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A DECADE OF TRIPLE BOTTOM-LINE SUSTAINABILITY AND INDIAN MSMEs

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Abstract

The current status of the recent developments among India's MSMEs point to the fact that these establishments are more technologically savvy than their smaller competitors. It's understandable that SMEs would rather take it slow when it comes to investing in such technologies. Experts are paying more attention to how Industry 4.0 innovations will affect sustainability in terms of economic, environmental, and social factors. Numerous articles highlight the detrimental effects of not adopting Industry 4.0 on a country's economy. Many SMEs are cash strapped and require proof of ROI before allowing upper management, customers, or employees to adopt new technologies. Non-empirically valid measurements are those used in investigations that rely on things like literature reviews or case studies. This means there is a substantial information gap when it comes to creating an all-encompassing performance monitoring system for Sustainable Manufacturing (SM) in the context of Industry 4.0. The impact of Industry 4.0 technologies on sustainability in society and the economy is of growing interest to academics. Using the Triple Bottom Line approach to sustainable development, this study set out to investigate these consequences. A sustainability-oriented model is provided to analyze the effect of Industry 4.0 technology on these metrics. This study aims to summarise current research efforts, identify key research themes, and identify research gaps and future development prospects to evaluate sustainable manufacturing research's contribution to the advancement of Industry 4.0. By examining the potential socio-economic impact in a developing country like India and identifying the benefits and challenges for its implementation process, this study goes beyond the technical approach that dominates academic literature on Industry 4.0.

Keywords: Industry 4.0, Smart manufacturing, Sustainable Manufacturing, Triple Bottom Line Sustainability

1 INTRODUCTION

Even after two or three decades of "lean" and "green" production, there are still problems with long-term sustainability. Sustainable development may be promoted by Industry 4.0. Find the flaws and address them. TBL discusses the responsible utilization of finite resources. Constrained resources and the environmental and social costs of conventional production methods. Sustainable manufacturing requires the integration of commodities, processes, and systems due to their interdependencies. Every single small and medium-sized enterprise (SME) tried to contain the epidemic. Businesses can't succeed without adopting cutting-edge technologies and green methods. The proposed study looks at the sustainability of Indian MSMEs. Through bibliometric and content analysis (SM), the conceptual framework of sustainable manufacturing literature will be uncovered. This initiative focuses on sustainable production, which will employ Industry 4.0. This essay will

focus on the impact of Industry 4.0 on India's micro, small, and medium-sized businesses. The sustainability challenges we face today are formidable, despite the fact that businesses have studied and implemented lean and green manufacturing for the past 25-30 years. There is a growing urgency to achieve the Triple Bottom Line (TBL) objective as a result of the opportunities and challenges brought about by the current level of industrialization, such as ecological hazards and the overuse of non-renewable natural resources. The implementation of Industry 4.0 in production has the potential to significantly advance sustainable development. In this context, it's crucial to single out issues and propose workable solutions. Sustainable production is a reaction to the problems of resource depletion and conventional production's negative effects on the environment and society. Because of the interconnected nature of the impacts on sustainability, sustainable manufacturing necessitates the integration of products, processes, and systems. Industry 4.0's technologies have the potential to greatly improve

manufacturing's competitiveness.

During the course of the epidemic, every SME encountered a number of challenges that made survival a constant struggle. All companies, if they are to survive, will need to implement innovative practises and environmentally friendly policies.

Given the above, the proposed work investigates and evaluates the factors that sustain India's MSMEs. Bibliometric and content analyses will be used to improve the theoretical foundation of the SM literature. This study aims to develop a strategy for greener production using Industry 4.0 technologies. Business sustainability issues arise when strategic planning ignores environmental, social, and financial factors[1]. If financial, social, and environmental benefits are unequal, businesses will not adopt a sustainable strategy. Consumer awareness of the social and environmental costs of operating industrial facilities is forcing manufacturers to change their industrial expansion model. A poorly executed SM strategy won't inspire businesses to implement sustainable projects.

