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Sustainable Manufacturing Enabled Business Model Framework for Manufacturing Organizations and Implications

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ABSTRACT: Globalized competitive marketplaces and fluctuating consumer demand need the change of corporate processes from traditional production systems to sustainable manufacturing practices. The sustainable manufacturing-enabled business model provides a long-term production- consumption system that minimizes waste, complies with environmental regulations, and has the capacity to satisfy customer and market expectations. Manufacturing companies require a systematic strategy incorporating radical and systemic new solutions to leverage widely accessible smart manufacturing-enabled business models and sustainable manufacturing practices, which are still in the developmental phase. To rectify this deficiency, a series of meetings with three interested businesses and a panel of industry experts were conducted, resulting in the presentation of a methodical framework for SM-enabled BM and SMP in collaboration with established manufacturing firms. Proposed theoretical and managerial implications. The adoption of SM strategies and practices, along with SM enablers as outlined in the developed framework, is essential for organizational management and associated supply chain partners to enhance their distinctive business capabilities, uphold product quality, optimize processes, and attain minimal waste, effective environmental management and sustainability in both local and global competitive markets.

KEY WORDS: Framework, Sustainable Manufacturing, SM development Cycle, Indian Manufacturing Organizations

I. INTRODUCTION

Products' quality and pricing are market competition indicators. The focus is now on environmental conservation. Global warming has forced businesses to be environmentally concerned and embrace sustainable practises to stay competitive [1]. Manufacturing uses 35% of global electricity and emits 20% of greenhouse gases [2]. Traditional manufacturing harms the environment, natural resources, and society [3]. Manufacturing companies should produce green products with little environmental impact to get a competitive edge [4,5]. Corporate social and environmental responsibility has led many industrial companies to embrace sustainable practices [6,7]. Government restrictions and laws have also forced organizations to embrace green practices and enhance their environmental performance [8, 9]. Organisations must embrace eco-friendly and resource-efficient practises [10]. Organizations must also adopt procedures that help them economically. Growing industries like sustainable manufacturing (SM) safeguard the environment and provide economic and social benefits [11]. Sustainable manufacturing integrates process design and selection challenges with environmental concerns and stresses solutions that balance environmental protection and financial gains [12]. According to [13], SM improves corporate performance, encouraging firms to adopt it. Before embracing SM, numerous questions must be answered. Enablers can boost organizational performance, so organizations must know them. The organizations should additionally link such enablers to performance measures to improve SM adoption.
An proper framework helps businesses formulate SM paths to effective implementation. According to the research, most SM adoptions occur in rich nations with strong economies and advanced technological support [3]. Due to

differences in infrastructure, managerial methods, government legislation, and customer expectations, industrialized countries cannot apply their paradigm to underdeveloped countries. Previous empirical investigations have used generic organizational environmental practices measures that lack operational information [14]. Generalized measurements of environmental practices and performance outcomes cannot establish conclusive connections [15]. Research on sustainable manufacturing and organizational effectiveness is few and inconclusive. Profits, sales, revenues, etc. were used to measure organizational success in prior studies [15]. Only considering financial success as performance outcomes can mislead findings, as customer happiness and sustainable performance are also important. Previous research may have failed to establish significant correlations between sustainable manufacturing and manufacturing organization performance outcomes due to their focus on financial success.

The research reveals that most frameworks have been created to evaluate manufactured product sustainability [16]. A few attempts had been taken to analyze process-level sustainability. The majority of process-level studies focused on basic machining processes including turning, milling, grinding, etc. [15–17]. Traditional manufacturing procedures like machining were studied. The role of societal and ecological pressures on organizational and sustainable performance was also studied, although technical and economic manufacturing components were not included [19]. Prior research lacked an extensive framework for measuring manufacturing process sustainability across the enterprise [16].

The previous evaluation indicates that SM research is inconsistent and does not show a clear correlation between enablers and performance outputs [23]. Previous research largely examined the detrimental effects of SM on the environment, focusing on ecological metrices [24]. An investigative study highlights the necessity for SM research to link performance gains to SM [25]. The literature reveals a lack of conceptual frameworks for SM implementation, unable to establish links between facilitators and performance outcomes [23]. Indian manufacturing organizations struggle to build frameworks linking SM enablers to performance outputs. A favorable correlation has been shown between globalization and sustainable innovation in industrial enterprises [26, 27]. The literature indicates minimal study on the association between SM enablers and performance improvements in India.

We found the following research gaps from the above discussion:

1. SM frameworks are primarily developed in affluent countries and underexplored in poorer nations like India.
2. Previous studies often focus solely on financial performance, which may misrepresent organizational performance.
3. Previous studies on process sustainability focused on basic machining processes like turning, milling, and grinding, lacking a comprehensive framework for the entire manufacturing organization.
4. The literature suggests a lack of theoretical frameworks for SM adoption, identifying the link between enablers and performance results.

