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Implementing industry 4.0 in the manufacturing sector: Circular economy as a societal solution

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ABSTRACT

The fourth industrial revolution, Industry 4.0 (I4.0), has disrupted the notions of economic transactions, value generation and appropriation to become a central interest among academics and practitioners. I4.0 is predicted to create new frontiers for society's sustainable growth by encouraging the development of a circular economy. However, significant obstacles prevent its widespread application. Therefore, this research investigates the broader social problems associated with the implementation of I4.0 and the potential solutions. The research takes the form of a comprehensive and systematic literature review that uses bibliometric analysis to consider papers published between 2011 and 2020. Fifty-two research articles from 32 different journals were thoroughly reviewed to fulfil the research objective. This innovative and novel study explores I4.0 technologies in terms of the potential to solve societal problems, the associated social challenges they present and the related opportunities. The paper concludes by discussing possible future research directions.

1. Introduction

The fourth industrial revolution, often referred to as Industry 4.0 (I4.0), refers to the continuous automation of traditional manufacturing and industrial activities (Frank, Dalenogare, & Ayala, 2019; Ghobakhloo, 2018; Dalenogare, Benitez, Ayala, & Frank, 2018). I4.0 encapsulates manufacturing digitisation, computerisation and data management and exchange in advanced manufacturing engineering systems (Arnold, Kiel, & Voigt, 2016; Bauer, Hämmerle, Schlund, & Vocke, 2015; Damani, 2020). This development builds upon the widespread use of automated and self-governing equipment, robots and processes in various production settings. These technologies can operate for longer periods of time and with more accuracy than people. This has enabled I4.0 to deliver changes to existing paradigms across the global business world (Marr, 2018), especially in the manufacturing sector. It should be noted that I4.0 can be used interchangeably with the terms Internet of things (IoT), Internet of services, digitalisation, cyber-physical systems and smart factories, all of which enable real-time data exchange guiding the decisions and approaches of actors and entities (Vial, 2019; Tortorella & Fettermann, 2018).

From the technical, managerial and organisational perspective, I4.0 poses substantial challenges to manufacturing companies (Luthra & Mangla, 2018). Significant changes in the manufacturing industry are projected to result from the increased use of new technologies and the transformation of machinery and processes (Müller, Kiel, & Voigt, 2018). New production methods will involve new types of talents and employee proficiencies, with I4.0 expected to change the entire manufacturing context (Müller et al., 2018, Kiel, Müller, Arnold, & Voigt, 2017). This will demand that manufacturing organisations become flexible in terms of time and space because workplaces are becoming more translucent and dispersed and less compartmentalised (Varghese & Tandur, 2014). Though the risk associated with digitalisation cannot be fully anticipated, it is apparent that workers in some countries are regarded as more unprotected than others. It should be acknowledged that automating the manufacturing process risks pushing some employees into unemployment (Brettel, Friederichsen, Keller, & Rosenberg, 2014), with reports indicating that 25% of the workforce in some countries is at a high risk due to the mechanisation of industrial processes (Marr, 2017).

I4.0 also implies the increasing digitisation, interconnectedness and circularity of the entire supply chain. Some procedures are expected to be optimised by linked production systems, while others will become

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considerably more intricate and entrenched (Erol, Jäger, Hold, Ott, & Sihn, 2016; Sundblad, 2018). This will probably increase the quantity of high-skilled positions and decrease the number of jobs entailing low-level qualifications (Turlica, 2021). Consequently, I4.0 is going to significantly impact both society and the labour market (Council, 2018).

However, the successful implementation of I4.0 depends completely on combining technical and economic feasibility with social acceptability and sustainability across the whole process. If I4.0′s technological transformations are not aligned with changes in the overall socio-economic environment and do not address sustainability via circular business models (CBMs), manufacturing industries will meet with immense social problems that ultimately undermine communal interrelations. This discussion indicates that I4.0 can be understood as a both technological and socio-economic phenomenon.

Furthermore, the changes associated with I4.0 may put pressure on economic regulations and economic policy and demand changes to education systems to deliver the new skills and qualities that new technologies require of workers (Chan, 2019). For many unskilled employees, joblessness is among the biggest problems with I4.0 and, thus, represents one of the most significant social challenges for manufacturing firms (Weise, 2020). However, many companies remain preoccupied with the application of new techniques to increase diversity, expand product life cycles and shift customer expectancies and the incorporation of CBMs to uphold long-term effectiveness and adjust to the volatile business environment and its transformations (Kossuth & Bessen, 2019). This contributes to the many factors that may prevent the manufacturers from effectively implementing I4.0., which include shortages of trained staff and limitations on financing, calibration hitches and cybersecurity concerns (Marr, 2016).

Notably, the extant research has mostly only highlighted the technical side of I4.0, with only a few authors undertaking empirical examinations. This is problematic given that I4.0 represents the new global paradigm for the entire business world (Ghadge, Kara, Moradlou, & Goswami, 2020).

It is especially critical to consider the role of I4.0 in responding to sudden disruptions in the manufacturing sector due to, for example, the COVID-19 pandemic, shortages of skilled labour, economic crises and war. Furthermore, the effects of social problems associated with I4.0 remain unclear and undefined. This study's in-depth review of the literature, which considers the totality of the research output and the role of various technologies in the manufacturing sector, demonstrates that the field contends with numerous research gaps. This study aims to fill these gaps by exploring the concept of I4.0 and identifying the driving forces behind new digital technologies and the critical social impediments, enabling a discussion of the steps that organisations can take to resolve these issues. The research has the objective of enriching the current knowledge of managers and policymakers about I4.0 implementation and its scope to influence the circular economy paradigm. It also contributes to the overall conceptual view of the fourth industrial revolution, exposing practitioners to new knowledge related to this new reality via a systematic review that provides insight into the current status of research in this area and enables future research propositions that can create a foundation for the increased attention of researchers in this area.

