Journal of Informatics Education and Research
ISSN: 1526-4726
Vol 4 Issue 1 (2024)

Industry 4.0 and Indian Manufacturing Companies: Barriers towards sustainability

Dr. Bhavna[1], Dr. Alok Singh Chauhan[2], Dr Alka Agnihotri[3], Dr. Mukta Makhija[4]

[1]Post Doc Researcher, D. Y. Patil Vidyapeeth, Pune,

Assistant Professor, Galgotias University, Greater Noida. Email: Bhavna656@yahoo.com.

[2]Associate Professor, School of Computer Applications and Technology Galgotias University, Greater Noida, Uttar Pradesh, India. Email: alokchauhan.1983@gmail.com.

[3]Associate Professor, School of Business, Galgotias University, Greater Noida Email: alkaapoorva@gmail.com.

[4]Associate Professor, Department of Computer Application

Integrated Academy of Management and Technology, Ghaziabad, Uttar Pradesh, India

Email: drmuktamakhija20@gmail.com.

1. Introduction

1.1 Industry 4.0

Industry 4.0 refers to the part of key enabling technologies which includes cyber-physical systems, the internet of things, artificial intelligence big data analytics, and digital twins. Major driving forces behind automated and digital manufacturing settings include these technologies(Castelo-Branco, 2019). Emphasizing sustainability as the cornerstone of business strategy and calling for smart manufacturing, energy-efficient construction, and low-impact industrialization led to the foundation of the United Nations (UN) Sustainability 2030 agenda. Industry 4.0 technology aids in making company processes more sustainable. Few research fields have reported on this technology as it is aimed at improving business sustainability through the innovation of manufacturing processes in different industries (Bag, 2018). These applications are used in a variety of cutting-edge technology to modernize assembly lines. The Internet of Things helps machines to create, process, and transmit data in real-time to both people and other machines, robots can operate independently or in conjunction with humans, manipulate task like grabbing and spinning through its programming and design. On one hand big data and analytics deals with enormous and unstructured data using business intelligence, machine learning and analytics software using cloud computing techniques. Material can be added to solid blocks rather than mechanically removed to create high quality physical items through additive manufacturing (Godina,2020). These technologies are utilized in Industry 4.0 to create cyber physical system that are applied on the production line (Bai, 2020). It supports several sustainability related subfields; advanced manufacturing solutions may be built around the networked systems. It reduces the time to market, improves manufacturing flexibility and make better use of resources (Beier, 2020).

1.2 Sustainability

The three fundamental component of sustainable manufacturing includes process, products and systems that support industry growth and sustainable value creation. These components contribute positively to society, economy and environment in order to ensure manufacturing is sustainable. Sustainable manufacturing is characterized by integration of systems and processes to manufacture high quality goods with minimal resource use, sustainable resources and safety for consumers, employees and communities (Birkel,2019). Sustainable Development goals 2030 of United Nations visualized the technical advancement as the driven force to solve the problem of shifting to intelligent machine. These technologies are used in supply chain, distribution channels, manufacturing have significant impact on environment, reducing greenhouse gas emissions, reducing energy use and increasing profits (Brozzi, 2019). The growth of Industry 4.0 creates the possibility of connecting technology with resources and talents as sustainable advantage. Its lower environmental impact of product, process and service, in addition to this, it aids in leveraging increased function efficiency. The development of smart technologies will affect sustainability that enables us to achieve the sustainability development goals (Ejsmont, 2020)