1.1 Industry 4.0 and Sustainability

Information technology and automation reshape industries. Societies are affected by population growth, resource depletion, land scarcity, pollution, food consumption, and waste management. New systems are required for manufacturing and consumption to be sustainable. Due to obstacles, research must be conducted on sustainable practises, standards, assessment methods, and new technologies. Industry 4.0 is enabled by technology. Assess first the social performance of organisations.[2]. Industry 4.0 promotes the longevity of businesses. A forward-thinking, multifaceted procedur will always increase sustainability. Using cutting-edge manufacturing procedures and technology to transform, record, distribute, and analyse data from production equipment and autonomous systems. Companies gain a competitive advantage by producing low-cost, high-quality goods with nonrenewable resources. Modern industrial technology can interact and adapt in real time, allowing businesses to create intelligent products and services .

It is possible to increase ROI by 15-20% by using BDA technologies. In order to increase customer loyalty, most businesses believe that combining CRM data with analytics is a good strategy (Rao, 2013). To better serve customers, one company used data mining to create a "face-lift automobile" (Chen et al., 2019). In addition, productivity and competitiveness can be increased by analysing data from all of a company's equipment and processes (Neri et al., 2018). To ensure accuracy, quality, and output in the biopharmaceutical production chain, for example, hundreds of variables must be monitored in real time. In order to make better products, manufacturers often analyse massive amounts of data in order to pinpoint crucial parameters.

The Internet of Things (IoT) is a network in which physical objects are equipped with sensors, actuators, and digital devices for data collection and exchange (Zhao et al., 2019). IoT allows devices, networks, and services to communicate and share data. The IoT can automate lighting, heating, machining, robotic vacuums, and remote monitoring. In the Internet of Things (IoT), auto-ID technology can create "smart objects." Internet and IoT data availability and accessibility have led to big data (Weking et al., 2020). Sensors, devices, video/audio, networks, log files, transactional apps, the web, and social media feeds generate big

data. A "big data environment" has developed in manufacturing. The Internet of Things (e.g., smart sensors) has accelerated data collection, but it is unclear if this data can be correctly processed to provide the right information at the right time (Waibel, Oosthuizen, and Du Toit 2018). Big data may challenge traditional data analytics (Tuptuk & Hailes, 2018). Tables 1 and 2 list, analyse, and rank Industry 4.0 tools by industry usage frequency.

Table 1. Industry 4.0 Tools and the respective support from the literature survey

Industry 4.0 Tools / Survey	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
Additive manufacturing	√		√		√	√	√			√	√	√
Artificial intelligence	√		√	√	√	√	√			√	√	√
Autonomous and collaborative robots	√		√		√		√	√	√	√	√	√
Big data analytics	√	√	√	√		√	√	√	√	√	√	√
Cloud computing and manufacturing	√		√		√		√	√	√	√	√	√
Cyber-physical systems			√	√	√	√	√	√	√	√	√	√
Cybersecurity	√	√			√	√	√	√	√		√	√
Industrial internet	√	√	√		√	√	√	√	√	√	√	√
Internet of things	√		√	√	√		√	√	√	√	√	√
Mobile systems and devices	√	√	√			√	√	√	√	√	√	√
Simulation	√	√	√	√		√	√	√	√	√	√	√

Table 2. Industry 4.0 Tools and the respective ranks

Sr.No	Rank	Industry 4.0 Tools
1	1	Big data analytics
2	2	Smart Sensor
3	3	Autonomous and collaborative robots
4	4	Cloud computing and manufacturing
5	5	Cyber physical systems
6	6	System integration
7	7	Additive manufacturing
8	8	Artificial intelligence
9	9	Cybersecurity
10	10	Industrial internet
11	11	Internet of things
12	12	Simulation
13	13	Augmented and virtual realit
14	14	Digitalization and virtualization
15	15	Machine to machine communication
16	16	Mobile systems and devices

Industry 4.0 is an industry transformation that integrates information technologies and automation to improve performance. Financial and social performance are examined. Industry 4.0 helps businesses achieve sustainability. [13]. [15] The author researched a number of different facets of sustainability and dove deeper into the environmental issues related to manufacturing to better understand the SM domain. [16], [17] Due to the digital revolution, businesses can now increase their productivity by implementing cutting-edge technology in their production processes.