These objectives are pursued via the following research questions:

RQ1: How has Industry 4.0 research evolved in recent years?

RQ2: What are the problems and benefits associated with the implementation of Industry 4.0?

Responding to these questions will enable the study to fulfil the following research objectives:

1. To provide an understanding of the previous literature concerning the role of Industry 4.0 in the manufacturing sector.
2. To identify the various opportunities, challenges and solutions associated with Industry 4.0.
3. To provide an overview of the growth in the literature related to Industry 4.0 and offer future research propositions.

This paper is organised as follows. Section 2 details the methodology and Section 3 presents the research findings. Section 4 discusses the findings, considering the incorporation of the concept of I4.0, the digitisation process, the advantages of embracing I4.0, the social challenges related to implementing I4.0 and the plausible solutions in the context of the manufacturing industry. Section 5 concludes the paper, noting limitations and suggesting future research directions.

2. Research methodology

A systematic literature review (SLR) was conducted to identify research gaps. The systematic approach ensures transparency, replicability and sensibility, as suggested by Tranfield, Denyer, and Smart (2003). This SLR aims to select, appraise and summarise the findings of extant studies to eventually make the data more comprehensible to decision-makers (Webster & Watson, 2002). SLRs also recognise gaps, biases and flaws in the existing knowledge, ultimately showing the directions that future research should take to obtain a better understanding of the issue of interest. A complete and extensive methodological approach was used, which is essential for performing any kind of literature review that intends to analyse and thoroughly discuss the existing research (Okoli & Schabram, 2010). Specifically, this investigation adopted the SLR methodology used by Agrawal, Wankhede, Kumar, Upadhyay, and Garza-Reyes (2021). The articles chosen for the SLR were chosen by defining appropriate keywords and using these to search for articles related to the topic of interest (Vinodh, Antony, Agrawal, & Douglas, 2020). Several researchers were involved in the selection and exclusion process to subjugate individual bias (Tranfield et al., 2003). The SLR was conducted over four stages. In the first stage, an electronic search of research databases was conducted to find relevant literature. The following databases were accessed: SCOPUS, EBSCO, Emerald, Google Scholar, IEEE explore, Science Direct, Taylor Francis, and Web of Science. The researchers first used the following terms as search strings anywhere in the title, abstract or keyword sections: Industry 4.0; 4th industrial revolution; Internet of Things; internet of services; digitisation; cyber-physical systems (Liao, Deschamps, Loures, & Ramos, 2017; Buer, Strandhagen, & Chan, 2018). The search string was subsequently designed to capture the social problems and potential solutions specific to this study's interests. Table 2.1 shows the research design.

In the second stage, a bibliometric study of the collected papers was conducted using the R package and VOS viewer. In the third stage, research fields analysis was performed via an in-depth review of the

Table 2.1
Research design.

Unit of analysis	Descriptions of social problems related to I4.0 implementation in the manufacturing industry.
Types of analysis	Qualitative
Period of analysis	No specific time frame.
Search sources	Google Scholar, Taylor and Francis, IEEE Explore, Scopus, Emerald, Web of Science, and Springer Link
Keywords used for searches	Industry 4.0; 4th industrial revolution; Internet of Things; Internet of services; Digitisation; cyber-physical systems; Industry 4.0 in the manufacturing industry; challenges for Industry 4.0; barriers for Industry 4.0; roadblocks for Industry 4.0; opportunities for Industry 4.0; social impact of Industry 4.0; possible solutions with Industry 4.0.
Language	English
Inclusion criteria	Papers containing one of the keywords associated with I4.0 in either the abstract, title or keywords.
Exclusion criteria	Non-English articles; journal articles that had not been peer-reviewed
Total number of articles	52

selected articles. This in-depth review is detailed in the subsequent sections of this paper. The fourth stage involved the development of a comprehensive framework for future studies based on the observations from the literature. Fig. 1 provides a visualisation of this four-stage SLR approach in the form of a flowchart depicting the various steps.

Table 2.2 lists the journals considered by the SLR, and Table 2.3 (see Appendix A) lists the articles selected for in-depth review. These journals and articles were selected based on their relevance to I4.0. Journals that published the most papers on I4.0 and related themes have been categorised. This can enable researchers to recognise the significance of these journals in terms of promoting information dissemination in the field of I4.0 usage in manufacturing, allowing them to engage industry leaders and nurture innovation. These 32 journals cover an array of study subjects and suggest a rising trend towards interdisciplinary investigation aimed at developing I4.0 systems that can contribute to the future sustainability of manufacturing.

These 32 journals have enabled the development of debates, ideas, concepts and conclusions because of their close congruence with the study's goal, notably their connection to the social problems and solutions associated with the implementation of I4.0. Table 2.3 (see Appendix A) lists the articles chosen for in-depth review based on their emphasis on I4.0, sustainable development, circular economy, CBMs, societal problems and solutions, digital technologies, the manufacturing sector and innovation.

3. Bibliometric analysis

To investigate the problems and benefits associated with the implementation of I4.0, this research first identified articles related to I4.0. These articles were evaluated for patterns, orientations, similarities and differences. Following thorough analysis, 52 publications were chosen to meet the study's research objectives.

Table 2.2
List of Selected Journals.