1.3 Industry 4.0 and Sustainable Manufacturing

The primary method in field of Industry 4.0 and sustainability are sustainable design, management life cycle, green and lean management and environmental management. The macro and micro perspective of sustainable production was framework and talked about long term advantage of Industry 4.0 technology. Industry 4.0 and sustainable manufacturing methods highlighted the approaches to reduce waste, increase resource efficiency and reduce energy use (Bag et al.'s., 2018). Industry 4.0 and sustainability have been linked in recent studies in certain research areas of supply chain and human machine interaction (Jayakrishna, 2019). It can promote process optimization and environmental sustainability performance. Secondly, it may cause a rise in the generation of waste such as electronic wise and increase the need for energy resources (Ford and Despeisse, 2016). Social sustainability performance and Industry 4.0 leads to strength and shortcomings link (Stock et al., 2018; Bremer, 2015; Isaias et al., 2015; Beier et al., 2017). Sustainability measures, energy inspection, green cloud computing was gained from Industry 4.0 and similar technologies (Bressanelli et al. (2018) and Rong et al. (2016). Previous literature focused on the connection between sustainability and Industry 4.0. For instance, integration of Internet of things into sustainable supply chain (Manavalan, 2019), green cloud computing (Radu, 2017), humanitarian health crisis for artificial intelligence (Fernandez- Luque and Imran, 2018), 4.0 maintenance, sustainable energy development optimization , energy efficiency in cloud software (Procaccianti et al., 2015).

1.4 Barriers faced in adopting sustainability

With a high prominence score that denotes a stronger association with other obstacles, prominent barriers are sometimes referred to as causative barriers. Because these obstacles have a big influence on other obstacles, managers must recognize them and devise a plan to get rid of them so that Industry 4.0 may be implemented smoothly in their companies (Bai and Sarkis, 2013). The main obstacle to the effective implementation of Industry 4.0 in both nations is "lack of a digital strategy alongside resource scarcity. Liao et al. (2018) also opine that a limited number of nations has enough understanding and discernment regarding digital technology. a mere 10-20% of Indian organizations has a well-defined plan for implementing digitalization. "Lack of a digital strategy alongside resource scarcity" is the primary reason of impediments to implementing Industry 4.0 technology, regardless of the nation under analysis. Managers should thus make strategic plans to direct business operations and provide funds to support Industry 4.0 implementation. By addressing the underlying causes of Industry 4.0's obstacles, businesses may prosper in the digital age. Based on the greatest net effect or value, the five most important influencing elements that will have a significant impact on Industry 4.0 deployment are determined. The most significant influencing factor is "lack of standards, regulations, and forms of certification , which is followed by "lack of internal digital training, " "lack of infrastructure ," "lack of clarity regarding the economic benefit ," and "lack of a digital strategy alongside resource scarcity" Since standards, laws, and forms of certification are the most significant obstacle identified in this study, they might provide a special difficulty for developing nations like India as they embark on their digital transformation path.

2. Review of Literature

The overview comprehension of Industry 4.0 support shop floor and human- machine integration process , resulting in automation and process safety as well as economic and environmental sustainability Kamble et al. (2018). The effect of Industry 4.0 on the planning and sourcing , logistics and intralogistics and recycling logistics Birkel and Müller (2020) not in all cases , direct relationship between technology and sustainability, which facilities visual design and simulation, support product and production design along the supply chain and helps in reducing quality and resource consumptions. Internet of things which help coordinate logistics operations to customer demands, making the entire process more flexible, virtual and augmented reality, as well as other assistance system, which support workers and reduces repetitive. This comprehensive assessment of the connection between Industry 4.0 and sustainability lays the groundwork for future research direction (Zheng, 2020). This study evaluates the benefits and drawbacks of Industry 4.0 and explores whether it has favorable or unfavorable impact on manufacturer’s (Müller et al., 2018). On the one hand, it limits waste and streamline logistics, but on the other, the production process itself uses more energy as compared to traditional techniques. Machado et al (2020) like the other two assessments, Industry 4.0 as a whole and do not concentrate on any particular technologies. They discuss connection to some sustainable practices, big data and additive manufacturing for the circular economy (Ethirajan,2019). It identifies a number of clusters where Industry 4.0 and sustainability are related. Industry 4.0 can significantly improve economic and environmental performance. For instance, it can boost energy efficiency or renewable energy sources and guarantee food industry quality, in addition, these clusters suggest Industry 4.0 assist with sustainable practices including recycling Furstenau et al (2020). The author occasionally links innovative (additive manufacturing) to methods (recycling) that can lessen negative effect on the economy and the environment Ghobakhloo (2018). IoT embedded in sustainable supply chains (Manavalan and Jayakrishna, 2019), green cloud computing (Radu, 2017), artificial intelligence (AI) for humanitarian health crises (Fernandez-Luque and Imran, 2018), maintenance 4.0, energy efficiency in cloud software (Procaccianti et al., 2015), and Industry 4.0 in the pharmaceutical sector (Ding, 2018) are some examples. There is a need for thorough assessment and thematic analysis of the connection between Industry 4.0 and sustainability Existing literature evaluations only touch on a few areas of Industry 4.0 and sustainability and do not assess these topics holistically to comprehend how they interact. Additionally, they do not attempt to explore the theoretical advantages and disadvantages associated with them, nor do they thematically study the connection between certain technologies and sustainability. industry 4.0 in the pharmaceutical industry (Ding, 2018), energy efficiency in cloud software (Procaccianti et al., 2015), maintenance 4.0 (Franciosi et al., 2018), or take sustainability into account among the numerous elements of industry 4.0 (Kamble et al., 2018).

