

# Industry 4.0 Technologies and Ethical Sustainability



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**Abstract** Industry 4.0 technologies are finding applications in many industrial sectors. But industrial development is societal, ethically sustainable only when the technologies used are cleaner and ethical sustainable. In this research paper, authors have shortlisted eight technologies that act as major pillars of Industry 4.0 (I4.0). These technologies have been critically examined on aspects of ethical sustainability considering Indian micro and small enterprises. For this study, authors have reviewed 55 research papers from different sources such as science direct, emerald insight, Taylor and Frances. The authors have also developed a framework, which reveals the ten major contributors toward ethical sustainable manufacturing in the digital era. Contributors or enablers such as availability of better software /hardware, reduction in e-wastage and manufacturing cost, and awareness on government policies and supports help to enable ethical sustainable manufacturing in the modern digital era.

**Keywords** Industry 4.0 · Ethical Sustainable Manufacturing · Concept paper

## 1 Introduction

Industry 4.0 stands for the fourth industrial revolution which is another trending topic and is discussed in both professional as well as academic areas [1–55]. According to B Sezen et al., “Industry 4.0 can be regarded as a new business mindset that will help businesses and communities move towards sustainable development” [38]. According to Aquilani et al., “The Fourth Industrial Revolution—i.e., Industry 4.0-, today involves the majority of firms and institutions and emerges as a new logic for business models focused on innovation, technology and sustainability” [24]. Smart manufacturing and smart production can be termed as synonyms for the term Industry 4.0, which consists of many technologies used for the development of the value chain resulting in the reduction of lead time, improvement of product quality and efficiency [2]. Because of an insightful availability between assembling frameworks, logistics

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frameworks, and items/administrations, Industry 4.0 considers progressive new plan, manufacturing, activity, and production frameworks [13]. Also, Industry 4.0 has become another theme for researchers and top managers. Combining systems such as CPS with I4.0 brings in further new features via networking with collaborators in both horizontal and vertical aspects [10].

On the other hand, ethical sustainability, also known as sustainable development, is the “ability to sustain ethically” or “manufacture safe products safely” [15]. The prime focus of sustainability is to meet the present demands without jeopardizing the needs of future generations [35]. Maintaining a sustainable environment has not only become important but essential in the past decades due to the ongoing industrial trends [18]. Sustainability can also be understood as the utilization of resources while considering their depletion and/or how they adversely affect the environment [32]. The significant sustainability issues from the manufacturing point of view include energy utilization, scrap generation, water consumption, and the impact of the manufacturing process on the environment [32]. For coping with the challenges being faced by the industry in meeting the global demand for capital and consumer goods, the industrial value chain ought to be oriented toward sustainability [1]. It, however, pertains to SMEs as the carbon footprint of the poor cannot be factored into the aspects of sustainability, while the MNCs have enough resources and funds to reduce their carbon footprint to an acceptable standard [14, 15, 44].

In this paper, authors have summarized the observations from the literature review done on industry 4.0 and the sustainability of its practices. Finally based on observations authors have developed a framework that reveals the ten major contributors toward sustainable manufacturing in the digital era. Section 2 of the research paper will discuss the literature review. Section 3 will discuss methodology and Sect. 4 will discuss observations of the study. Section 5 will conclude and propose a framework (developed by authors in the current study) on ethical sustainable manufacturing in the digital era of I4.0. This framework highlights the enablers which gives an edge to ethical sustainable manufacturing in the modern era of I4.0. Observations and implications of the study could be beneficial for the manufacturing industries of developing economies.

## 2 Literature Review

Industry 4.0 has made new changes and vulnerabilities that must be regulated and administered to emphatically affect both business and society [6]. A major transformation can be observed in the way companies are producing goods after the digitalization of manufacturing [8]. The point is to incorporate the maximum number of industries as possible and adjust and upgrade the current innovations to give the necessities of advanced assembling a better fit [11]. The new concept situation originates from the intermingling of various rising advances that permit the progress to a digitized time that presents in the manufacturing plants a keen domain where

machines, gadgets, and items are interconnected to adjust, be adaptable, and react rapidly to showcase changes [5].

