Influence of Digitized Transforming Enablers on Manufacturing Performance in the Context of Social Dimension of Sustainability

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Abstract Every manufacturing revolution has so far been progressively developing toward sustainability goals, considering the environment, social, and economic pillars. Impacted by the new technologies, the manufacturing sector, globally, is on the wheels of Fourth Industrial Revolution "I4.0". The umbrella keyword "digitized transforming enablers (DTE)" discussed in the study encompasses the digital technologies of the I4.0. To date, research on the impact of DTE on manufacturing performance in the context of the social dimension of sustainability has been scant and scattered, especially in the case of small and medium-sized businesses (SMEs). The discussion available in the literature reflects both positive as well as negative results. Due to the lack of relevant literature and inconsistent results, there has been a demand for further research on the subject. The objective of this study was to synergize the DTE implementation and manufacturing performance through the lens of the social dimension of sustainability within the SMEs segment. The study presents a mediation research model developed with the help of theoretical background, based on descriptive and content analyzes. This was done, while also describing the constructs selected and the hypotheses developed by collaborating DTE implementation, indicators of social sustainability as well as manufacturing performance.

Keywords I4.0 · DTE · Social sustainability · Manufacturing performance

1 Introduction

Manufacturing ecosystem is on the wheels of Fourth Industrial Revolution (I4.0), the first giant in itself, targeted toward optimized performance across every value creation stage. This study introduces an umbrella keyword "digitized transforming enablers (DTE)", defined as the digital technologies of I4.0 for transforming reporting processes, acquiring and analyzing data in real time as well as applying insights to limit risk and enhance efficiency. The digital technologies of I4.0 are expected to

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enable manufacturers choose the optimal facilities and employees, reduce operating expenses, increase productivity, better utilize resources, and identify process bottlenecks that can be closed [1], leading to enhanced overall manufacturing performance. The role of social capital is always at the focus for the successful implementation of DTE [2], which would require life-long safe work places, social well-being, and equality. This brings the second giant, sustainability, into action.

The intersection between the two giants, i.e., DTE and sustainability, is growing leaps and bounds, endorsing positive as well as negative remarks in the extant literature. Multiple study reports that the link between DTE and sustainability is in its early stage of research [3], and much more attention is required [4, 5]. But, as reported in [6], there is strong evidence that reflects the intersection between DTE and sustainability goals. Also, as reported [7], effective DTE implementation ensures sustainability. From the findings of [3] and [8], mostly, DTE positively supports the sustainable practices of firms, emerging especially for the literature focusing on manufacturing. For small and medium-sized enterprises (SMEs), research shows that DTE implementation is still below the expectations [9, 10].

The association of employees with a specific job category will end, and they need to coexist in the same space as intelligent robots [11]. The key elements of digital work culture will be information and data. Hence, continuous skilling and reskilling would be essential to develop the skills required for the digital technologies of I4.0. Since employees are in the middle of action, it brings forth social dimension of sustainability (SDS) in the frame of our study. The growth of physical and digital network integration into industrial production processes signals the progress toward achieving the objectives of social sustainability [10]. Technology benefits workers [12], but it also has inherent restriction that makes it difficult to use it in many manufacturing applications. The results from [13] reveal that the attention on human being is lost, in the quest for productivity, performance as well as competition and sustainability was left as a secondary consideration with its social dimension being undervalued and understudied. The extant literature linking the impact of DTE on SDS is still young, underdeveloped, and further, research is required, and this has also been corroborated in [3, 14, 15]. The concerns and gaps raised above have motivated to the efforts articulate and compose this study. The research agenda conceptualized as part of this study was

(1) To identify the indicators relating SDS from the extant literature.
(2) To explore the influence of DTE implementation on manufacturing performance through the lens of SDS, and
(3) To develop the research model and research propositions collaborating DTE implementation, SDS, and manufacturing performance.

The paper is structured as follows: Sect. 1 covers the introduction, and Sect. 2 offers the theoretical background along with the current review of the literature linking DTE implementation, SDS indicators, and manufacturing performance. Section 3 presents the research model, describing the constructs and the hypotheses developed.

2 Literature Review

The following section presents a theoretical background on the indicators of social dimension of sustainability, collaborated with the digital technologies of I4.0, and its influence on the parameters of manufacturing performance.