S. no.	Journal name	S. no.	Journal name
1.	British Journal of Management	17.	Journal of Business Media Psychology
2.	Advances in Economics and Business	18.	Journal of Cleaner Production
3.	Computers in Industry	19.	Journal of International Affairs
4.	Digital Transformation in Smart Manufacturing	20.	Journal of Knowledge Management
5.	European Planning Studies	21.	Journal of Management Studies
6.	Information and Software Technology	22.	Journal of Manufacturing System
7.	International Journal of Advance corporation Learning	23.	Journal of Manufacturing Technology management
8.	International Journal of Entrepreneurial Behaviour & Research	24.	Journal of Open Innovation: Technology, Market, and Complexity.
9.	International Journal of Human Resource Management	25.	Journal of Vocational Education and Training
10.	International Journal of Innovation Management	26.	Management and Production Engineering Review
11.	International Journal of Mechanical, Industrial Science and Engineering	27.	Management and Economics Review
12.	International Journal of Precision Engineering and Manufacturing-Green Technology	28.	MIT Sloan Management Review
13.	International Journal of Production Economics	29.	Process Safety and Environmental Protection
14.	International Journal of Recent Technology and Engineering	30.	Strategic Management Journal
15.	International Small Business Journal	31.	Technological Forecasting and Social Change
16.	Journal of Business Management	32.	The Journal of Strategic Information Systems

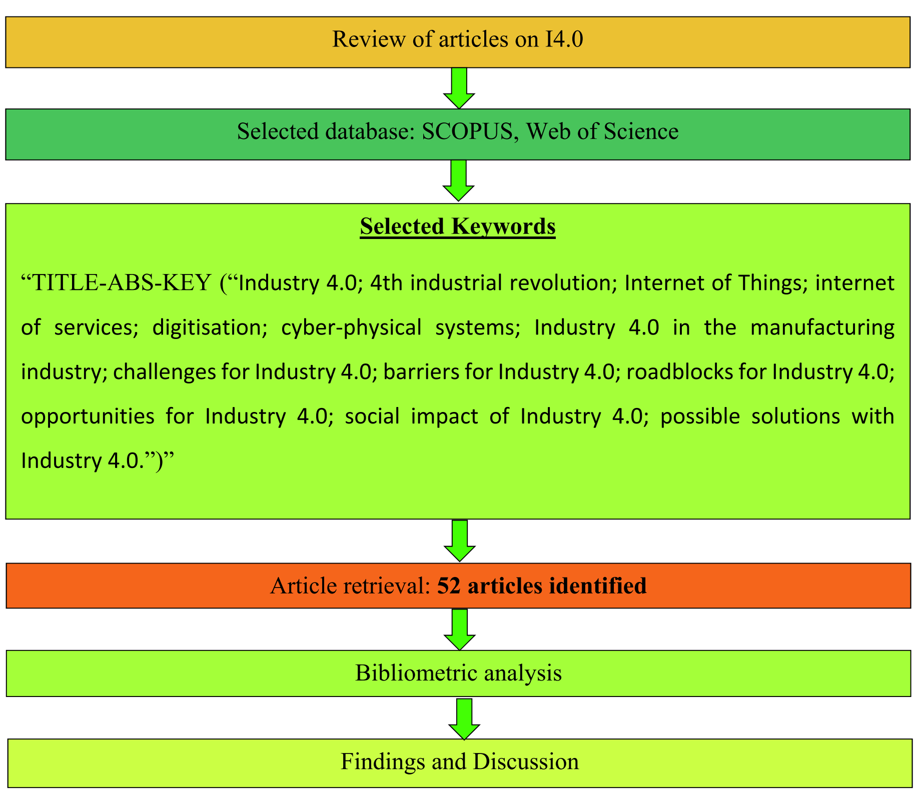

Fig. 1. SLR flowchart.

3.1. Growth of research related to I4.0

Fig. 2.1 shows that scientists are becoming increasingly interested in I4.0, as demonstrated by the constant growth in publications on the subject, with two especially substantial waves of increases observed between 2011 and 2015 and from 2016 onwards. This shift revealed by the trend in Scopus indexed papers and reviews confirms a surge in scholarly inclination towards addressing the implications, benefits and issues associated with I4.0. The year-wise article statistics show the growth trajectory of the research conducted in the I4.0 field. Interestingly, the surge in academic research interest dropped off between 2015 and 2016, gradually increasing again after 2017. However, the development of the research in this field still demands expansion to reveal the evolution of I4.0 in the manufacturing sector.

According to Fig. 2.2, the technological aspects of I4.0 have experienced an especially substantial increase in attention. Notably, although various publications have published scholarly articles on the topic, we have only listed publications in the most relevant fields to target those fields for prospective future research and communication of advances. This is because it is essential for future researchers to understand the function that well-known journals have in the dissemination of knowledge in their field of study. This process revealed that engineering and decision science have published more articles on I4.0, followed by energy and environmental science. As such, it is evident from the findings that there is a growing inclination towards cross-disciplinary exploration to develop I4.0 systems that can provide solutions and encourage sustainable development.

3.2. Categorisation of journals

Fig. 2.3 describes the sector-wise analysis, showing that articles on technical aspects appeared with substantially more frequency than articles focused on social aspects. The scarcity of publications with a social perspective on I4.0 demonstrates a major research gap in this field. Addressing this research gap could enable the development of a comprehensive knowledge background. Nonetheless, the research shows significant development in terms of technical perspectives, providing considerable opportunities for novel research work on social aspects. This review will attempt to elucidate the specifics of this research gap and the possible opportunities to harness technical insights in the development of research on social aspects.