3. Methodology

The Purpose of this study piece is to examine how long Industry 4.0 enabling technologies would be used in Indian manufacturing sectors. Big, medium and small sized Indian manufacturing Industries are investigated in order to gather data using questionnaire and expert interviews. After conducting literature review and the use case analysis, twenty-four highly relevant technologies for manufacturing companies could be identified. Last, the list of preselected technologies was validated and, if required, expanded by experts from industry and science. Therefore, a link to the online questionnaire was sent to respondents representing 50 companies drawn from the Centre for monitoring Indian economy database. The manufacturing companies were randomly selected from four manufacturing cities in order to obtain a representative sample of the population. Participation in the survey will be kept voluntary, with follow up message send at regular intervals. A cover letter accompanied the email, requesting that the respondents fill their responses only if they were aware of Industry 4.0 and had minimum work experience of one year in manufacturing organizations. The recipients of the online questionnaire were requested to submit their responses within a time frame of four weeks. All statistical analysis was performed on the collected survey.

Table 1

Barriers/constructs	**AVE**	**Composite Reliability**	**Cronbachs Alpha**
Influencing Barriers	0.5181	0.7600	0.7286
Prominent barriers	0.6458	0.8447	0.7332

Table 3
Discriminant validity of constructs

	Organizational Barriers	**Personal barriers**
Influencing Barriers	0.72	
Prominent barriers	-0.342	0.804

Table 4
Summary of measurements of barriers

Barrier	**Original Statements**	**Removed**	**Retained statements**
Influencing Barriers	4	1	3
Prominent barriers	5	2	3

Table 5
Factor loadings of measurement model of barriers

	Influencing Barriers	**Prominent barriers**
Influencing_barrier11	0.7854	-0.248
Influencing _barrier12	0.7784	-0.2841
Influencing _barrier9	0.5758	-0.197

P_barrier2	-0.3538	0.8823
P_barrier3	-0.228	0.7858
P_barrier4	-0.2075	0.7358

Table 6

Descriptive statistics of barriers

Barrier/Construct	N	Minimum	Maximum	Mean	Std. Dev.	Skewness	Kurtosis
Influencing Barriers	350	1.00	5.00	3.448	0.921	-0.453	-0.278
Prominent Barriers	350	1.00	5.00	3.250	1.134	-0.293	-1.052

4. Data Analysis and Discussion

The most popular measure of reliability of construct are Construct Reliability (also known as composite reliability CR) and Cronbach's alpha. The desired level of Construct Reliability (CR) and Cronbach alpha is minimum of 0.7. Confirmatory factor analysis was used to establish the one-dimensionality of the measurements. Also, confirmatory factor analysis technique is used to establish the reliability and validity of the constructs. Partial least square (PLS) technique was used for confirmatory factor analysis. The desired level of Construct Reliability (CR) and Cronbach alpha is minimum of 0.7. As it can be seen from the table5 that the composite reliability of both constructs is above 0.7 supporting construct reliability (Hair. Jr, Black, Babin, & Anderson, 2010). Also, the cronbach's alpha is above .70 suggesting acceptable level of internal consistency (Meyers, Gamst, & Guarino, 2013). The AVE of a constructs should be above 0.5 suggesting that at least 50% of the variance in the measurement or indicator variables has been explained by the construct. As it can be seen from table5 that the AVE of both the constructs is more than 0.5 supporting the convergent validity of the constructs. The bivariate correlation between influencing and the prominent barrier is -0.342 which is lower that the square root of AVEs of both constructs. As it can be seen that on diagonal elements are greater than bivariate correlation between two barriers, suggesting that the unique variance is more that the shared variance. It may be interpreted as the discriminant validity of the construct is highly supported. Both organizational and personal barriers in IT sector are not very strong as the mean scores are just average and does not suggest any prominent problem. But the relative strength of influencing barriers was higher as compared to prominent barriers.