1.2 Performance measurement

[18] lists over 40 sustainability indices and rating systems. Even though sustainability and Industry 4.0 are increasingly important in scientific discourse, [19] used several metrics to evaluate sustainable manufacturing to better understand the process's stages and features. Waste reduction, flow enhancement, pull-driven systems, multifunctional teams, and information systems organised the 21 performance metrics. Because automated production systems are expensive, many companies use the OEE as a success metric [20]. Condition-based and reliability centered maintenance helped organisations. [21] After classifying 73 indicators into twelve performance domains, the authors found that manufacturing firms prefer financial over non-financial metrics.

Table 3. Manufacturing indicators and the respective support from the literature survey in the context of sustainability

Manufacturing Performances/Authors	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]
Pollutant and effluent emission		*	*	*			*	*	*		*
Higher productivity	*		*	*	*	*		*	*	*	*
Smart working	*	*	*	*	*	*		*	*	*	*
Higher job satisfaction		*	*	*	*	*		*	*	*	*
Collaboration between companies	*		*	*	*	*	*	*	*	*	*
Collaboration between governments		*	*	*	*	*	*	*	*	*	*
Rate of investments	*	*	*		*						
Cost of manufacturing	*	*	*	*	*				*	*	*
Revenue	*	*	*	*	*	*	*	*	*	*	*
Salary and benefits	*	*	*	*	*	*	*	*	*	*	*
Profitability		*	*	*	*	*	*	*	*	*	*
Return on investment	*	*	*	*	*	*	*	*	*	*	*
SALES and Market Share	*	*	*	*	*	*	*	*	*	*	*
Operational cost	*	*	*	*	*	*	*	*	*	*	*
Acceptance rate of product	*	*	*	*	*	*	*	*	*	*	*
Machine /Equipment performance	*	*	*	*	*	*	*	*	*	*	*

Table 4. Ranking of Manufacturing indicators

Rank	Indicator
1	Higher productivity
2	Smart working
3	Collaboration between companies
4	Occupational health and safety
5	Manufacturing Performances
6	Pollutant and effluent emission
7	Higher job satisfaction
8	Collaboration between governments
9	Human resources and rights
10	Community and regulatory compliance
11	Job creation

1.3 Industry 4.0, TBL sustainability

Companies should embrace Industry 4.0 to maximize their resources for sustainable manufacturing. Successful sustainability adaption in Indian MSME,s would boost nation-building[33]. Sustainability and Industry 4.0 are important organizational elements for sustainable production[34]. Industry 4.0 technologies help overcome competition, changes, unpredictable market demands, and short product life cycles. They contribute to long-term growth. Several academic studies and concepts define sustainable manufacturing (SM). "It's the process of making manufactured things in a way that reduces environmental impacts and conserves energy and natural resources," says one definition. Productivity gains benefit labour, the environment, and the consumer. Globally, environmental management is more important. Many industrial enterprises lost money because they misunderstood sustainability. Industrialized nations' manufacturing industries are eco-friendly. India has a lower sustainability adoption rate than the U.S. The latest business technology includes Big Data Analytics, Blockchain, and Machine Learning. If used in manufacturing, these technologies belong to Industry 4.0. This requires examining how to embrace sustainability. This study is focused on use of Industry 4.0 to help MSMEs in underdeveloped nations to adopt sustainable practices.