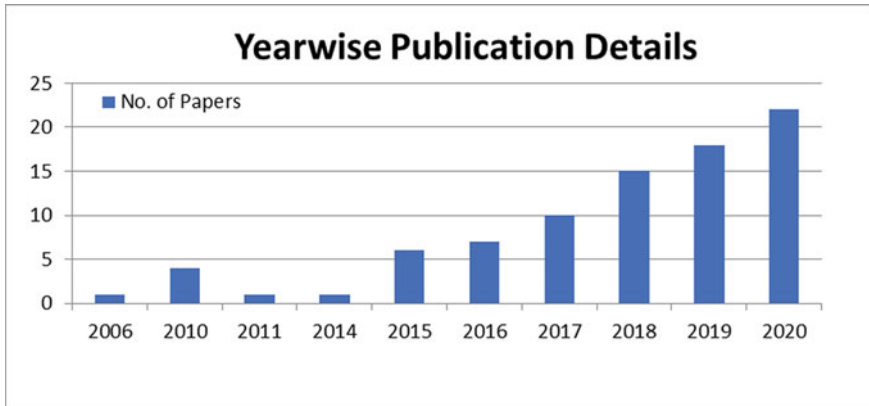
Industry 4.0 is based upon technologies that can again be classified in many ways. In this paper, the authors have identified eight major technologies, such as Internet of Things (IoT), cloud computing, flexible manufacturing, additive manufacturing, big data analytics, augmented reality (AR), cyber-physical system (CPS), and autonomous robots from review of literature of more than 55 papers. Technologies can be divided into two categories of front and base end technologies. Front end technologies were those which plays a major role such as smart supply chain, smart product, smart manufacturing, and smart work, whereas the base technologies were the supporting ones like IoT, Cloud, Big Data analytics, etc. [4, 43]. Industry 4.0 gives the industry another point of view that enables it to work with innovations to gain the highest efficiency with the negligible utilization of assets in the manufacturing industry; however, it might expose the industry to some cyber threats as well [22].

Adoption of Industry 4.0 technologies in an existing manufacturing system is not very easy due to the presence of many challenges, but its adoption not only helps industrial managers to increase process safety, efficiency, and flexibility but also in making the processes more sustainable in economic, social, and environmental terms [7 & 42]. Man and Strandhagen define sustainable business models as those which instead of simply following a neoclassical approach also incorporate the social and environmental aspects [3]. According to Stock and Obenaus, sustainability has three different dimensions, which are social, environmental, and economical [16]. These are also known as the three pillars of sustainability.

The environmental aspect of it pertains to reducing the environmental impact of the technologies involved in the industry as much as possible. Organizations are focusing on reducing their carbon footprint, water consumption, waste created by packaging, especially the usage of plastics. These organizations, however, have found out that the implementation of some technologies in turn also leads to financial improvements, such as the reduction in packaging material not only benefits environmentally but also economically [36]. However, the fields that will always have great environmental impacts, such as the production of food, mining, curb this issue by imposing and setting benchmarks or standards which help monitor the factors that are required to maintain a healthy physical environment [37].

On the social front, what is important are answers to questions like whether the implementation of new technologies in the industry will lead to the huge layoff of the workforce, how is the product being made, whether any unethical means are being utilized in making of the product, such as child labor, or unfair/unpaid wages to the workers, hazardous/toxic working environment, and how much is the risk of cyber-crime. Employees should be satisfied with the work that is being done by the organization, should feel valued and approved of the business being conducted, and their pre-existing knowledge should complement the implementation and integration and not hinder it [40].