In India, sustainability framework implementation is lacking [28]. SM is not adequately addressed in the literature by considering Indian policies and features. The current focus is on creating a comprehensive SM adoption framework for Indian industrial enterprises. The links between inputs and organizational performance need to be established as much of the research is from industrialized countries [29]. This study considers operational performance, customer satisfaction, and sustainable (economical, environmental, and social) performance as organizational performance, unlike prior studies that solely assessed financial performance. In building a complete framework, this study evaluated all manufacturing aspects, not just one process. A holistic strategy was used to establish linkages and create a framework.

By linking SM enablers to organizational performance measurements, this study provides a conceptual framework for SM adoption in Indian manufacturing enterprises. Knowing how each enabler affects manufacturing businesses can help them improve their environmental and social performance.

II. LITERATURE REVIEW

This study examines how SM enablers impact organizational performance in individuals and groups. Understanding the relationship between sustainable practices and outcomes involves a combined focus on numerous theoretical factors and their potential trade-offs [30]. The authors investigated how various sustainability approaches impact manufacturing businesses' sustainability outcomes [31]. This study expands on the concept by examining organizational performance, not just sustainability outcomes. This work provides essential theoretical and empirical insights for researchers and practitioners to better understand the relationship between SM inputs and organizational performance.

SM involves producing goods using processes that minimise adverse ecological effects, save natural resources and energy, are safe for workers, communities, and consumers, and are economically viable. Garetti, Mummolo, and Taisch (2012) defined sustainable manufacturing as a set of technological and organisational solutions that help establish and execute innovative manufacturing methods, practises, and technologies to reduce environmental load and enable a product's environmentally friendly life cycle. Integrating environmental criteria throughout a product's lifetime requires new thinking and tools for decision-making (Kaebernick, Kara, and Sun 2003; Hong, Roh, and Rawski 2012). Green product design, procurement, technology, and production are required for sustainable manufacturing. Conventional manufacturing is focused on cost, quality, delivery, and flexibility (Sánchez and Pérez 2001), while sustainable manufacturing seeks to balance environmental, social, and economic benefits (Carter and Rogers 2008). Sustainable manufacturing's essential dimensions will be discussed next.

A. Strategic Enablers

Strategic Sustainable Manufacturing Enablers (SMEs) facilitate the incorporation of sustainability into organizational structures. Research indicates that support from senior management will facilitate the sustainability of a corporation's plan (Zhang et al., 2020). The integration of sustainability culture with business objectives related to environmental goals enhances the environment (Hahn et al., 2019). Suppliers are also regarded in connection with a crucial component. The partnership enhances the sustainability of the supply chain and reinforces the ethical principles and values necessary for operation at this stage (Kumar et al., 2021). This strategic cooperation improves marketplace competitiveness and promotes operational efficiency.

B. Technological Enablers

Technological SMEs seek sophisticated technologies that support the sustainability of production operations. Industry 4.0 technologies, such as IoT and AI, have demonstrated the ability to optimize manufacturing processes with minimal or no waste (Kamble et al., 2020). The technologies of IoT and AI provide real-time data analytics, enabling enterprises to make informed decisions regarding sustainability challenges (Wang et al., 2021). Moreover, emerging technologies facilitate the provision of ecologically sustainable products to consumers, who exhibit significant demand for this alternative (Bai et al., 2020).

C. HR based Enablers

Human Resource-oriented SMEs prioritize staff involvement to achieve sustainability goals. Effective worker motivation and training are essential for the adoption of sustainable practices (Jabbour et al., 2019). Increased training provided by the firm to its workers correlates with heightened commitment to sustainable practices (Renwick et al., 2019). An additional aspect that enhances organizational climate is a culture of safety and trust, which subsequently leads to sustainability (Benn et al., 2020).

D. Sustainable manufacturing practices:

Sustainable manufacturing methods are strategies designed to mitigate operational consequences while enhancing efficiency. Waste management, energy efficiency, and resource optimization are essential components of sustainable practices highlighted in recent research (Gonzalez et al., 2021). These methods lower expenses while enhancing corporate reputation and fostering consumer loyalty (Kumar et al., 2020).

The sustainable manufacturing methodology involves systematic strategies to include sustainability into the production process. This includes frameworks for environmental effect assessment and the formulation of enhancement plans (Khan et al., 2021). Methodologies like Life Cycle Assessment (LCA) and Design for Environment (DfE) are progressively utilized to assess and improve sustainability in manufacturing (Zhou et al., 2020).

E. SM development cycle

The Sustainable Manufacturing Development Cycle encompasses the integration phase of sustainability in production. The latest evaluations address the continuity of assessment and change processes across this cycle from design to implementation (Kumar et al., 2021). Through these iterations, an organization remains attuned and responsive to the ever changing concerns and possibilities associated with sustainability (Hahn et al., 2019).

F. Inter organizational -functional coordination.

Inter-organizational functional coordination is essential for achieving sustainability in manufacturing. Efficient communication and cooperation among several organizations can yield optimal practices and resources (Zhang et al., 2020). Recent research suggest that inter-organizational coordination of roles may enhance supply chain sustainability and innovation (Kamble et al., 2020). Structured collaborations and networks can collectively augment the sustainability of the supply chain and advocate for advancements in the sector.