5. Conclusion

Among the industrial industries, the adoption of Industry 4.0 is the top priority for both established and emerging nations. Based on a thorough analysis of the literature and consultation with specialists in both established and emerging countries, 15 obstacles were determined to lower the installation failure risk. The most significant obstacle in both developed and developing nations was found to be "lack of a digital strategy alongside resource scarcity "It follows that in order to direct activities and resource investments and ease the shift to Industry 4.0, managers should develop roadmaps and make strategic plans. One potential strategy for prospering in the digital revolution is to address the underlying reasons of the obstacles to Industry 4.0 adoption. "Lack of standards, regulations, and forms of certification (IR6)" was the most significant influencing factor found in the setting of emerging economies, whereas "low maturity level of the desired technology (IR3)" was the most significant influencing element in the developed economy. Thus, in the instance of the Indian company, Industry 4.0 adoption may be facilitated by changes in government regulations and standards.

6. Implications

The study's findings, which cover all potential obstacles to Industry 4.0 implementation, might potentially act as a manual for managers. To attain a better level of implementation success, businesses should develop suitable strategies. Taking into account the inherent capacities of their companies, managers may overcome the obstacles associated with Industry 4.0 implementation, according to our findings. Whether a company operates in an established or developing economy, internal competency remains a crucial concern. Building roadmaps and strategically planning investments are two areas where senior management should concentrate in order to increase internal capabilities. To assist businesses in overcoming obstacles like "lack of standards and government regulation," developing nations should keep developing initiatives to support the shift to Industry 4.0 technology.

7. Limitation and Further Studies

Further research opportunities are presented by several study limits and issues. For instance, just a small number of experts were used in our analysis. More replies from other businesses might be gathered and examined in order to provide a more comprehensive analysis of the research findings.. In this study , we looked at implementation difficulties for Industry 4.0. Future studies might examine various supportive elements for Industry 4.0 adoption in order to assist in overcoming these obstacles.