4. Discussion

I4.0 has increased the effectiveness of various sectors by providing sustainable solutions. Although applications of I4.0 technologies were initially intended to boost productivity, the trend has begun to move towards exploring sustainable and green solutions that would automate and minimise resource consumption in manufacturing processes. Studies have also emerged on utilising data intelligence automation tools, such as extreme machine learning, to offer sustainable solutions (Kouadio et al., 2018).

This section develops various inferences from the bibliometric analysis of the literature published during the period 2011–2020, with 52 research articles from 32 journals thoroughly reviewed to fulfil the research objectives. This innovative research represents a novel approach to exploring how I4.0 technologies can be utilised to address potential technical and social challenges and the related opportunities, challenges and opportunities that are detailed in the following subsections.

4.1. The concept of the fourth industrial revolution

The first industrial revolution occurred when mechanical production facilities powered by steam were first used. The second industrial revolution occurred when mass production was enabled by electricity and the division of labour (Hudson, 2014). The third industrial revolution began in the 1970s. Almost all business organisations correspond to this third revolution, which was characterised by high levels of automation of different production and work processes at companies (Mishina et al., 2004). The third industrial revolution was achieved by the industrial application of electronics and information technology.

Meanwhile, the fourth industrial revolution, or I4.0, sees new channels of production evolve via shared substances, learning appliances and autonomous robots (Philbeck & Davis, 2018). From another perspective, I4.0 can be defined as the horizontal extension of communication technology (Kerin & Pham, 2019; Maynard, 2015). In I4.0, information and communication technologies are used much more extensively in all spheres, crossing from business organisations to public administration to everyday life. As such, interconnectedness is a principal and fundamental component of I4.0 (Bloem et al., 2014).

Furthermore, I4.0 has witnessed the emergence of new sectors of production that employ communicating objects, learning machines and autonomous robots (Hirschi, 2018), with components becoming increasingly interconnected to enable fast adaption to changing environmental conditions. There are five key elements of I4.0: digitisation, optimisation and customisation of production; automation and adaptation; human–machine interaction; value-added services and stores; and automatic data exchange and communication. Using digital know-how in production activities is also regarded as “smart manufacturing”, “integrated industry”, and “industrial internet” (World Economic Forum (2016), 2016). Broadly speaking, I4.0 concerns applying information and communication technologies to the industrial environment. It is also considered a collective term for digital technologies, with some experts defining I4.0 as putting innovative products into physical and digital processes (Petrillo, De Felice, Cioffi, & Zomparelli, 2018) and others

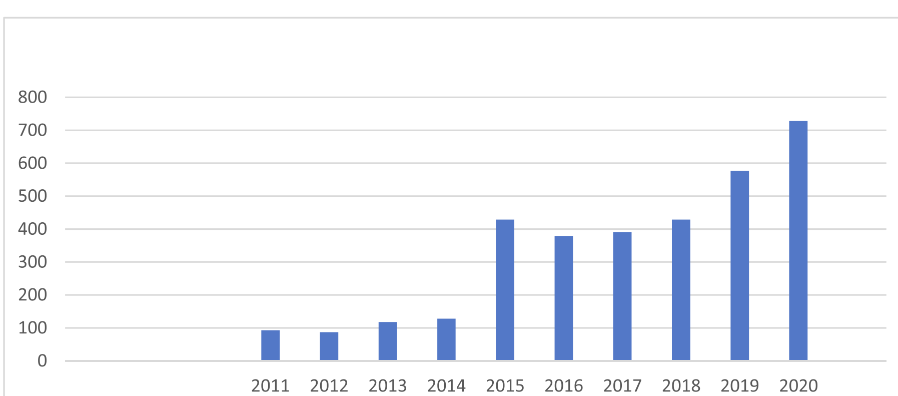

Fig. 2.1. Number of papers published related to Industry 4.0.

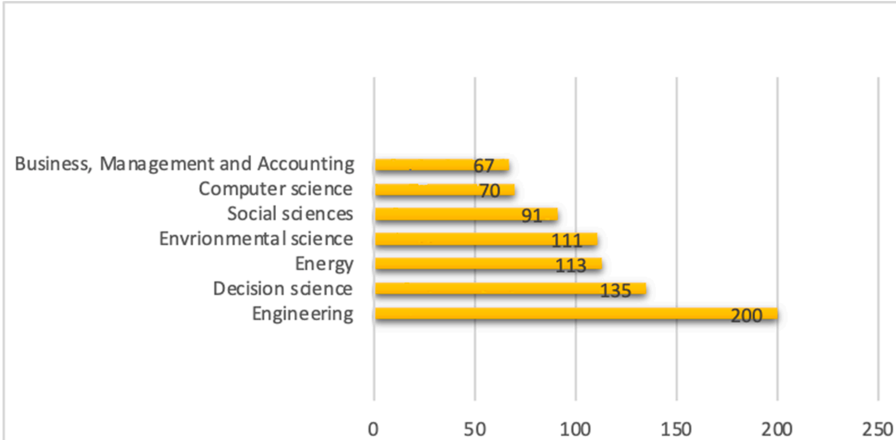

Fig. 2.2. Number of papers published according to field of study.