The present status of MSMEs in India reveals that medium-sector enterprises have more matured technology than micro and small-scale enterprises. Understandably, the MSMEs prefer to

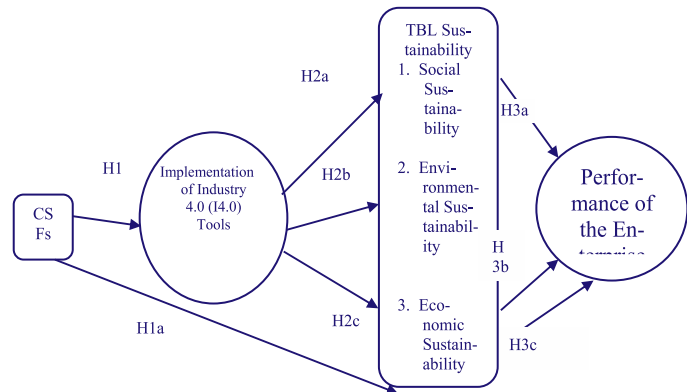
invest in such systems using a step-by-step approach. Therefore, these MSMEs are constrained with the budget and would see the benefits from the investments before allowing their management, customers, and employees to adopt the technology.

Moreover, many studies used literature reviews or case study approaches and lacked empirical validity for the measures. Thus, a significant knowledge gap is evident in developing a holistic performance measurement system for SM within the context of Industry 4.0. There is a need to conduct empirical studies seeking practitioner's views on the adequacy and applicability of performance dimensions in the Industry 4.0 context.

The following questions are the Research questions, which will be answered through this study.

1. To study and explore the Critical success factors (CSFs) influencing effective implementation of industry 4.0.
2. To study the effective implementation of CSFs which will affect/contribute to achieve TBL sustainability
3. Developing a well defined road map to analyze the critical success factors affecting implementation of Industry 4.0 tools in Indian MSMEs

2. RESEARCH METHODOLOGY AND STUDY HYPOTHESES



Top managers organize business activities and develop sustainable business models, policies, and strategies. The accomplishment of any strategic changes of a firm requires enthusiastic supports from the top management (Sony, Naik, & Therisa, 2019). Accordingly, Industry 4.0 requires involvement and support from top management (Sony, 2018). In the Industry 4.0 context, the top management influences the firm's financial and strategic guidance [35]. In fulfilling the specific expectation, the top management needs to have a practical understanding of the fundamentals of Industry 4.0 in order to redesign the managerial function to combine the vertical, horizontal, and end-to-end integration [36]. [37] found that top managers who are attentive and perceptive are more likely to recognize the emerging transformative changes. [38] revealed that top management could help firms become familiar, acknowledge any change, and systematically integrate all of the information. Top management needs to be very responsive to understand the firm's goals and objectives for incorporating Industry 4.0 technologies and sustainable industrial methods into the current production system, contributing to manufacturing transformation. Hence the following hypotheses can be formulated.

H1: The CSF's have a significant direct and positive influence on the implementation of Industry 4.0 Tools in Indian MSMEs.

H2a: implementation of Industry 4.0 Tools in Indian MSMEs will help achieving Social Sustainability.

H3a: Social Sustainability of the enterprise will have a significant direct and positive influence on performance of the enterprise

The smart technologies of Industry 4.0, such as IoT, cloud computing, and big data enable organizations' data sharing, improved collaboration, and interoperability, resulting in advanced supply chain integration and logistics management [39]. These technologies offer organizations effective supply chain collaboration among partners, including transport providers, suppliers, and customers, providing higher efficiency, liquidity, and flexibility with lower costs [40]. Employment of smart technologies in the supply chain delivers warehousing amenities, joint warehousing, logistic, and inventory management on a real-time basis allowing organizations to deal with real-time paradigms [11]. Furthermore, smart technologies streamline an organization's efficient ordering and transportation, providing competitive supply chain integration. IoT promotes transparency and improves supply chain integration, including planning, packaging, and order picking [41]. Hence the following hypotheses can be formulated.