2.1 Social Dimension of Sustainability (SDS) and Its Indicators

Human-centered work is related with the social attribute. Social sustainability encompasses features that guide towards life-long social development of human beings. The indicators representing social dimension of sustainability are job satisfaction, quality of life, health and well-being, safety, social integration in communities, equity and justice in the distribution of goods and services and equal opportunities in education and training, and these have been reported in the literature [16–18]. Table 1 represents the list of SDS indicators reported in the extant literature.

The manufacturing-social sustainability pillar, which is concerned with the stakeholder's well-being and the community in which a manufacturing value chain functions, is the least well-defined and accepted component of manufacturing sustainability [30]. Social risks have been identified as being the most harmful to an organization's health, out of all the constituent risks taken into account in the study [31]. The importance of the workforce should be recognized through upskilling, counseling,

Table 1 List of SDS indicators reported in the extant literature

Indicators	Source
Worker's health and safety	[19–24]
Resistance to change	[19]
Employee turnover	[23, 25, 26]
Working conditions	[22, 23, 25, 26]
Accident rate	[22, 23, 25–27]
Gender ratio/gender equity	[23, 27]
Training opportunities	[23, 24, 27, 28]
Employee satisfaction	[20, 23, 27, 29]
Salary and benefits	[18, 23]
Full time/part time employee rate	[23, 25]
Customer satisfaction	[22, 28]
Participation of employees in business decisions	[25, 28]
Workforce diversity	[24, 28]
Stakeholder collaboration	[23, 25]

training, and mentoring by practitioners [31]. In terms of the social dimension of sustainability, highly educated and skilled workers are required to keep up with technology advancements [32].

Based on the above insights, the first research agenda was addressed, identifying the indicators for social dimension of sustainability (SDS).

2.2 Influence of DTE on Manufacturing Performance Through the Lens of SDS

The extant literature has reported positive as well negative findings of the influence of DTE implementation on SDS and further its impact on manufacturing performance.

The findings from the study [7] show that effective DTE implementation boosts a company's revenue earnings, i.e., financial performance, which is because of improved manufacturing performance. This has also been corroborated in the study [33]. Hence, it can be concluded that DTE implementation boosts manufacturing performance. Several other manufacturing performance indicators reported in literature are process and turnover rate optimization, product consistency, production quality, and dependability as well as production flexibility [19]. It also promotes the use of natural and renewable resources, reduces resource consumption, and improves social well-being, which affects SDS. The conclusion from [34] suggests that a more effective and optimized production process is one of the advantages of DTE. Along with that, it benefits the social systems by providing improved employee working conditions and enhanced function of the worker on the assembly line. The study [35] remarks positively on the influence of DTE adoption on sustainability and further, significant impact of sustainability on organizational performance. The research [36] demands to raise consciousness of the opportunities occurring from DTE to promote sustainability and corporate performance indicators. As a result, a huge need for activities to facilitate knowledge transfer in future can be foreseen.

Digital divide is raising social inequality [4]. The digital transformation changes human habits and would affect quality of life of the future generations. The emerging social digital culture indicates that social sustainability has become paramount in the digital shift [4]. Findings from [37] confirm that manufacturing needs to pay greater attention to the social side, which is frequently ignored. Technology adoption has resulted in job losses in the manufacturing sector, due to the automation of routine labor [38]. For SMEs to help accelerate I4.0 adoption and sustainable transition, governments should strengthen vendor support and expert consultation groups as well as the IT infrastructure [39].

The study [40] reports that smart sensors and actuators, big data analytics and simulation, and additive manufacturing are the technological categories of the sustainability cluster that are most connected, because of their high association with traits like optimized energy use and reduced waste. The work from the authors of [37] has found a beneficial effect of I4.0 technology on sustainability pillars. The existing, positive relationship between the digital transition and social sustainability has been made noticeable by scientific studies [4]. The study [24] suggests that corporate sustainability in case of SMEs is not well-practiced, as compared to big organizations. Also, among developing nations, social practices are grossly ignored in SMEs. Many CEOs believe that DTE implementation will have a positive effect on social issues in society [15].

Based on the above insights, the second research agenda was addressed, exploring the influence of DTE implementation on manufacturing performance, through the lens of SDS.

3 Research Model and Hypotheses Development

The following section proposes a research model, constituting DTE implementation, indicators of SDS as well as manufacturing performance, leading to the hypotheses developed.