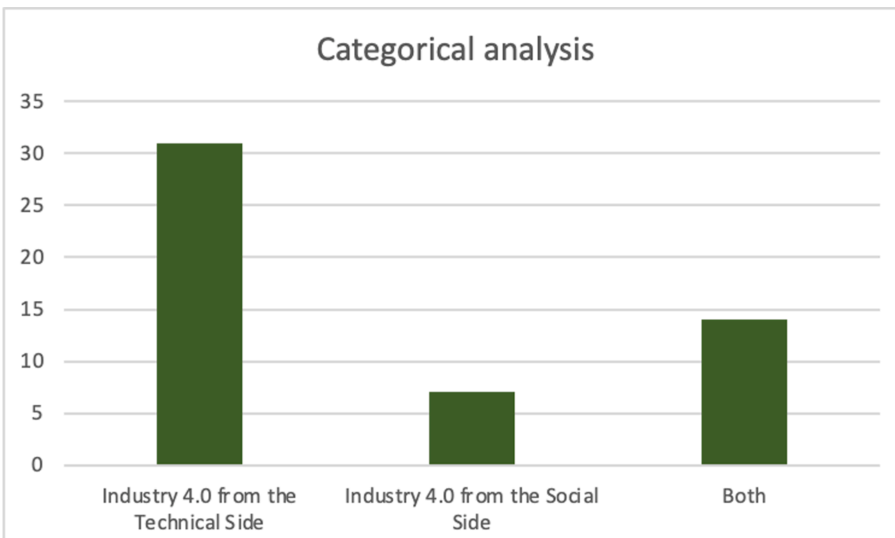

Fig. 2.3. Categorisation of Journals.

indicating that it concerns the application of connected systems with software solutions to enable a manufacturing company to control and monitor the production process, commissioning, analysis and processing of information (Lukes & Stephan, 2017; Kuhl et al., 2016). It has been claimed that I4.0 should focus on solving significant social and ecological problems and promoting CBMs and aim for equitable and sustainable growth via product personalisation, modularity, product life-cycle extension and decentralisation (Carvalho, Chaim, Cazarini, & Gerolamo, 2018). Meanwhile, from the perspective of decision-making for manufacturing organisations, I4.0 supports the overall decision-making process, enabling an overall increase in the productivity of manufacturing companies (Lee et al., 2018).

4.2. Digital transformation

The traditional approach to digitisation refers to the use of internet technology and computers to develop more efficient and effective economic value creation processes. It should be noted that digitisation is a process that ultimately affects all sectors. In the context of digital transformation, existing products can be changed in two ways: either by replacement with digital versions or the addition of new digital features (Jankowska & Götz, 2017, Ebert & Duarte, 2018; Zhao, Jeong, Noh, & Yee, 2015). More importantly, digital transformation or digitalisation affects the business plans, organisational and management characteristics and procedures of entire supply chains, which poses considerable difficulties for businesses operating in the modern business world, especially in the manufacturing sector (Bleicher & Stanley, 2016; Hess, Matt, Benlian, & Wiesböck, 2016; McMahon, 2001). Furthermore, digital transformation, often known as digitalisation, encompasses more than just process and product enhancements. Essentially, the process of digital transformation affects not only the physical products of business organisations but also the characteristics of businesses and their organisational strategies and structures, promoting their movement towards sustainable development via CBMs (Vial, 2019; Ghobakhloo & Modares, 2018; Lukes & Stephan, 2017). It should be acknowledged that manufacturing companies must first identify the needs and preferences of consumers to complete the process of digital transformation and implement CBMs. Among the biggest challenges associated with digital transformation is deciding how far and how fast an organisation should pursue the digital renovation (Ghadge et al., 2020; Tabrizi, Lam, Girard, & Irvin, 2019).

It should also be noted that the gravity of the digital transformation of business organisations is significant, regardless of the size of the organisation. All business organisations, regardless of their size, should craft a digital strategy to execute the digital transformation. However, there remains a paucity of research on how managers can approach and manage digital transformation and, consequently, implement the attendant strategies. Broadly speaking, I4.0 implies the digitisation of manufacturing processes (Tortorella, Cawley Vergara, Mac Garza-Reyes, & Sawhney, 2020), meaning digital revolution can be considered a comprehensive field of study of which I4.0 is a sub-concept. From here, the following propositions can be made to guide future researchers in the development of their study:

To understand models and procedures that incorporate a combined approach for manufacturing processes, automated modelling methods should be used by future research projects.

It is critical to understand the capabilities and shortcomings of the I4.0 models already in use in the manufacturing sector.

4.3. Opportunities related to the implementation of Industry 4.0

Beyond having a solid conceptual foundation concerning the idea of I4.0, it is essential to know which forces contribute to a company's transformation. It should be noted that the current changes across the global community have already contributed to a more networked, interconnected and, most importantly, informed society (Pereira, Lima, & Charrua-Santos, 2020). These changes include increasing awareness and calls for the resolution of societal and environmental challenges via sustainable business development. These changes have affected both business and private life and demanded that manufacturing companies change their processes to adapt to the changing environment and promote CBMs. It has been claimed that business organisations are moving towards a ubiquitous knowledge society (Dangayach & Deshmukh, 2005), with companies finding the use of intelligent and autonomous machines inevitable (Birkel, Veile, Müller, Hartmann, & Voigt, 2019) if they want to pursue sustainable development.

Nonetheless, it is also essential to address the challenges associated with the previous industrial revolutions, which include poverty, environmental degradation, unequal income distribution and economic development, and reductions in available labour due to declining populations and an ageing society (Bai, Dallasega, Orzes, & Sarkis, 2020). These problems can be addressed by inventing and implementing new technologies and CBMs in business organisations (Kamble, Gunasekaran, & Gawankar, 2018; Erol et al., 2016).

