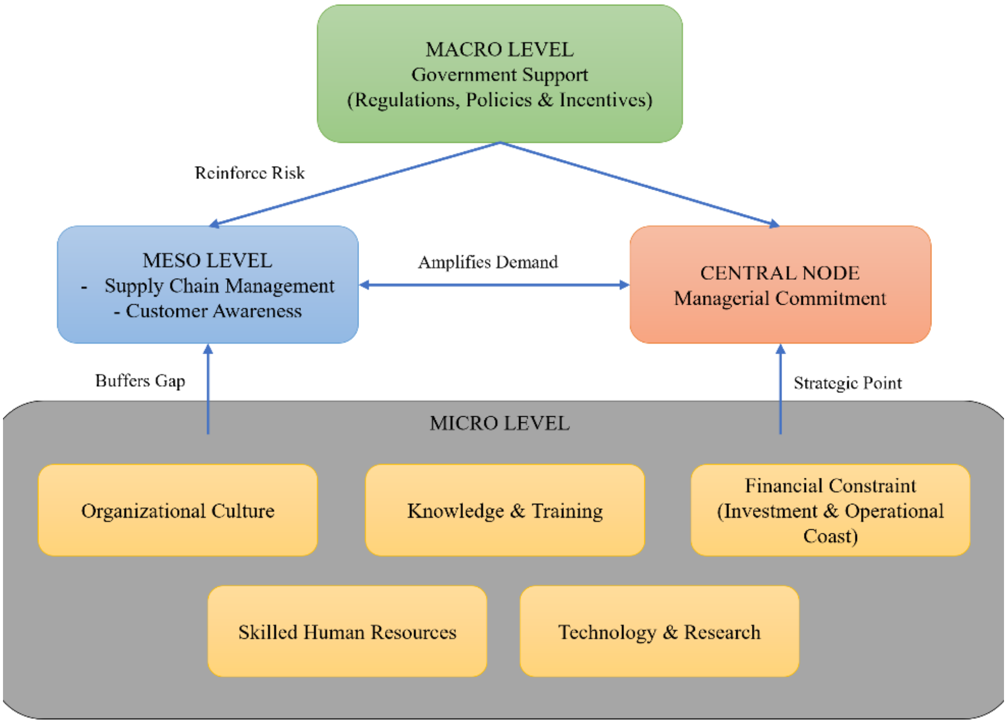

Fig. 4. Conceptual model of barriers interrelationships

The barrier configuration identified in this review, clustering around financial constraints, managerial commitment, technological gaps, government support, and their interdependencies closely mirrors yet extends key insights from prior SLR on green manufacturing challenges. According to Kannan et al. (2022), in their comprehensive SLR of green manufacturing obstacles, emphasize a similar core set of barriers including high investment costs, lack of technological readiness, inadequate policy frameworks, and internal competency deficits, while underscoring the need for mitigation strategies that address barrier interactions rather than isolated fixes. Their analysis, drawn from pre-2022 literature, highlights financial and regulatory hurdles as primary blockers for SMEs, a pattern strongly reaffirmed here with updated evidence from 2020–2025 publications that further reveals the amplifying role of post-pandemic supply chain disruptions.

According to Bendig et al. (2023) advance this discourse through a structured green manufacturing framework derived from an SLR, categorizing barriers across dimensions like organizational enablers (culture, leadership), technological infrastructure, and institutional conditions, dimensions that parallel the organizational-institutional dichotomy in Table 2 and Table 3. Unlike their more process-oriented focus, the present study provides a sharper delineation of barrier sources (e.g., distinguishing skilled HR shortages from broader knowledge gaps) and introduces explicit cross-barrier mappings, such as how low customer demand reinforces internal cultural resistance, offering a more granular view for practitioner application in developing economies.

Compared to these foundational works, this review contributes three key advancements: first, an updated temporal scope capturing 45 high-quality articles from 2020–2025, including emerging emphases on digital-green technology mismatches and supply chain resilience post-COVID; second, quantitative aggregation via publication trends in Fig. 2 and Fig. 3 that quantifies barrier prominence; and third, a conceptual model in Fig. 4 visualizing interrelationships, which builds on interaction calls in Kannan et al. (2022) and framework by prioritizing managerial commitment as a systemic leverage point (Bendig et al., 2023). These extensions address gaps in prior SLRs regarding relative barrier importance and actionable interdependencies, particularly for resource-constrained manufacturers.

The findings also carry several managerial implications. First, firms should treat GM as a strategic transformation agenda rather than a marginal compliance project, embedding environmental objectives into corporate strategy, performance indicators, and leadership development initiatives. Second, managers in manufacturing firms, especially SMEs, need to prioritize capability building through targeted training, cross-functional knowledge sharing, and selective R&D partnerships to gradually relax internal constraints related to skills and technology. Third, proactive supply chain engagement for example, through green procurement criteria, joint process improvement projects with suppliers, and information-sharing platforms can help offset institutional weaknesses and create meso-level support for green investments even when customer demand remains nascent.

In terms of policy implications, the review suggests that governments should move from fragmented or punitive regulatory approaches toward coherent policy mixes that combine clear standards with credible financial and technical support. Priority instruments include stable environmental regulations, tax incentives or subsidies for green technologies, funding schemes for skills development, and programs that encourage collaborative R&D and industrial symbiosis among manufacturers. Furthermore, public campaigns and eco-labeling schemes that raise customer awareness and signal the value of green products can gradually strengthen market-pull forces and reduce manufacturers' perceived demand risk.

Despite its contributions, this review has several limitations that should be acknowledged. The analysis is confined to journal articles indexed in four databases and filtered using an SJR threshold, which may exclude relevant insights from high-quality conference proceedings, industry reports, or studies in lower-ranked but contextually rich outlets. The focus on the 2020–2025 period, while justified by the objective of capturing the most recent developments, also means that earlier foundational works were only used as background and not systematically integrated into aggregation procedures. In addition, the reliance on content analysis of published studies implies that the strength and direction of barrier relationships are inferred rather than empirically estimated, and may be influenced by reporting biases in the underlying literature.

4. Conclusion

This study demonstrates that the implementation of green manufacturing (GM) in the post-2020 industrial landscape is constrained by an interconnected system of barriers rather than isolated factors. Key challenges include weak sustainability-oriented culture, limited knowledge and skilled human resources, high costs, technological constraints, low managerial commitment, and insufficient government support, supply chain effectiveness, and market demand. The interaction between internal organizational limitations and external institutional gaps particularly hinders GM adoption in developing countries and SMEs. From a theoretical perspective, this study proposes an integrated conceptual model that captures the interdependencies of barriers across macro, meso, and micro levels, with managerial commitment serving as a central mediating factor. The model highlights reinforcing feedback loops, where weak external incentives reduce managerial prioritization of sustainability, thereby limiting investments and strengthening organizational resistance. For future research, empirical studies using longitudinal and comparative designs are recommended to test and refine the proposed model. Additionally, mixed-method approaches combining qualitative and quantitative techniques are encouraged to better understand the dynamic interactions among barriers. Further research should also explore the linkages between GM, digital transformation, circular economy, and industrial resilience.

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