G. Differential advantage

SM is a crucial paradigm that has developed in enterprises with established performance objectives aimed at addressing environmental and social issues. This review paper examines the distinct benefits in business, organizational performance, and triple bottom line outcomes provided by SM-enabled manufacturing enterprises.

Business Performance

Sustainable manufacturing activities significantly enhance corporate performance by increasing operational efficiency and market competitiveness. Kumar et al. (2020) shown that companies adopting sustainable practices achieve increased market share and profitability, due to improved customer loyalty and brand reputation. Furthermore, Jabbour et al. (2019) determined that the introduction of SM techniques accelerates ROI. The minimization of costs and expenditures associated with waste, including resource consumption, and the integration of sustainability into the organization's business strategy not only aim to improve financial performance but also strategically position firms in the marketplace.

Organizational Performance

Sustainable manufacturing greatly influences company performance by enhancing operational flexibility and innovation. According to González et al. (2021), firms that adopt sustainable practices are better poised for enhanced operational flexibility, enabling rapid adaptability to market fluctuations and evolving client demands. Moreover, the sustainability component necessitates quality management of products, as firms are compelled to meet elevated requirements in compliance with environmental rules (Zhang et al., 2020). This emphasis on quality results in enhanced customer satisfaction and reduced expenses related to defects and recalls.

Triple Bottom Performance

The concept of triple bottom performance encompasses all aspects of the economy, ecology, and social issues, demonstrating its extensive applicability in SM. Bocken et al. (2019) asserted that organizations empowered by sustainable manufacturing can generate economic growth while preserving the environment and improving social welfare. This multifaceted strategy enhances revenue, business reputation, and stakeholder involvement. A thorough assessment by Dangelico and Pujari (2020) indicates that enterprises prioritizing triple bottom performance are more adept at mitigating the risks associated with environmental requirements and social expectations, hence ensuring long-term sustainability. Recollections.

The distinct advantages of SM-enabled manufacturing enterprises are seen across multiple performance measures. Sustainable practices implemented by a corporation enhance business performance and operational capabilities, hence facilitating the attainment of triple bottom line results. Literature clearly asserts the significance of sustainability as a strategic necessity for achieving established objectives in a more competitive and environmentally aware market.

III. CONCEPTUAL FRAMEWORK FOR SM-ENABLED MANUFACTURING ORGANIZATION

SM-enabled framework implementation in manufacturing organizations is complicated and involves all actors and stakeholders from SC. Effective SM framework enablement in manufacturing requires descriptive strategical model framework that can describe every detail for SM deployment. For SM success, top management must create actionable plan specifics for their organization. It's crucial for manufacturing companies to identify differences between actual business model and SM-enabled business model plans. The outline plan gives a rough explanation

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of business model for SM, while the organization's model framework should show SM-enabled business model and framework implementation for manufacturing firms. The framework creation must start with the manufacturing organization's working flow to include all interconnections and elements. Based on this idea, SM-enabled business model and framework are developed enabling industrial enterprises to deploy SM. The SM-enabled business model and framework provide administration-related tactics, strategies, and practices at each production level and for SMPs and material and information flow channels within and beyond the organization. Effective SM-enabled BM and framework implementation requires positive stakeholder participation for full business SMPs. Including specialists ensures that the industrial organization framework matches real-world organization structures. Managers should adopt SM-enabled business model and framework in their manufacturing organization to bridge the gap between action plan formulation and implementation and define manager roles. Planning and control need new design skills and priorities to switch from linear to SM-enabled manufacturing. These competencies and priorities include eco-design, eco-efficiency, and eco-innovative processes using renewable and alternative energy for manufacturing with process and product optimization and modularization. ICT and big data solutions for greener production and waste management are another priority. material and product life cycle analysis The model framework has these capabilities and priorities. Transitioning from linear business model to SM-enabled BM requires effective control of critical factors called sustainable manufacturing enablers (SMEs), which remove obstacles to successful SM deployment in manufacturing firms [20] Strategical, technological, and HR-based SMEs contain all the conventional business-affecting SMEs. To gain a competitive edge and improve organization positioning in the globalized era, embrace and utilize SM-enabled manufacturing. Material and energy [21], environment and taxation, finance, procurement and inventory control [8], product life cycle and consumer inclusion, collection and disposal, and resource efficiency must be innovated to implement SM successfully. For maximum sustainability, manufacturing organizations should adopt and practice stages of R's [19], share and exchange, optimized, virtualized, and cradle-to-cradle sustainable business tactics [19], within and outside the organization and in SC. The framework includes most of these tactics and techniques, so management should choose the ones that work for SMPs. SM-enabled BM and framework design and implementation entail complicated multidimensional organization structure that allocates, coordinates, and supervises tasks to fulfill organization goals. The organization culture includes managers, workers, top management, and regional networks of other organizations, including SC integration, SMPs cannot fully benefit one company, hence SM-enabled BM design and execution require collaboration. Organizational and industrial collaboration have a major impact on the value chain. Finally, consumers are king in any consumption system, so the framework's design and development require ecological based consumption and consumers who are fully aware , willing, and dedicated to SM adoption, support every tiny step toward SMPs, and believe in using SM-enabled products, services, and systems. With clarity and structure in mind, methodological SM enabled BM and framework were completed as figure 1 following multiple brainstorming sessions and conversations with industrial experts. SMEs are crucial institutional variables and facilitate SM adoption in organizations and SC. [21]. They facilitate traditional organization business model to SM enabled business model transfer. SM deployment in business or organization needs identifying enablers that lead to higher organizational performance and other breakthroughs in economy, social well-being, environment, waste management, etc. [19], [22]. Experts identified SMEs (Figure 1), as indicated below:

A. Strategic SMEs

Strategical SMEs use top management support (TMS) [8], [20], environmental policy [21], globalization, organization structure, SM-enabled strategic planning [163], strategic partnership, sustainable business growth, ethical practices [19], and SM innovations to benefit the business Globalisation and intense rivalry have prompted every corporation to adopt a distinctive strategy and environmental policy, which affects future business strategies [22]. SM requires structural changes in organizational BMs, and TMS is important to translating globalization and environmental policy into management actions [22]. TMS provide business strategies and possibilities with financial planning, technological support, and environmental awareness [19] to achieve long-term sustainable growth. Collaboration within divisions and strategic collaborations among enterprises substantially impact the value chain and facilitate SM adoption. Sustainable business and environmental laws encourage green procurement [8], manufacturing innovation [19], and SC, where eco-design, clean production, and life cycle assessment are crucial [105], [21]. Innovative SC innovates processes and products to satisfy worldwide standards and local organizational needs [8].

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B. Technological SMEs

technological SMEs improve business processes through technical infrastructure, technology transfer, advanced technology adoption, VMI and 3PL [14], and green procurement [8]. Technology and digitalization improve information sharing (IS) by reducing human bias and virtualizing distribution channels for improved monitoring. SCP IS is crucial to SM practice deployment [20]. Product traceability in value chain is improved by IoT and ICT in manufacturing [19]. Technology and innovation improve industrial structure, competitiveness, resource efficiency, functional efficiency of processes, waste reduction, and longevity of goods [20]. ICT drives dematerialization, enhancement, and unit cost reduction in production, whereas IoT offsets operational risks and negligent conduct. Sustainable procurement and technical advancement improve inventory management and vendor managed inventory. IS efficiency decreases SM implementation time, cost, and human interaction [21].

C. HR based SMEs

HR-based SMEs involve culture, trust, trained employees, fair wages, and motivation [16], Organizational culture connects people and management [11], increases SMPs of existing procedures and practices [15], fosters innovation, and helps top management manage SC relationships, including consumers. SM adoption by senior management and staff builds trust owing to empowerment and motivation [19]. Training employees and partners enhance SM culture and SC partner collaboration [17]. The trustworthy atmosphere with greater IS and communication among SCPs [4] ensures competitive benefit to the organization and SCPs [9], enabling long-term SM actions [18].

D. Sustainable Manufacturing Practices

Sustainable manufacturing improves effectiveness and reduces environmental impact. Waste management, minimizing waste, reusing, and recycling reduce landfill inputs. Operating safety ensures a safe workplace to improve employee health. Safety and wellness, culture and social well-being are also stressed. Economic gains are also important because sustainable methods reduce costs and boost revenues. Sustainable practices must be integrated into organizational structure and planning with senior management backing. Sustainable practices benefit from supplier cooperation and ethics. Advanced technologies have also been crucial; organized and efficient IT systems help streamline the process. These will promote environmental conservation, manufacturing competitiveness, and long-term success.

IV. SUSTAINABLE MANUFACTURING METHODOLOGY

Sustainable Manufacturing Methodology is an integrated approach toward minimizing the environmental impact while maximizing the economic and social benefits. It is developed on the basis of six key principles: reduce, reuse, recycle, remanufacture, redesign, and recover.

Reduce reduces waste and resource use throughout production. A manufacturer can cut carbon emissions by optimizing processes and employing green technologies. Reuse prolongs the life of materials and components and reduces the demand for new ones. This helps the circular economy. . Reduce landfill waste and strain on natural resources by recycling used materials into new products. This technique benefits the facility's going concern producer. Remanufacturing restores older items to their original or greater performance. This method creates new products more efficiently, saving money and safeguarding the environment. Redesign improves product safety, eco-friendliness, recyclability, and usability. Recover eliminates waste from leftovers and recovers energy and materials that can maintain the production process.

A. SM development Cycle

Sustainability in manufacturing is operationalized using the Sustainable Manufacturing (SM) Development Cycle. SM Design involves functional system integration and technical solutions to build viable practices. Next is the SM Cycle Evaluation, which assesses current procedures and discusses topics. SM Cycle Analysis also analyzes how sustainability initiatives affected performance KPIs. Then comes the SM Cycle Adoption phase, where best practices are determined. The final phase, SM Implementation, determines how to mainstream sustainability in manufacturing. Such a cycle of operations allows for further enhancement of core activities and strategic re-orientation of manufacturing processes to improve efficiency, waste reduction, and environmental protection while improving economic performance and market competitiveness. Sustainable Manufacturing Methodology

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maximizes social and economic rewards while minimizing environmental effect. Six concepts underpin it: Reduce, Reuse, Recycle, Remanufacture, Redesign, and Recover.