Meanwhile, the growing level of global competition has made it inevitable for business organisations to focus on innovation and production capacity (Saniuk, Grabowska, & Gajdzik, 2020). They have also had to reduce the overall time to market to increase operational effectiveness. To do so, business organisations are now increasingly investing in new technologies to respond to the I4.0 context (Vaidya, Ambad, & Bhosle, 2018), which ultimately helps companies develop competitive advantage. Notably, because markets have become more heterogeneous over time (Dalenogare et al., 2018), changes have often been forced. Meanwhile, other factors influencing change include shorter product life cycles and shifting consumer expectations and wants. It should be acknowledged that the previous production system has become obsolete, unable to meet the expectations of today's market. Furthermore, the previous system of production frequently caused damage to the environment. In these circumstances, if a company can improve its overall level of productivity, the quality of manufacturing will significantly increase, reducing overall wastage. Energy efficiency may also contribute to significant improvements (De Sousa Jabbour, Jabbour, Foropon, & Filho, 2018; Witham, 2018). Furthermore, I4.0 can positively impact ecologically friendly production and value chains, with green goods, green manufacturing techniques and green supply chain management all representing possible outcomes of I4.0. According to Li and Wang (2017), technical advancement may significantly contribute to economic growth, the modernisation of industrial structures, and the modification of energy structures, all of which can significantly lower carbon emissions. Furthermore, reports suggest that companies can drastically lower their carbon intensity by combining AI and robots (Liu, Yang, Fujii, & Liu, 2021) Consequently, it is essential to create an eco-friendly supply chain system that works successfully and efficiently to improve not only profits but also the environment (Elhedhli & Merrick, 2012).

This suggests that business organisations can increase sales volume via I4.0, enabling significant cost savings. More importantly, I4.0 exposes business organisations to the potential scope for radical micro-level performance improvements (Columbus, 2016). Meanwhile, collecting and analysing production data from the field enables additional benefits, such as faster decision-making and enhanced knowledge management assistance (Inezari & Gressel, 2017, Moktadir, Ali, Kusi-Sarpong, & Shaikh, 2018). In this context, I4.0 technologies can help business organisations supervise manufacturing activities, including production planning and scheduling, capacity utilisation, maintenance, and energy management (Müller et al., 2018; Uden & He, 2017). To increase the recycling rate, a hybrid manufacturing-remanufacturing mathematical model based on an RFID return route has been developed by (Ullah & Sarkar, 2020), with another model, by (Chen & Akmalul'Ulya, 2019), considering the government's reward-penalty system in its consideration of remanufacturing operations and greening initiatives.

Elsewhere, it is anticipated that I4.0 will change current business models (Frank et al., 2019; Müller et al., 2018), requiring that business organisations adopt different approaches to find circular ways of creating value. The changes to existing business models are expected to change the traditional value chain. These changes may encourage the development of a business model that can ultimately enable business organisations to involve consumers at a comparatively higher level in multiple capacities. Additionally, I4.0 is likely to impact three aspects of small and medium businesses in the manufacturing sector, namely, value creation, value capture, and value offers. Because I4.0 sees products becoming digital at an increasingly rapid rate (Venkatraman & Iyer, 2015), these channels will be increasingly digitised. This new pattern in business may contribute to changes in not only product and service design innovations but also customer relationships. The following propositions result from this discussion and can provide guidance to future researchers:

Because there is limited research concerning the creation of I4.0-based models to reduce risks related to manufacturing processes, future studies should incorporate these issues on the basis of the COVID-19 pandemic.

It is critical to identify more advanced I4.0-based innovations that can promote sustainable manufacturing and construction.

4.4. Social challenges related to Industry 4.0

It must be acknowledged that the significant challenges regarding the implementation of I4.0 are the lack of a skilled workforce and the need to retrain employees to adapt to the changing environment (Gaskell, 2018). It is evident that there is a need for innovative ways of working in the future. This will have both positive and negative consequences for the workforce. More importantly, changes in the operating atmosphere may encourage organisational disagreement (Bai et al., 2020; Horváth & Szabó, 2019).

Meanwhile, a lack of financial resources might substantially impede implementation of I4.0 (Sony, 2019). Low degrees of regulation, which correspond to environmentally harmful processes, and the implementation of I4.0 standards will be hampered by a lack of knowledge of integration and compounded by concerns about data security. This may also undermine inter-organisational relationships, especially due to standardisation issues in terms of tools and systems (Raj, Dwivedi, Sharma, de Sousa Jabbour, & Rajak, 2020). Business organisations will be concerned about cybersecurity and data ownership, potentially introducing a considerable obstacle to I4.0 adoption (Horváth & Szabó, 2019). Especially because new technologies will be widespread following I4.0 adoption, concerns about handling private information and data are anticipated to intensify in the short term (Kamble, Gunasekaran, & Gawankar, 2018; Tortorella & Fettermann, 2018). On a different note, the demand for privacy-enhancing technologies is expected to increase, contributing to the aim of using technical solutions to protect data and privacy. However, using privacy-enhancing technologies involves several associated risks, such as the risk of re-identification.

Furthermore, the underdevelopment of sustainability-conscious manufacturing systems is likely to affect the risk of fragility, ultimately creating more uncertainties in the business ecosystem (Stentoft, Jensen, Philipsen, & Haug, 2019). The dependability and stability of systems will have to be assured for the smooth execution of the overall operation. It should be noted that many business organisations have yet to provide feasibility assessments that strongly justify the need for the investment in data and systems building required to implement I4.0 technologies (Masood & Sonntag, 2020). This creates a further barrier to I4.0 adoption. On a different note, many business organisations are inadequately informed about the benefits of using I4.0 technologies (Frank et al., 2019). Thus, organisational cultures should have to be considered when considering implementing I4.0. That is, the proper management of organisational resistance and cultural acceptance of innovations should be prioritised when implementing I4.0 projects. The following propositions can help future researchers develop their study:

Identifying and ranking various challenges to the implementation of I4.0 technologies in the manufacturing sector should be based on different factors and use advanced methodologies.