H2b: implementation of Industry 4.0 Tools in Indian MSMEs will help achieving Economic Sustainability.

H3b: Economic Sustainability of the enterprise will have a significant direct and positive influence on performance of the enterprise

H2c: implementation of Industry 4.0 Tools in Indian MSMEs will help achieving Environmental Sustainability.

H3c: Environmental Sustainability of the enterprise will have a significant direct and positive influence on performance of the enterprise

H1a: implementation of Industry 4.0 Tools in Indian MSMEs mediates relation between the CSF's and TBL Sustainability

3. RESULTS AND DISCUSSIONS

The paper uses references from 46 articles found in Scopus, Web of Science, and Google Scholar to demonstrate the key Industry 4.0 technologies influencing long-term adoption and performance measurement. In this survey, we used the frequency with which respondents wrote to rank industry 4.0 technologies. This research investigates the factors affecting Indian MSMEs' adoption of Industry 4.0 technology for the sake of societal and economic goals. By analysing and forecasting production performance in their deployed industries, IoT, sensor, and CPS technologies have a positive impact on economic and social pillars. The research confirmed that geographic factors do influence implementation. There is a complete absence of evidence. Taking a multidisciplinary approach to analysis may be useful in the age of Industry 4.0. There is a dearth of grounded, in-depth case studies and analyses of how these innovations have affected workers' lives in the existing literature. The impact of 4.0 on industrial production has been disruptive. Sustainable technologies, the report finds, actively promote recycling. Digital and intelligent technologies aid in social sustainability by reducing the number of people required to complete monotonous

tasks and increasing employee morale and job satisfaction. According to studies, Industry 4.0 practises continuity with the past. The research concluded that industry 4.0 gives less priority to promoting sustainable growth than it does to maintaining reliance on "conventional" routes. Attempts to encourage sustainable growth run counter to this.

4. CONCLUSION

This study demonstrates how bringing Industry 4.0 to India's SMEs could aid in the economic growth of the country. A research agenda and a projection of future growth were both derived from this survey of the existing literature. This study investigates how Indian SMEs are adapting to the opportunities presented by Industry 4.0. The findings of this research laid the groundwork for more normative studies of Industry 4.0's implementation in the future. There is no danger to TBL's survival from any of the primary growth generators powering the introduction of I4.0. There will be significant changes to your setup times, labour costs, lead times, and bottom line as a result of implementing I4.0. This research shows that companies can accomplish all of Industry 4.0's aims by making use of the aforementioned best practises and existing technologies. The sustainability crisis needs to be brought to the forefront of the minds of people from all walks of life. Everyone, regardless of where they live, what they've been taught, or what culture they come from, needs to be exposed to and familiar with these ideas. Recent studies have shown that researchers are not doing enough work to accurately quantify or rigorously analyse the social and economic implications of Industry 4.0 and its potential contribution to sustainable development. More research is needed to fill this information gap. The research process revealed that the sentence's actual execution is affected by geographical factors. This theory is supported by all available evidence. More in-depth studies in Industry 4.0 might benefit from interdisciplinary research. There is a shortage of nuanced scenario-playing and in-depth evaluations of these innovations' effects on workers or employers in the existing literature. The advent of Industry 4.0 has ushered in a period of profound change throughout the manufacturing sector.

The research found that recycling rates increased when more people used environmentally friendly technology. Digital and intelligent technologies protect workers by reducing the number of potentially dangerous and repetitive tasks they must complete, while also boosting morale and improving job satisfaction. This undermines efforts to foster sustainable development, so more study in this area is warranted.

REFERENCES

1. S. S. Kamble, A. Gunasekaran, and S. A. Gawankar, "Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications," *Int. J. Prod. Econ.*, vol. 219, pp. 179–194, Jan. 2020, doi: 10.1016/J.IJPE.2019.05.022.
2. C. Hemalatha, K. Sankaranarayanan, and N. Durairaj, "Lean and agile manufacturing for work-in-process (WIP) control," *Mater. Today Proc.*, no. xxx, 2021, doi: 10.1016/j.matpr.2020.12.473.