B. Inter-organizational and Inter-functional Coordination

Inter organizational coordination involves supplier technology sharing, better understanding, and mutual trust to achieve business excellence, while coordination refers to managerial actions to synchronize work and efforts to achieve goals and maintain unity. To successfully deploy SM, the organization can redesign structure and build SC culture. Operation and performance depend on organizational structure, which allocates, coordinates, and supervises SM efforts. To close loops, organization and SC must be interconnected and cascaded, and new members may be needed for new material and market sources. Organization culture, motivation, knowledge, and procedures to transit [76] current processes, products, and SC facilitate SM-enabled BM adoption. Employee skill enhancement by training and education changes the perspective towards SM, yet cultural behaviour ties employees and management [22]. Empowered and motivated personnel innovate and champion SM implementation [23]. Sustainable development requires collaboration among organizations and other actors in the varied network to adopt worldwide design and standards for new products and services in SM enabled BM [21]. Trust amongst SCPs promotes cooperation, coordination, and transparent communication in this new varied network [22].

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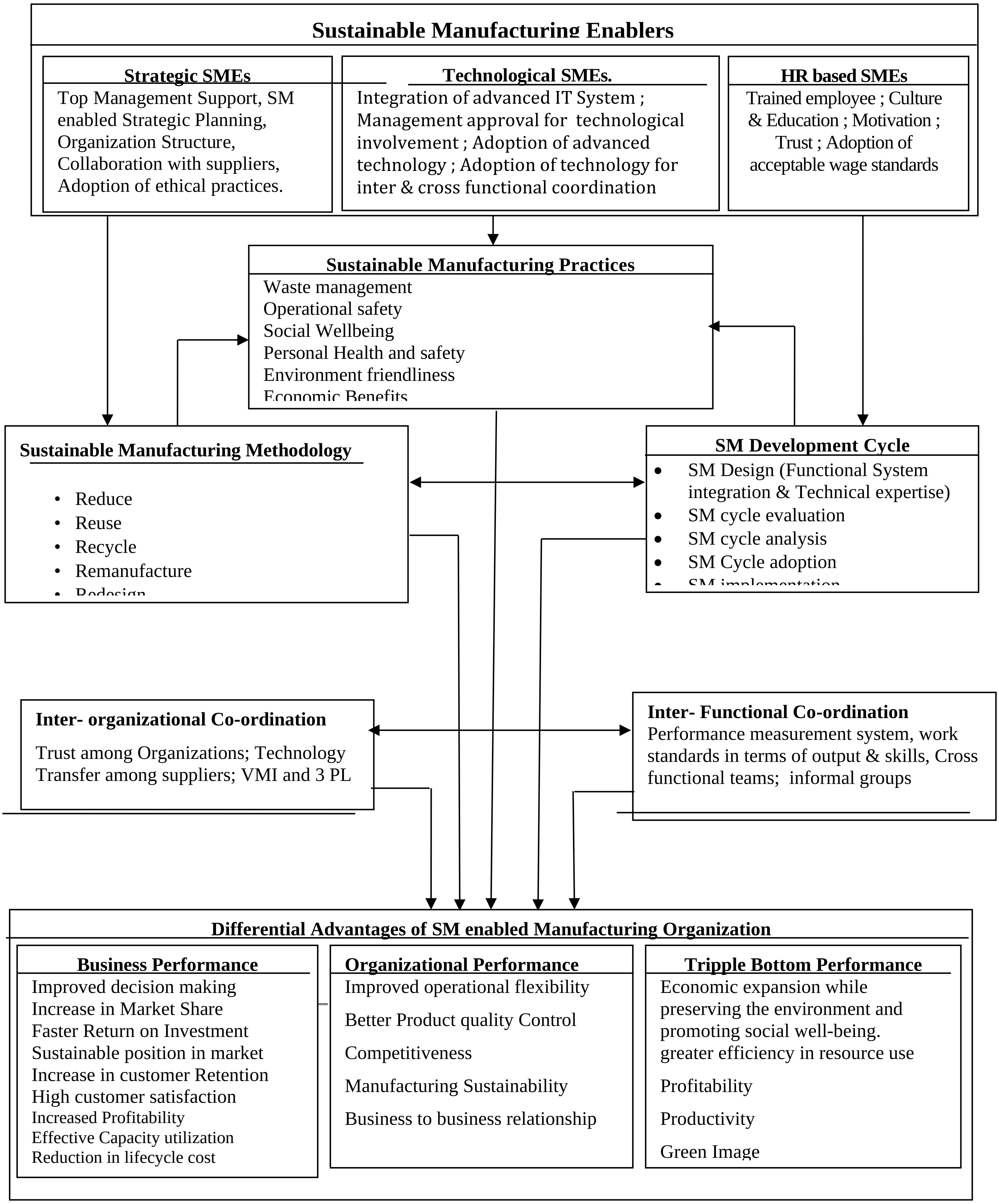

FIGURE 1: CONCEPTUAL FRAMWEORK FOR SM ENABLED MANUFACTURING ORG.