Studies should classify various digital manufacturing technologies and provide information concerning the manufacturing industry's technology acceptance capacity.

4.5. Potential solutions related to the implementation of I4.0

Broadly speaking, it is critical to develop a clear strategy for implementing I4.0. Sustainability and visions of a circular economy should be included in this process, which details the goals of I4.0. Understandable and achievable business goals that align with sustainable development goals should be established thwart the problems with implementing I4.0, including social problems (Bauer et al., 2015). The implementation of I4.0 projects is often considered chaotic. For example, there are no standard procedures for implementing sustainability-oriented CBM projects at significant scale. Furthermore, achieving acceptance by employees is likely to become increasingly challenging if they are not clear and convincing instructions encouraging them to engage in I4.0-related activities. In this context, a comprehensive digital picture of a corporation might be a feasible vision of the future that could drive this kind of participation.

In addition, to implement I4.0 both effectively and efficiently, the top management of companies must commit to the I4.0 implementation schedule. Top management can obtain company-wide acceptability by clearly and effectively communicating the benefits of introducing I4.0 to subordinates. It is essential to make quick and effective decisions to provide solutions and resolve conflicts between ecologically sensitive and economically sensitive processes. From the internal perspective of the organisation, collaboration must take place between different departments and groups. This practice should be promoted across company boundaries, and sufficient resources should be provided to ensure a thriving I4.0.

Meanwhile, top management must also be prepared for disruptive changes at all levels. For example, a problem pertinent to I4.0 implementation is that the projects are not adequately managed if the benefits of capital and sustainability-oriented practices are indeterminate or demand substantial time investment for realisation. If there are insufficient resources and an absence of human talent, senior management must determine whether they want to transform the entire firm into a sustainability-oriented intelligence factory. This implies that strategic management is critical.

Critically, implementing I4.0 should be managed and coordinated by a capable project management team for effectiveness and, ultimately, success. Teams should comprise members from various functions because it is necessary to create synergies between people, information technology and companies. The project management team must make a detailed plan for the project and initiate the implementation needed to accomplish the clearly stated objectives. The plans must be monitored and evaluated from the beginning, which can be aided by adopting a transparent approach to the introduction of I4.0. Realistic expectations concerning performance and timetables should be conveyed effectively in manufacturing businesses. This can enable the consistency and commitment necessary to implement I4.0, which demands involvement of prospective users of the circular business solutions from the very beginning. This process should consider I4.0 implementation in areas beyond manufacturing.

Employee acceptance is critical to the successful implementation of I4.0. It should be mentioned that ambiguity about the unknown and unfamiliarity with the use of new ecologically sensitive technologies cab instigate problems. In this context, a clear plan and appropriate personnel training can help. However, it must be verified that a company's improvements are executed over a sufficiently long term. If employees do not get practice with I4.0, all efforts will automatically be futile. Overall acceptance and motivation problems are significant obstacles to the successful implementation of I4.0.

The proper skills and know-how needed to introduce I4.0 must be created in the company (Brettel et al., 2014). This can be achieved by employing extensive training and further education and learning. This involves addressing the limited understanding surrounding I4.0, which results in employees not being suitably skilled. Similarly, it should be noted that a high level of expertise in the IT sector has great importance for a company's implementation of I4.0 (Avis, 2018). Business organisations must prioritise the expansion of know-how and I4.0-related competencies. Furthermore, developing the necessary skills should begin before a company starts to implement I4.0. Essentially, the fact that an effective and efficient I4.0 performance requires a skilled workforce and sufficient resources requires the willingness to make a considerable investment.

In this context, technological improvements have opened doors for the integration of web-based technologies and suggested strategies for establishing web-based support systems for planning and production (Cheng, Pan, & Harrison, 2001). However, for the industry to control demand during disruption, it is crucial to create a decision-support tool (Govindan, Mina, & Alavi, 2020). For the transformation of intelligent manufacturing, several entrepreneurial criteria must be established. Supposing that a company's processes become de-centralised via the allocation of responsibility and the creation of independent units. In this context, applying I4.0, given the increasing complexity associated with I4.0, companies must focus on learning and sharing knowledge. Furthermore, there is a need for cultural willingness to change among organisations wanting to shift towards I4.0. However, to achieve the shared innovation goal, businesses must accelerate the intervention process via collaboration and modifying current technology rather than creating completely new technology (Liu, Yang, Fujii, & Liu, 2021). Additionally, manufacturing flexibility and design skill are essential for innovation in times of technological upheaval and market change (Auernhammer, 2020)

Finally, from a legal perspective, it is necessary to clarify the legal framework. The level of joint data access must be legally defined and certain contract types should be introduced to ensure responsibility for data security, trade secrets and profit allocation in collaborative ventures involving many firms. Furthermore, companies must develop clear rules for employee monitoring and protection of personalised data. Consequently, I4.0 can only be implemented successfully by ensuring data security, operational security and IT security. The following propositions can guide future researchers in the development of studies addressing these ideas:

It is critical to establish data-driven models using I4.0 techniques for sustainable manufacturing that can be used at the time of disruption.

It is necessary to address the dearth of studies concerning data management, data security and data personalisation to address the sustainable use of I4.0 models in the manufacturing sector.

This section's points of discussion and the propositions for future research enable the development of a conceptual model, which is depicted in Fig. 3.