3. Z. Shao, Y. Feng, and Q. Hu, "Impact of top management leadership styles on ERP assimilation and the role of organizational learning," *Inf. Manag.*, vol. 54, no. 7, pp. 902–919, Nov. 2017.
4. A. Grybauskas, A. Stefanini, and M. Ghobakhloo, "Social sustainability in the age of digitalization: A systematic literature Review on the social implications of industry 4.0," *Technol. Soc.*, vol. 70, no. February, p. 101997, 2022, doi: 10.1016/j.techsoc.2022.101997.
5. I. Henao-Hernández, E. L. Solano-Charris, A. Muñoz Villamizar, J. Santos, and R. Henríquez-Machado, "Control and monitoring for sustainable manufacturing in the Industry 4.0: A literature review," *IFAC-PapersOnLine*, vol. 52, no. 10, pp. 195–200, 2019, doi: 10.1016/J.IFACOL.2019.10.022.
6. X. Shao, Y. Zhong, W. Liu, and R. Y. M. Li, "Modeling the effect of green technology innovation and renewable energy on carbon neutrality in N-11 countries? Evidence from advance panel estimations," *J. Environ. Manage.*, vol. 296, Oct. 2021.
7. F. Longo, L. Nicoletti, and A. Padovano, "Smart operators in industry 4.0: A human-centered approach to enhance operators' capabilities and competencies within the new smart factory context," *Comput. Ind. Eng.*, vol. 113, pp. 144–159, Nov. 2017.
8. S. K. Mangla, K. Govindan, and S. Luthra, "Prioritizing the barriers to achieve sustainable consumption and production trends in supply chains using fuzzy Analytical Hierarchy Process," *J. Clean. Prod.*, vol. 151, pp. 509–525, May 2017, doi: 10.1016/j.jclepro.2017.02.099.
9. J. Qin, Y. Liu, and R. Grosvenor, "A Categorical Framework of Manufacturing for Industry 4.0 and beyond," *Procedia CIRP*, vol. 52, pp. 173–178, 2016.
10. F. Tao, Y. Tang, X. Zou, and Q. Qi, "A field programmable gate array implemented fibre channel switch for big data communication towards smart manufacturing," *Robot. Comput. Integr. Manuf.*, vol. 57, pp. 166–181, Jun. 2019, doi: 10.1016/J.RCIM.2018.12.005.
11. D. Tan, A. Nokhodchi, and M. Maniruzzaman, "3D and 4D Printing Technologies: Innovative Process Engineering and Smart Additive Manufacturing," *3D 4D Print. Biomed. Appl.*, pp. 25–52, Dec. 2018, doi: 10.1002/9783527813704.CH2.
12. J. Horbach, "Determinants of environmental innovation New evidence from German panel data sources," *Res. Policy*, vol. 37, no. 1, pp. 163–173, Feb. 2008, doi: 10.1016/J.RESPOL.2007.08.006.
13. S. S. Kamble, A. Gunasekaran, and S. A. Gawankar, "Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives," *Process Saf. Environ. Prot.*, vol. 117, pp. 408–425, Jul. 2018, doi: 10.1016/J.PSEP.2018.05.009.
14. G. Yadav, A. Kumar, S. Luthra, J. A. Garza-Reyes, V. Kumar, and L. Batista, "A framework to achieve sustainability in manufacturing organisations of developing economies using industry 4.0 technologies' enablers," *Comput. Ind.*, vol. 122, p. 103280, Nov. 2020, doi: 10.1016/j.compind.2020.103280.
15. A. M. Kitsis and I. J. Chen, "Do stakeholder pressures influence green supply chain Practices? Exploring the mediating role of top management commitment," *J. Clean. Prod.*, vol. 316, Sep. 2021.