Reference

1. Agostini, L., Filippini, R., (2019). Organisational and managerial challenges in the path toward Industry 4.0. Eur. J. Innov. Manag. 22, 406–421. https://doi.org/10.1108/EJIM-02-2018-0030.
2. Bai, C., & Sarkis, J. (2013). A grey-based DEMATEL model for evaluating business process management critical success factors. International Journal of Production Economics, 146(1), 281- 292.
3. 3.Bai, C., Dallasega, P., Orzes, G., Sarkis, J., (2020). Industry 4.0 technologies assessment: a sustainability perspective. Int. J. Prod. Econ. 229, 107776. https://doi.org/10.1016/ j.ijpe.2020.107776.
4. Bag, S., Telukdarie, A., Pretorius, J.H.C., Gupta, S., (2018). Industry 4.0 and supply chain sustainability: framework and future research directions. Benchmark Int. J. https:// doi.org/10.1108/BIJ-03-2018-0056.
5. Beier, G., Andr´e, Ullrich, Niehoff, S., Reißig, M., Habich, M., (2020). Industry 4.0: how it is defined from a sociotechnical perspective and how much sustainability it includes – a literature review. J. Clean. Prod. 259, 120856. https://doi.org/10.1016/j. jclepro.2020.120856.
6. Birkel, H.S., Veile, J.W., Müller, J.M., Hartmann, E., Voigt, K.-I., (2019). Development of a risk framework for industry 4.0 in the context of sustainability for established manufacturers. Sustainability 11, 384. https://doi.org/10.3390/su11020384.
7. Braccini, A.M., Margherita, E.G., (2018). Exploring organizational sustainability of industry 4.0 under the triple bottom line: the case of a manufacturing company. Sustainability 11, 36. https://doi.org/10.3390/su11010036.
8. Bressanelli, G., Adrodegari, F., Perona, M., Saccani, N., (2018). Exploring how usagefocused business models enable circular economy through digital technologies. Sustainability 10, 639. https://doi.org/10.3390/su10030639.
9. Brozzi, R., Forti, D., Rauch, E., Matt, D.T., (2020). The advantages of industry 4.0 applications for sustainability: results from a sample of manufacturing companies. Sustainability 12 (9), 3647.
10. 10.Burns, A. C., & Bush, R. F. (2006). Marketing Research (5th ed.). Upper Saddle River, NJ: Prentice Hall.
11. Castelo-Branco, I., Cruz-Jesus, F., Oliveira, T., (2019). Assessing industry 4.0 readiness in manufacturing: evidence for the European union. Comput. Ind. 107, 22–32. https:// doi.org/10.1016/j.compind.2019.01.007.
12. Castelo-Branco, I., Cruz-Jesus, F., Oliveira, T., (2019). Assessing industry 4.0 readiness in manufacturing: evidence for the European union. Comput. Ind. 107, 22–32. https:// doi.org/10.1016/j.compind.2019.01.007.
13. 13.Dalenogare, Lucas & Benitez, Guilherme & Ayala, Néstor & Frank, Alejandro. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics. 10.1016/j.ijpe.2018.08.019.
14. de Sousa Jabbour, A.B.L., Jabbour, C.J.C., Foropon, C., Godinho Filho, M., (2018). When titans meet – can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors. Technol. Forecast. Soc. Change 132, 18–25. https://doi.org/10.1016/j.techfore.2018.01.017.
15. Ding, Baoyang. (2018). Pharma Industry 4.0: Literature review and research opportunities in sustainable pharmaceutical supply chains. Process Safety and Environmental Protection. 119. 10.1016/j.psep.2018.06.031.
16. Ejsmont, K., Gladysz, B., Kluczek, A., (2020). Impact of industry 4.0 on sustainability—bibliometric literature review. Sustainability 12, 5650. https://doi. org/10.3390/su12145650.
17. 17.Ethirajan, Manavalan & Kandasamy, Jayakrishna. (2019). An Analysis on Sustainable Supply Chain for Circular Economy. Procedia Manufacturing. 33. 10.1016/j.promfg.2019.04.059.
18. 18.Fernandez-Luque, L., Imran, M., (2018). Humanitarian health computing using artificial intelligence and social media: a narrative literature review. Int. J. Med. Inf. 114, 136–142. https://doi.org/10.1016/j.ijmedinf.2018.01.015.
19. Frank, A.G., Dalenogare, L.S., Ayala, N.F., (2019). Industry 4.0 technologies: implementation patterns in manufacturing companies. Int. J. Prod. Econ. 210, 15–26.
20. Ford, S.J., Routley, M.J., Phaal, R., Probert, D.R., (2014). The industrial emergence of commercial inkjet printing. Eur. J. Innov. Manag. 17 (2), 126e143