5. Implications

This study was conducted to determine I4.0′s impact on the manufacturing sector. To analyse the body of literature on I4.0 already in existence, an approach combing a SLR with bibliometric analysis was adopted. This study's results can help managers utilise the I4.0 technologies already in use across the manufacturing industry to address risks and problems. The findings show that there is increasing interest in investigating various I4.0 applications in the manufacturing context. Enterprises can use I4.0 strategies to reduce the danger of unexpected breakouts of viruses and to build resilience across the industrial sector. This study will help researchers to detect gaps in the literature by demonstrating that there is a paucity of literature on I4.0 and its application, allowing for novel research pursuits that can respond to the identified possibilities, problems and potential solutions. Researchers can benefit from the research propositions for each aspect of the I4.0 implementation problem, which have been developed by considering the different research themes introduced by scholars with diverse backgrounds and distinct experiences. The fact that there is a smaller body of literature than appears in other bibliometric studies suggests that there is room to publish additional literary and research articles. This study also draws reader attention to under-exploited possibilities, encouraging them to close various research gaps. A more efficient method for developing appropriate scholarly study ideas in this specific theme area is offered by the research framework illustrated in Fig. 3.

6. Conclusion, limitations and future research directions

The study has examined the social problems associated with I4.0 together with plausible solutions. According to studies considered by the SLR, the major barriers are joblessness and shortages of highly skilled labour, technological know-how, top management support, cyber security and the misalignment of organisational goals vis-à-vis the long-term sustainable development goals. Correspondingly, proper training and education about I4.0, a sound security system, motivation and support from top management, rewards and shows of appreciation, and long-term socially conscious managerial goals represent some potential solutions.

The insights generated from the study are very relevant for managers and policymakers. Analysis of the findings can help managers and policymakers enhance their knowledge and understanding of I4.0 and formulate appropriate strategies for the effective and efficient implementation of I4.0 in their corporations. This has been specifically achieved by emphasising the role of CBMs in enhancing the value created. Consequently, future research should focus on the specific hurdles to I4.0 adoption. However, it is also necessary for research related to organisational transformation in general. Additionally, future research should aim to investigate the impact of I4.0 from the apparently complementary perspectives of managers and employees. It should be noted, however, that this study is not exempt from limitations. First, the results must be expanded and confirmed within a larger context adopting quantitative or mixed-method research designs. Furthermore, a clearly defined approach and strategy should be adopted to address social problems and provide effective solutions.

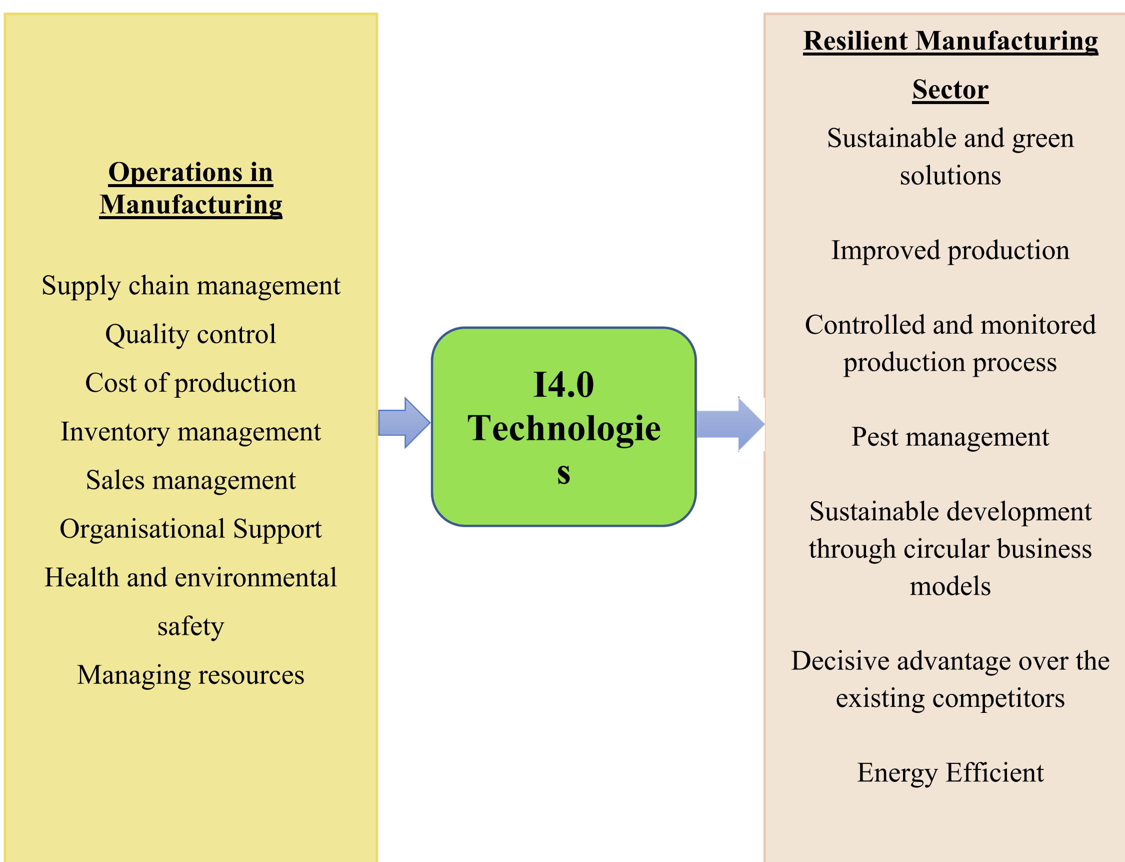

Fig. 3. Proposed research framework.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cie.2023.109072.

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