The economic front of a sustainable business is that which is profitable, has a competitive advantage and market orientation which is specific, while keeping in



**Fig. 1** Year-wise publication details

mind resource conservation and improved quality of life [16]. Economic viability in industrial terms also means that the project or the changes being implemented are economically feasible in the long run, and also affordable, or viable for SMEs, such as setting up of advanced facilities such as autonomous robots and cyber-physical systems, which requires a very high investment and also needs lots of capital to maintain and run [41, 55]. It is also the incorporation of the profits and the economic aspect such as reduced manufacturing cost that convinces organizations to agree with practicing and implementing sustainable strategies [2]. Figure 1 shows the year-wise publication details.

### 3 Methodology

In this paper, first, relevant sources of publications were searched and selected like science direct, emerald insight, Taylor and Frances. Research papers related to Industry 4.0, sustainability, ethical sustainability, and their applications were searched. The literature review was made by the method of systematically reviewing papers. The review methodology followed is shown graphically in Fig. 2.

This concept paper tries to find research which has been conducted in the past related to sustainability and industry 4.0, the keywords used during the search were



**Fig. 2** Research methodology

“Industry 4.0”, “Sustainability”, “Sustainable Manufacturing”, “Industry 4.0 Technologies”, “ethical sustainability” and “Industry 4.0 and Sustainability”. The searches were carried out on the following three websites: “Science Direct”, “Emerald Insight”, and “Taylor and Francis”. Year-wise distribution of research papers has been shown in Fig. 1.

The authors focused on selecting the research papers or case studies relevant in the Indian scenario. Since the review was focused on the manufacturing sector, it was decided to select as many papers related to this field as possible, and eventually narrowed the papers finally studied down to 55.

## 4 Observations of Study

This paper discussed I4.0 technologies and issues related to ethical sustainability of these technologies. Key analysis of I4.0 technologies, keeping sustainability in background are summarized in Table 1.

## 5 Conclusion and Proposed Framework on Ethical Sustainable Manufacturing

Many researchers have studied the Industry 4.0 and ethical sustainability as separate issues. Very few studies have been conducted about I4.0 technologies and ethical sustainability aspects holistically considering Indian micro and small enterprises. There is a need to identify the technologies which are globally recognized and ethical sustainable too. Later, these technologies should be checked for their ethical sustainability, individually. Authors developed a framework connecting all the major enablers, which supports or enables the ethical sustainable manufacturing in I4.0. After critically analyzing the industry 4.0 technologies, on three aspects of sustainability, the authors have identified ten enablers for sustainable manufacturing in the digital era (as input enablers for framework). These ten enablers are “Increased customer awareness on Technology”, “Top management support and planning”, “Attracting local/Foreign Investment”, “Infrastructure for new Technologies”, “Availability of advanced software /Hardware”, “Reduction in e-wastage and manufacturing cost”, “Availability of trained workforce”, “Development in E-economy”, “Social responsibility and investor demands”, “manufacture safe products safely” and “Awareness on government policies and support”. These enablers help in making the manufacturing processes more ethical sustainable in the scenario of industry 4.0. As these are supporting factors, the arrows point inward toward the “ethical sustainable manufacturing in the digital era” bubble, showing that they are guiding input. For the future course of action/study, the framework suggested by the authors should be analyzed and examined in the practical scenarios of different developing economies.