16. M. Ghobakhloo and M. Fathi, "Industry 4.0 and opportunities for energy sustainability," *J. Clean. Prod.*, vol. 295, May 2021.
17. M. Ghobakhloo and M. Fathi, "Industry 4.0 and opportunities for energy sustainability," *J. Clean. Prod.*, vol. 295, May 2021, doi: 10.1016/J.JCLEPRO.2021.126427.
18. V. Bhakar, K. S. Sangwan, and A. K. Digalwar, "Readiness self-assessment of cement industry for sustainable manufacturing implementation: A case study of India," *Procedia CIRP*, vol. 90, pp. 449–454, 2020, doi: 10.1016/j.procir.2020.02.042.
19. U. Kumar, D. Galar, A. Parida, C. Stenström, and L. Berges, "Maintenance performance metrics: A state-of-the-art review," *J. Qual. Maint. Eng.*, vol. 19, no. 3, pp. 233–277, 2013, doi: 10.1108/JQME-05-2013-0029.
20. E. O. B. Nara et al., "Expected impact of industry 4.0 echnologies on sustainable development: A study in the context of Brazil's plastic industry," *Sustain. Prod. Consum.*, vol. 25, pp. 102–122, 2021, doi: 10.1016/j.spc.2020.07.018.
21. G. Miragliotta, A. Sianesi, E. Convertini, and R. Distante, "Data driven management in Industry 4.0: a method to measure Data Productivity," *IFAC-PapersOnLine*, vol. 51, no. 11, pp. 19–24, Jan. 2018, doi: 10.1016/j.ifacol.2018.08.228.
22. A. Albadvi, S. K. Chaharsooghi, and A. Esfahanipour, "Decision making in stock trading: An application of PROMETHEE," *Eur. J. Oper. Res.*, vol. 177, no. 2, pp. 673–683, Mar. 2006, doi: 10.1016/J.EJOR.2005.11.022.
23. A. Issa, D. Lucke, and T. Bauernhansl, "Mobilizing SMEs Towards Industrie 4.0-enabled Smart Products," *Procedia CIRP*, vol. 63, pp. 670–674, 2017, doi: 10.1016/J.PROCIR.2017.03.346.
24. A. K. Kulatunga and M. Jayatilaka, P. R. Jayawickrama, "Drivers and barriers to implement sustainable manufacturing concepts in Sri Lankan manufacturing sector," *11th Glob. Conf. Sustain. Manuf.*, no. September, pp. 171–176, 2013, doi: 10.13140/2.1.2952.1927.
25. M. C. Huang and H. H. Huang, "How transaction-specific investments influence firm performance in buyer-supplier relationships: The mediating role of supply chain integration," *Asia Pacific Manag. Rev.*, vol. 24, no. 2, pp. 167–175, Jun. 2019.
26. C. Müller, M. Grunewald, and T. S. Spengler, "Redundant configuration of robotic assembly lines with stochastic failures," *Int. J. Prod. Res.*, vol. 56, no. 10, pp. 3662–3682, May 2018, doi: 10.1080/00207543.2017.1406672.
27. S. Sadiq, M. S. Amjad, M. Z. Rafique, S. Hussain, U. Yasmeen, and M. A. Khan, "An integrated framework for lean manufacturing in relation with blue ocean manufacturing - A case study," *J. Clean. Prod.*, vol. 279, Jan. 2021, doi: 10.1016/J.JCLEPRO.2020.123790.
28. A. Gunasekaran and A. Spalanzani, "Sustainability of manufacturing and services: Investigations for research and applications," *Int. J. Prod. Econ.*, vol. 140, no. 1, pp. 35–47, Nov. 2012, doi: 10.1016/J.IJPE.2011.05.011.
29. W. D. Leong et al., "Enhancing the adaptability: Lean and green strategy towards the Industry Revolution 4.0," *J. Clean. Prod.*, vol. 273, Nov. 2020, doi: 10.1016/J.JCLEPRO.2020.122870.