3.1 Research Model Development

After a thorough descriptive and content analyzes of the theoretical background, the study developed a mediation model as shown in Fig. 1, proposing the relationship between DTE implementation, SDS indicators, and manufacturing performance. Based on the developed conceptual framework, the study has further proposed research hypotheses in the following section, covering the crux of the research agenda.

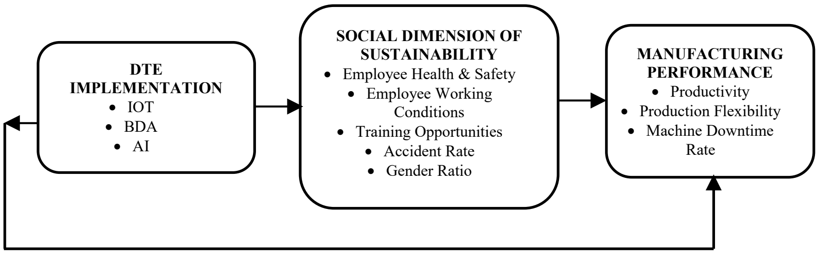

Fig. 1 Research model

3.2 Linking DTE Implementation, SDS, and Manufacturing Performance

The following section identifies key SDS indicators, which mediate the relationship between DTE implementation and manufacturing performance, derived from the extant literature as well as the conceptualization of the research propositions.

The results from [41] show that DTE components improve organizational performance metrics like profitability, sales, production volume, production volume per person, capacity utilization rate, production speed, and product quality. They can also result in significant cost savings throughout production. The study [42] highlights productivity and sustainability as potential outcomes of DTE implementation.

Internet of things (IoT) ecosystem provides improved visibility of the manufacturing execution systems, allowing real-time processing, leading to improved product and productivity [43, 44]. The investigation of the study [45] uncovers that the use of big data analytics (BDA) improves project performance in the manufacturing industry. The study [1] suggests that artificial intelligence (AI) and smart technologies can provide manufacturing alerts, seeing issues before they arise. Thus, operators can plan to turn off equipment before it breaks, preventing potentially hazardous work situations. The investigation from [46] indicates that business earnings and DTE sustainability are linearly correlated. The conceptual framework proposed for Malaysia manufacturing sector in the study [47] and further demands to investigate the relationship between DTE implementation and productivity. This has led to hypothesize the following:

H1a: IoT implementation positively influences manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H1b: BDA implementation positively influences manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H1c: AI implementation positively influences manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

From the extant literature [48–50], the digital technologies of I4.0 frequently mentioned in the sustainability field are IoT, additive manufacturing, cloud computing, big data analytics (BDA), and cyber-physical systems. The study from [16] confirms that DTE implementation encourages sustainability through economic improvements in productivity and product quality, ongoing environmental energy monitoring, safer workplace conditions, lighter workloads, and job enrichment. The research [24] posits positive remarks on the impact of social sustainability performance and business performance indicators, such as sales growth, positive cash flow, profitability, and return on asset. There is a dearth of empirical evidence on the positive as well as negative impacts of DTE on social sustainability as reported in [15].

The findings from theoretical research of [51] indicate that automation, digitization, and robotics would rapidly replace monotonous simple jobs over the next decade, but the impact of the ongoing manufacturing revolution would also lead to new jobs and interesting labor market opportunities. Skilling, reskilling, and upskilling ecosystem for the future-ready workforce of the digital era are the need of the hour [52], which will assure confidence and well-being for the workforce [38]. The research work from [53] recommends investigating the impact of DTE for the worker and the work environment. The review from [3] indicates that social sustainability pillar is the least investigated in the digital context. Further, implication of technological advances for social capital could lead to interesting insights. The findings from [26] reveal that there is lack of theoretical and empirical research on the social sustainability aspect of I4.0. Hence, it recommends future work on providing solutions for enhancing the abilities and skills of workers, in-line with digital manufacturing support. DTE implementation is thought to enhance consumer satisfaction, work environments, and career prospects [54].