**Table 1** I4.0 technologies and ethical sustainability

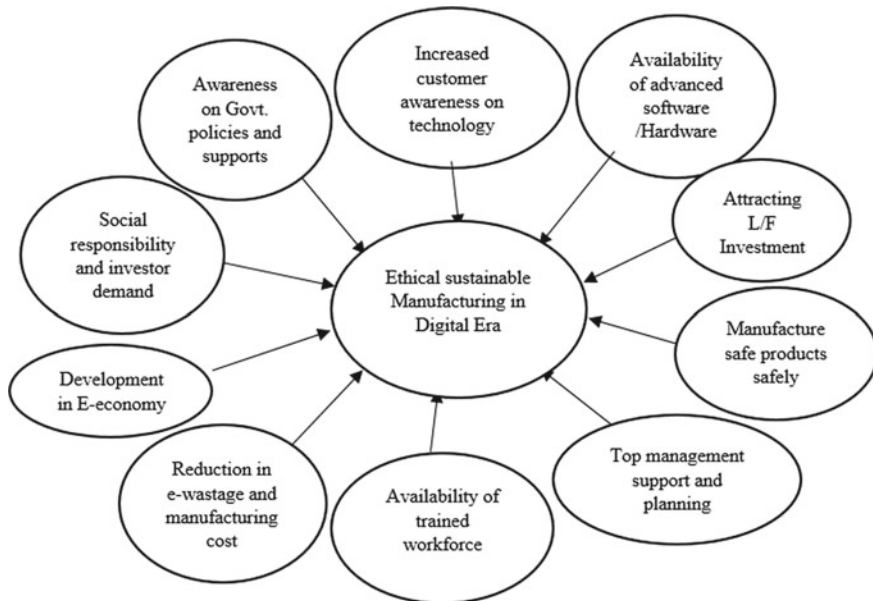
I4.0 technologies	Sustainability issues			References
	Environmental	Social	Economical	
IoT	Many IoT devices are used; Increased use of non-renewable resources for making chipsets; Increases E-waste generation, abundance of data generated	Privacy and security issues; Increased vulnerability from hackers; Impacts the human willingness to work due to decreased human intervention	Highly competitive industry; Constant up-gradation is required; High initial cost required; Needs expensive supporting technology	[45, 48, 49]; Own contribution
Cloud computing	Big servers of cloud services companies consumes energy $24 \times 7 \times 365$ ; Leaves high carbon footprint too	Security and trust issues; chances of data loss and leakage on public cloud spaces	Private cloud space are paid, Not affordable for many SMEs	[46, 47]; Own contribution
Flexible Manufacturing lines	Energy consumption will increase; Will create more e-waste, as there is no proper disposal plan	Have to Lay off unskilled workers; Lack of education and knowledge; Small businesses will shut down	High cost of R&D; Difficult design and installation; High maintenance cost; Difficult to fit in an existing facility	[9, 52]; Own contribution
Additive manufacturing	Can't recycle the support structure material used; Consumers more energy than conventional machining and molding processes	Copyright issues; Requires skilled labor; Cuts on labor employment	Very slow process, Expensive process implementation; Not suitable for mass manufacturing; Requires controlled environment for the functioning of expensive machines	[12, 23, 51]; Own contribution
Big Data and Analytics	High specification machines required; Consumes more energy; Leaves high carbon footprint	Requires high skilled manpower; job loss for semi-skilled and unskilled manpower;	Requires highly trained and hence high paid employees; Required software is expensive	[17, 34, 53, 54]; Own contribution

(continued)

**Table 1** (continued)

I4.0 technologies	Sustainability issues			References
	Environmental	Social	Economical	
Augmented Reality	Will create a need for more electronic gadgets attached to every new manufacturing facility, leading to increased e-waste; Increased carbon footprint	Performance varies based on workers' experience; Training and skills of operators not utilized; Leads to the layoff of workers	The hardware required and the devices are costlier as compared to training existing manpower	[31–33]; Own contribution
Cyber-Physical Systems (CPS)	Reliability of real-time data; Availability of data in abundance; High energy consumption; High carbon footprint	Requires highly trained operators for running and maintenance of automated devices; Leads to the layoff of workers	Requires high initial investment; Expensive equipment; Difficult to procure; Difficult to incorporate with pre-existing systems	[1, 28–30, 39, 50]; Own contribution
Autonomous Robots	Has high energy consumption; The robots work autonomously with minimum interference	Large no of workforce layoff, due to automation of the procedures and tasks	Very expensive equipment; Requires high and expensive maintenance, not suitable for most of micro and small firms; Requires high paid & trained workforce	[25–27]; Own contribution

The two pillars of research, that is academia and industry should do empirical examination on all insights of outcomes and elements of the framework. Figure 3 shows the proposed framework on ethical sustainable Manufacturing in the Digital Era.



**Fig. 3** Proposed framework on ethical sustainable Manufacturing in the Digital Era

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