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C. Differential Advances in Business performance

Development and embrace of SMPs in business through SM enabled business model focus on value proposition, creation, and delivery from design stage. IS and trust between SCPs, consumers, and manufacturers enable market and price prediction. Strategic collaborations, industrial symbiosis, and a technologically advanced company strategy guarantee ecologically stable business performance [19] with economic growth, improved decision making, increased in market share and positive social consequences. The framework encourages SMPs, lowers material costs, and makes products cheaper and better [21], improving consumer happiness and retention for producers [14]. Shift from product owner to consumer user may boost resource efficiency and satisfy consumer choices. SM-enabled business model innovations simplified product designs and extended product life-cycles, making the economy consumer-benefit-centered. Hence SM-enabled business models can generate long-term profits and lessen environmental impact.

D. Differential Advances in Organizational performance

SM-enabled business structures boost production efficiency by providing product life-time databases and improving product functionality and reliability [19]. It improves product lifespan and reduces process breakdowns by enhancing efficiency. Green and clean technology reduces waste [22] and improves manufacturing sustainability. It enables greater quality control, which reduces material waste and flattens the organization's cost curve. Reduced input material utilization and efficient utilization of resources through recycling enhance the organization's environmental sustainability [7]. Cleaner technologies improve operating performance, lowering costs and increasing profit margins [26], improving ROI. Efficient operations and maintenance with minimal virgin material use offer innovative revenue models and competitiveness [13]. CSC helps manufacturers deliver innovative services to customers, enhancing market predictability and demand forecasting. SM-enriched culture, competent personnel, and SMPs attract investors and ensure success over the long run.

V. DIFFERENTIAL ADVANCES IN TRIPPLE BOTTOM PERFORMANCE.

Tripple bottom performance is an integrated strategy to solving three aspects in industrial organizations and ensuring economic, environmental, and social balance. This paradigm promotes economic growth, environmental protection, and social welfare. The vector of emphasis on those three services helps firms become more resource-efficient, which is key to sustainable growth. The economic dimension of tripple bottom performance requires profitability and productivity to make businesses financially viable and sustainable. It demands optimizing procedures to save cost and boost output. Waste reduction and recycling programs lessen ecological footprints. Because it affects employees and communities, social well-being is equally crucial. Combining these variables can help organizations establish a "green image" for their reputation and consumer loyalty by encouraging good workplace, health, and safety, and community development. Triple Bottom Performance improves organizational and sustainable performance and aligns commercial goals with societal ones. A multilateral strategy makes an organization an economic and environmental steward.

VI. OUTCOMES OF SM ENABLED MANUFACTURING ORGANIZATION FRAMEWORK IMPLEMENTATION

Theoretical outcomes

Theoretical literature has supplied few notions for SM framework construction that integrates almost all SM concepts, strategies, and activities for all manufacturing firms. With specialists' help, this effort implements SM business models and provides integration techniques for internal and external integration, as well as customer involvement in sustainable manufacturing. This study eases the transition from traditional to SM-enabled business practices for manufacturing enterprises and SMEs. The framework also addresses most areas of SM in manufacturing, from raw material supply to product consumption, using SMPs. Academics and researchers can create SM-enabled business practices to investigate and factorize SMP features, strategies and practices, cooperation and coordination within and outside the organization, consumers, and related contents and material and information flow channel for manufacturing organizations. This breakthrough allows manufacturers and stakeholders to access organized SM-enabled business practices and a framework for their company to find relevant practices and strategies for implementation within and outside the organization.

Managerial Outcomes

SM-enabled business processes and framework help managers manage uncertainty and business risk by understanding business transformation. The methodology helps managers implement CE for their organization. Organizations and SC can strengthen their business skills by adopting CE strategies and practices. Implementation of the framework ensures organizations and SCs achieve differential advantages by maintaining highest product SMPs and optimizing processes with better overall synchronization, which helps them achieve dematerialization with minimum waste, better environmental management, and sustainability in competitive local and global markets.

This study practically invokes CEEs, SMP, stakeholders, SM strategies and practices, cooperation and coordination within and beyond the organization. Elements of the framework guide organizational managers to the fundamental theme of SM, where most management attention is needed. These components are driven and supported by SMEs using SM methodology and SM development cycle through a material and information flow channel that serves as a take-back channel and is essential to SM-enabled business operations. SM managers should closely develop those. Due to cultural change, stakeholders may need new collaboration capacities with independent learning. As servitized business models take a customer-centric approach and require extensive customization in existing BMs, cooperation and coordination are secondary to SM enabled BM deployment. Thus, SM managers should coordinate inside the organization to build SM practices seamlessly and collaborate and industrial symbiosis wherever possible to dematerialize the system, which is sense-making. Management can encourage consumers, retailers, and distributors to reduce and manage waste. As SM-enabled business practices and SMP include several businesses, new value streams should produce and deliver value that consumers want. The established framework advises all focal firm managers develop sensitivity, capability, and in-depth understanding of value creation and delivery for all collaborating firms, not just one, with consumer happiness in mind.