30. D. Makris, Z. N. L. Hansen, and O. Khan, "Adapting to supply chain 4.0: an explorative study of multinational companies," <https://doi.org/10.1080/16258312.2019.1577114>, vol. 20, no. 2, pp. 116–131, Apr. 2019, doi: 10.1080/16258312.2019.1577114.
31. M. Habibi Rad, M. Mojtahedi, and M. J. Ostwald, "Industry 4.0, Disaster Risk Management and Infrastructure Resilience: A Systematic Review and Bibliometric Analysis," *Buildings*, vol. 11, no. 9, p. 411, Sep. 2021, doi: 10.3390/BUILDINGS11090411.
32. T. Stock and G. Seliger, "Opportunities of Sustainable Manufacturing in Industry 4.0," *Procedia CIRP*, vol. 40, pp. 536–541, 2016, doi: 10.1016/J.PROCIR.2016.01.129.
33. S. S. Kamble, A. Gunasekaran, and R. Sharma, "Analysis of the driving and dependence power of barriers to adopt industry 4.0 in Indian manufacturing industry," *Comput. Ind.*, vol. 101, no. May, pp. 107–119, 2018, doi: 10.1016/j.compind.2018.06.004.
34. R. Sindhvani, V. K. Mittal, P. L. Singh, A. Aggarwal, and N. Gautam, "Modelling and analysis of barriers affecting the implementation of lean green agile manufacturing system (LGAMS)," *Benchmarking*, vol. 26, no. 2, pp. 498–529, Feb. 2019, doi: 10.1108/BIJ-09-2017-0245.
35. M. Sony and S. S. Naik, "Ten Lessons for Managers while Implementing Industry 4.0," *IEEE Eng. Manag. Rev.*, vol. 47, no. 2, pp. 45–52, Apr. 2019, doi: 10.1109/EMR.2019.2913930.
36. A. Raj, G. Dwivedi, A. Sharma, A. B. Lopes de Sousa Jabbour, and S. Rajak, "Barriers to the adoption of industry 4.0 technologies in the manufacturing sector: An inter country comparative perspective," *Int. J. Prod. Econ.*, vol. 224, no. August 2018, p. 107546, 2020, doi: 10.1016/j.ijpe.2019.107546.
37. J. Y. Yong, M. Y. Yusliza, T. Ramayah, C. J. Chiappetta Jabbour, S. Sehnem, and V. Mani, "Pathways towards sustainability in manufacturing organizations: Empirical evidence on the role of green human resource management," *Bus. Strateg. Environ.*, vol. 29, no. 1, pp. 212–228, Jan. 2020, doi: 10.1002/BSE.2359.
38. K. Roy and P. Khokle, "Staged Development of Dynamic Capabilities: A Study of International Joint Ventures in India," *Thunderbird Int. Bus. Rev.*, vol. 58, no. 6, pp. 537–554, Nov. 2016, doi: 10.1002/TIE.21796.
39. T. S. H. Teo and Y. Pian, "A contingency perspective on Internet adoption and competitive advantage," *Eur. J. Inf. Syst.*, vol. 12, no. 2, pp. 78–92, 2003, doi: 10.1057/PALGRAVE.EJIS.3000448.
40. A. Iyer, "Moving from Industry 2.0 to Industry 4.0: A case study from India on leapfrogging in smart manufacturing," *Procedia Manuf.*, vol. 21, pp. 663–670, 2018, doi: 10.1016/J.PROMFG.2018.02.169.
41. S. Bag and N. Anand, "Modelling barriers of sustainable supply chain network design using interpretive structural modelling: an insight from food processing sector in India," *Int. J. Autom. Logist.*, vol. 1, no. 3, p. 234, 2015, doi: 10.1504/IJAL.2015.071722.