21. 21.Furstenau, L.B., Sott, M.K., Kipper, L.M., Machado, E.L., Lopez-Robles, J.R., Dohan, M.S., Imran, M.A., (2020). Link between sustainability and industry 4.0: trends, challenges and new perspectives. Ieee Access 8, 140079–140096. https://doi.org/10.1109/ ACCESS.2020.3012812.
22. 22.Ghobakhloo, M. (2018), "The future of manufacturing industry: a strategic roadmap toward Industry 4.0", Journal of Manufacturing Technology Management, Vol. 29 No. 6, pp. 910-936.
23. 23.Ghadimi, P., Wang, C., Lim, M.K., Heavey, C.,(2018)." Intelligent sustainable supplier selection using multi-agent technology: theory and application for Industry 4.0 supply chains, Computers & Industrial Engineering , doi: https://doi.org/10.1016/j.cie.2018.10.050
24. Godina, R., Ribeiro, I., Matos, F., T Ferreira, B., Carvalho, H., Peças, P., (2020). Impact assessment of additive manufacturing on sustainable business models in industry 4.0 context. Sustainability 12 (17), 7066. https://doi.org/10.3390/su12177066.
25. Goralski, M.A., Tan, T.K., (2020). Artificial intelligence and sustainable development. Int. J. Manag. Educ. 18, 100330. https://doi.org/10.1016/j.ijme.2019.100330.
26. Jena, M.C., Mishra, S.K., Moharana, H.S., (2020). Application of industry 4.0 to enhance sustainable manufacturing. Environ. Prog. Sustain. Energy 39, 13360. https://doi. org/10.1002/ep.13360.
27. Kamble, S.S., Gunasekaran, A., Gawankar, S.A., (2018). Sustainable Industry 4.0 framework: a systematic literature review identifying the current trends and future perspectives. Process Saf. Environ. Protect. 117, 408–425. https://doi.org/10.1016/ j.psep.2018.05.009.
28. 28.Kamble SS, Gunasekaran A, Sharma R (2018) Analysis of the driving and dependence power of barriers to adopt industry 4.0 in Indian manufacturing industry. Comput Ind 101:107–119.
29. Liao, Y., Loures, E. R., Deschamps, F., Brezinski, G., & Venâncio, A. (2018). The impact of the fourth industrial revolution: a cross-country/region comparison. Production, 28
30. 30.Luthra, Sunil & Mangla, Sachin. (2018). Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. Process Safety and Environmental Protection. 117. 10.1016/j.psep.2018.04.018.
31. 31.Machado, C.G., Almstr€om, P., Oberg, A.E., Kurdve, M. and Almashalah, S.Y. (2020), € "Maturity framework enabling organisational digital readiness", in S€afsten, K. and Elgh, F. (Eds), Advances in Transdiciplinary Engineering, SPS2020, Vol. 13, pp. 649-660, doi: 10.3233/ ATDE200204
32. Manavalan, E., Jayakrishna, K., (2019). A review of internet of things (IoT) embedded sustainable supply chain for industry 4.0 requirements. Comput. Ind. Eng. 127, 925–953. https://doi.org/10.1016/j.cie.2018.11.030.
33. 33.Masood, Tariq & Egger, Johannes. (2019). Augmented reality in support of Industry 4.0—Implementation challenges and success factors. Robotics and Computer-Integrated Manufacturing. 58. 181-195. 10.1016/j.rcim.2019.02.003.
34. 34.Miller, Tim. (2017). Explanation in Artificial Intelligence: Insights from the Social Sciences. Artificial Intelligence. 267. 10.1016/j.artint.2018.07.007.
35. Müller, J.M., Kiel, D., Voigt, K.I., (2018). What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability. Sustainability 10, 247. https://doi.org/10.3390/su10010247.
36. Radu, L.D., (2017). Green cloud computing: a literature survey. Symmetry 9, 295. https:// doi.org/10.3390/sym9120295.
37. 37.. Pasi, B.N., Mahajan, S.K., Rane, S.B., (2020). The current sustainability scenario of Industry 4.0 enabling technologies in Indian manufacturing industries. Int. J. Prod. Perform. Manag. https://doi.org/10.1108/IJPPM-04-2020-0196.
38. Procaccianti, G., Lago, P., Bevini, S., (2015). A systematic literature review on energy efficiency in cloud software architectures. Sustain. Comput.: Informat. Syst. 7,2–10. https://doi.org/10.1016/j.suscom.2014.11.004.
39. Stock, T., & Seliger, G. (2016). Opportunities of sustainable manufacturing in industry 4.0 13th Global Conference on Sustainable Manufacturing - Decoupling Growth from Resource Use, Vol 40 pp 536-541.
40. **40.Surendra Pratap** and Annavajhula J.C. Bose (2015), "Working People in Indian Economy: A Structural Analysis",International Journal of Social and Economic **Research** (Online ISSN: 2249-6270), Vol.5, Issue 2, July. 11.
41. Yadav, G., Kumar, A., Luthra, S., Garza-Reyes, J.A., Kumar, V., Batista, L., (2020). A framework to achieve sustainability in manufacturing organisations of developing economies using industry 4.0 technologies' enablers. Comput. Ind. 122, 103280 https://doi.org/10.1016/j.compind.2020.103280.
42. Zheng, T., Ardolino, M., Bacchetti, A., Perona, M., (2020). The applications of Industry 4.0 technologies in manufacturing context: a systematic literature review. Int. J. Prod. Res. 1–33. https://doi.org/10.1080/00207543.2020.1824085