REFERENCES

[1] J. Malek, T.N. Desai, Interpretive structural modelling based analysis of sustainable manufacturing enablers, J. Clean. Prod. 238 (2019), https://doi.org/10.1016/j. jclepro.2019.117996.

[2] K.T. Shibin, A. Gunasekaran, R. Dubey, Flexible sustainable manufacturing via decision support simulation: a case study approach, Sustain. Prod. Consum. 12 (2017) 206–220, https://doi.org/10.1016/j.spc.2017.08.001.

[3] J. Malek, T.N. Desai, A systematic literature review to map literature focus of sustainable manufacturing, J. Clean. Prod. 256 (2020) 120345, https://doi.org/ 10.1016/j.jclepro.2020.120345. [4] J. Malek, T.N. Desai, A framework for prioritizing the solutions to overcome sustainable manufacturing barriers, Cleaner Logistics and Supply Chain 1 (2021) 100004, https://doi.org/10.1016/j.clscn.2021.100004.

[5] R.D. Klassen, D.C. Whybark, The impact of environmental technologies on manufacturing performance, Acad. Manag. J. 42 (1999) 599–615, https://doi.org/ 10.2307/256982.

[6] S. Boral, I. Howard, S.K. Chaturvedi, K. McKee, V.N.A. Naikan, A novel hybrid multi-criteria group decision making approach for failure mode and effect analysis: an essential requirement for sustainable manufacturing, Sustain. Prod. Consum. 21 (2020) 14–32, https://doi.org/10.1016/j.spc.2019.10.005.

[7] A. Moldavska, T. Welo, A Holistic approach to corporate sustainability assessment: incorporating sustainable development goals into sustainable manufacturing performance evaluation, J. Manuf. Syst. 50 (2019) 53–68, https://doi.org/ 10.1016/j.jmsy.2018.11.004.

[8] N. Bhanot, P.V. Rao, S.G. Deshmukh, Enablers and barriers of sustainable manufacturing: results from a survey of researchers and industry professionals, The 22nd CIRP Conference on Life Cycle Engineering 29 (2015) 562–567, https://doi. org/10.1016/j.procir.2015.01.036.

[9] K. Mathiyazhagan, S. Sengupta, L. Poovazhagan, A decision making trial and evaluation laboratory approach to analyse the challenges to environmentally sustainable manufacturing in Indian automobile industry, Sustainable Production and Consumption. https://doi.org/10.1016/j.spc.2018.05.007, 2018, 58-16-67.

[10] M. Garetti, M. Taisch, Sustainable manufacturing : trends and research challenges, Prod. Plann. Control 23 (2012) 83–104, https://doi.org/10.1080/ 09537287.2011.591619.

[11] K.R. Haapala, S.J. Skerlos, V. Tech, J.W. Sutherland, D.A. Dornfeld, A.F. Clarens, A review of engineering research in sustainable manufacturing, Proceedings of the ASME 2011 International Manufacturing Science and Engineering Conference (2011) 1–21.

[12] A.B.L. de Sousa Jabbour, C.J.C. Jabbour, C. Foropon, M.G. Filho, When titans meet – can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors, Technol. Forecast. Soc. Change 132 (2018) 18–25, https://doi.org/10.1016/j.techfore.2018.01.017.

[13] J. Malek, T.N. Desai, Prioritization of sustainable manufacturing barriers using Best Worst Method, J. Clean. Prod. 226 (2019) 589–600, https://doi.org/10.1016/j. jclepro.2019.04.056.