From the viewpoint of social sustainability, digital and smart technologies safeguard worker's health and safety by reducing monotonous and repetitive work, which inspires people and raises their level of job satisfaction [7]. Due to increased traceability, the incorporation of Industry 4.0 technologies, namely blockchain, IoT, and big data analytics, can benefit workplace health and safety. Adoption of such technology can replace laborious manual labor, lowering injury risk, and improving workplace environment [55]. Firm's actions can be tracked to stop the misuse of those by the application of technologies like blockchain, big data, and IoT to labor-related concerns, like fair working conditions, wages, and equity [55]. The investigation from [46] validates that with improved I4.0 sustainability, job creation is linear. The research study by [56] recommends exploring how synergy between human and machine boost employee health and safety and simultaneously encourage positive impact in the social dimensions. The research by [57] reflects negative relation of I4.0 with the sustainability pillars. With regard to the social pillar, indicators such as job losses, threats linked with organizational transitions, and employee requalification are reported. The research [58] recommends exploring how I4.0 is poised against the digital divide issue and the threat of social disruptions.

The findings obtained from [36] ratify that, businesses frequently disregard considerations like social and environmental sustainability, in favor of economic sustainability. The demand from extant literature [23, 48, 59–61], recommends further research on the social impacts of I4.0, due to the intricateness of the topic. The research by [23] demands further investigation of factors that drive social attributes associated with DTE to boost market share as well as sales through optimized manufacturing performance. This has led to hypothesize the following:

H2a: Employee health and safety mediate the relationship between IoT implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H2b: Employee health and safety mediate the relationship between BDA implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H2c: Employee health and safety mediate the relationship between AI implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H3a: Employee working conditions mediate the relationship between IoT implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H3b: Employee working conditions mediate the relationship between BDA implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H3c: Employee working conditions mediate the relationship between AI implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H4a: Training opportunities mediate the relationship between IoT implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H4b: Training opportunities mediate the relationship between BDA implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H4c: Training opportunities mediate the relationship between AI implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H5a: Accident rate mediates the relationship between IoT implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H5b: Accident rate mediates the relationship between BDA implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H5c: Accident rate mediates the relationship between AI implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H6a: Gender ratio mediates the relationship between IoT implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H6b: Gender ratio mediates the relationship between BDA implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

H6c: Gender ratio mediates the relationship between AI implementation and manufacturing performance (i) productivity, (ii) production flexibility, and (iii) machine downtime rate in the SMEs.

The third research agenda of the study is therefore proposed to be addressed, by developing a research model for DTE implementation, SDS with its indicators as well as manufacturing performance, as shown in Fig. 1 and by constructing the research hypotheses posited above.

4 Conclusion

The umbrella keyword DTE discussed in the study encompasses the digital technologies of the I4.0. After descriptive and content analyzes, based on theoretical background, this study has aimed at exploring three research agendas, mentioned in Sect. 1. For the first agenda, study identified the indicators of social dimension of sustainability that are frequently reported in the extant literature. The social indicators are employee health and safety, employee working conditions, training opportunities, accident rate, and gender ratio. For the second agenda, study explored the influence of DTE implementation on manufacturing performance through the lens of SDS indicators. The insights of the study revealed that the digital technologies of I4.0 like IoT, BDA, and AI are repeatedly interconnected with manufacturing performance parameters, such as productivity, production flexibility, and machine downtime rate. On synergizing the above with the indicators of social dimension of sustainability for SMEs, the study found minimal and scattered research in the literature. Further, findings of the study report that the influence of DTE implementation on manufacturing performance of SMEs in the context of social dimension of sustainability has positive as well as negative interpretations. In the third agenda, a mediation research model is developed with the help of a theoretical background, based on descriptive and content analyzes, while also describing the constructs selected and the hypotheses developed by collaborating DTE implementation, indicators of social sustainability as well as manufacturing performance. In all, the study presents eighteen propositions to the research world, guiding toward the influence of DTE implementation on manufacturing performance through the lens of social dimension of sustainability.

Future research work could be aimed at testing of the proposed hypotheses, which would add statistical robustness to the findings as well as significance to the work presented in the study. Other social sustainability indicators, such as stakeholder collaboration, workforce diversity, full time/part time employee rate, employee satisfaction, salary and benefits, and employee turnover could be explored in future. Also, in future, the influence of digital technologies, like additive manufacturing, cyber-physical system, cloud computing, advanced robotics, cybersecurity, and mobile technologies on manufacturing performance of SMEs may be investigated. To further bolster the sustainability goals, future research work could be carried out to establish the influence of DTE implementation on manufacturing performance in the context of both the environment and economic dimensions of sustainability.

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