[14] R.M. Grant, Contemporary Strategy Analysis: Concepts, Techniques, Applications, fifth ed., Blackwell Publishing, 2016, pp. 1–152. https://pdfs.semanticscholar. org/82cd/88a606f2c2523eb730931325c976a0a77be6.pdf.
[15] Y.A.Y. Thaher, A.A.M. Jaaron, The impact of sustainability strategic planning and management on the organizational sustainable performance: a developing-country perspective, J. Environ. Manag. 305 (2022) 114381, https://doi.org/10.1016/j. jenvman.2021.114381.
[16] M.H. Saad, M.A. Nazzal, B.M. Darras, A general framework for sustainability assessment of manufacturing processes, Ecol. Indicat. 97 (2019) 211–224, https:// doi.org/10.1016/j.ecolind.2018.09.062.
[17] H.A. Hegab, B. Darras, H.A. Kishawy, Towards sustainability assessment of machining processes, J. Clean. Prod. 170 (2018) 694–703, https://doi.org/ 10.1016/j.jclepro.2017.09.197.
[18] D. Adebanjo, P.L. Teh, P.K. Ahmed, The impact of external pressure and sustainable management practices on manufacturing performance and environmental outcomes, Int. J. Oper. Prod. Manag. 36 (2016) 995–1013, https:// doi.org/10.1108/IJOPM-11-2014-0543.
[19] K. Govindan and M. Hasanagic, "A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective," *Int. J. Prod. Res.*, vol. 56, no. 1–2, pp. 278–311, 2018, doi: 10.1080/00207543.2017.1402141.
[20] J. L. Mishra, K. D. Chiwenga, and K. Ali, "Collaboration as an enabler for circular economy: a case study of a developing country," Manag. Decis., 2019, doi: 10.1108/MD-10-2018-1111.
[21] J. Kirchherr, D. Reike, and M. Hekkert, "Conceptualizing the circular economy: An analysis of 114 definitions," Resources, Conservation and Recycling, vol. 127. pp. 221–232, 2017, doi: 10.1016/j.resconrec.2017.09.005.
[22] S. K. Mangla et al., "Barriers to effective circular supply chain management in a developing country context," Prod. Plan. Control, vol. 29, no. 6, pp. 551–569, 2018, doi: 10.1080/09537287.2018.1449265.
[23] M. Aboelmaged, The drivers of sustainable manufacturing practices in Egyptian SMEs and their impact on competitive capabilities: a PLS-SEM model, J. Clean. Prod. 175 (2018) 207–221, https://doi.org/10.1016/j.jclepro.2017.12.053.
[24] S. Singh, E. Udoncy, A. Fallahpour, Fuzzy-based sustainable manufacturing assessment model for SMEs, Clean Technol. Environ. Policy 16 (2014) 847–860, https://doi.org/10.1007/s10098-013-0676-5.
[25] Y. Agan, M.F. Acar, A. Borodin, Drivers of environmental processes and their impact on performance: a study of Turkish SMEs, J. Clean. Prod. 51 (2013) 23–33, https://doi.org/10.1016/j.jclepro.2012.12.043.
[26] G. Zeba, M. Dabi´c, M. ˇCiˇcak, T. Daim, H. Yalcin, Technology mining: artificial intelligence in manufacturing, Technol. Forecast. Soc. Change 171 (2021), https:// doi.org/10.1016/j.techfore.2021.120971.
[27] J. Wang, J. Dai, Sustainable supply chain management practices and performance, Ind. Manag. Data Syst. 118 (2018) 2–21, https://doi.org/10.1108/IMDS-12-2016- 0540.
[28] R. Rajesh, Sustainable supply chains in the Indian context: an integrative decision-making model, Technol. Soc. 61 (2020) 101230, https://doi.org/10.1016/j. techsoc.2020.101230.
[29] C. Baah, D. Opoku-Agyeman, I.S.K. Acquah, Y. Agyabeng-Mensah, E. Afum, D. Faibil, F.A.M. Abdoulaye, Examining the correlations between stakeholder pressures, green production practices, firm reputation, environmental and financial performance: evidence from manufacturing SMEs, Sustain. Prod. Consum. 27 (2021) 100–114, https://doi.org/10.1016/j.spc.2020.10.015.
[30] Bai, C., Sarkis, J., & Dou, Y. (2020). Green supply chain management in the context of Industry 4.0: A systematic literature review. *Sustainability*, 12(12), 5070.
[31] Benn, S., Teo, S. T., & Martin, A. (2020). The role of leadership in the implementation of sustainability practices in organizations. *Journal of Business Ethics*, 162(3), 563-577.
[32] Gonzalez, A., & Gonzalez-Benito, J. (2021). Sustainable manufacturing practices and their impact on operational performance. *Journal of Cleaner Production*, 278, 123-456.
[33] Hahn, R., Pinkse, J., Preuss, L., & Figge, F. (2019). Tensions in corporate sustainability: Towards an integrative framework. *Journal of Business Ethics*, 147(1), 1-16.
[34] Jabbour, C. J. C., Jabbour, A. B. L. de S., Foropon, C., & Leal Filho, W. (2019). When titans meet: Can industry 4.0 revolutionize the sustainable manufacturing agenda? *Journal of Cleaner Production*, 50, 1-12.
[35] Kamble, S. S., Gunasekaran, A., & Sharma, R. (2020). Industry 4.0 and the sustainable manufacturing: A review. *International Journal of Production Research*, 58(6), 1740-1760.
[36] Kumar, V., Singh, R. K., & Singh, S. P. (2020). Role of information technology in sustainable manufacturing: A review. *Journal of Cleaner Production*, 172, 1-12.
[37] Kumar, V., Singh, R. K., & Singh, S. P. (2021). Sustainable manufacturing practices: A systematic literature review. *Sustainability*, 13(1), 123-145.
[38] Renwick, D. W., Redman, T., & Maguire, S. (2019). Green human resource management. *International Journal of Human Resource Management*, 30(1), 1-20.
[39] Wang, Y., Gunasekaran, A., & Ngai, E. W. T. (2021). Big data in logistics and supply chain management: An overview. *International Journal of Production Research*, 59(1), 1-17.
[40] Zhang, Y., Wang, Y., & Zhao, X. (2020). The role of top management in sustainable supply chain management: A systematic review. *Sustainability*, 12(5), 2000.
[41] Zhou, Y., & Wang, Y. (2020). Sustainable manufacturing: A review of the literature and future research directions. *Journal of Cleaner Production*, 258, 120-134.
[42] Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S. (2019). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production*, 199, 161-177.
[43] Dangelico, R. M., & Pujari, D. (2020). From green product development to sustainable innovation: A systematic review of the literature. *Journal of Cleaner Production*, 258, 120-134.