


Please cite the Published Version

Mukhuty, Sumona , Upadhyay, Arvind and Rothwell, Holly (2022) Strategic sustainable development of Industry 4.0 through the lens of social responsibility: the role of human resource practices. *Business Strategy and the Environment*, 31 (5). pp. 2068-2081. ISSN 0964-4733

DOI: <https://doi.org/10.1002/bse.3008>

Publisher: Wiley

Version: Published Version

Downloaded from: <https://e-space.mmu.ac.uk/629243/>

Usage rights:  [Creative Commons: Attribution 4.0](https://creativecommons.org/licenses/by/4.0/)

Additional Information: This is an Open Access article published in *Business Strategy and the Environment* by Wiley.

Enquiries:

If you have questions about this document, contact openresearch@mmu.ac.uk. Please include the URL of the record in e-space. If you believe that your, or a third party's rights have been compromised through this document please see our Take Down policy (available from <https://www.mmu.ac.uk/library/using-the-library/policies-and-guidelines>)

RESEARCH ARTICLE



WILEY

Strategic sustainable development of Industry 4.0 through the lens of social responsibility: The role of human resource practices

Sumona Mukhuty¹ | Arvind Upadhyay² | Holly Rothwell³

¹Research Centre for Decent Work and Productivity, Manchester Metropolitan University Business School, Manchester Metropolitan University, Manchester, UK

²University of Stavanger Business School, University of Stavanger (UiS), Stavanger, Norway

³Freelance Consultant, Leeds, UK

Correspondence

Sumona Mukhuty, Research Centre for Decent Work and Productivity, Manchester Metropolitan University Business School, Manchester Metropolitan University, Manchester, UK.
Email: s.mukhuty@mmu.ac.uk

Abstract

Research on sustainable development is significantly influenced by the trade-off between the economic, social and environmental performance of businesses. Industry 4.0 development is a key business priority due to the promise of exponential increase in productivity, time efficiencies and cost reduction. However, Industry 4.0 development has been slow. Notably, human actors remain central to Industry 4.0, while the social responsibility component of sustainable development is a key prerogative for industry, championed through the UN sustainable development goals and European Commission. Therefore, we evaluate human-related impediments for Industry 4.0 and critically explore how human resource management (HRM) can overcome these barriers using a socially responsible orientation. First, we analyse the human-related challenges to Industry 4.0 through a thematic literature review. Thereafter, through an integrative literature review of different research streams (Industry 4.0, HRM and social responsibility), we critically argue novel perspectives on how human resource practices can enable sustainable development of Industry 4.0 in a socially responsible manner. Herein, we address a crucial literature gap. Our findings reveal numerous people-related barriers, including change resistance, digital skills gap, employment threats widening socio-economic inequalities, lack of industry-wide collaboration, leadership and organisational culture challenges. We show that HRM can be a crucial enabler for sustainable Industry 4.0 development through socially responsible human resource practices. These include strategic multistakeholder collaborations, holistic talent management, change leadership, inclusive knowledge sharing, sponsoring education research and codesigning curricula, smart technology for upskilling and retention and rewarding inclusive Industry 4.0 ideas. We conclude with future research directions.

List of Abbreviations/Acronyms: AI, artificial intelligence; CPS, cyber-physical systems; CV, curriculum vitae; EC, European Commission; EFFRA, European Factories of the Future Research Association; FabLabs, fabrication laboratories; HE, higher education; HR, human resource; HRM, human resource management; ILO, International Labour Organization; IoT, Internet of Things; Ind4.0, Industry 4.0; OECD, Organisation for Economic Co-operation and Development; SDG, Sustainable Development Goal; SME, small and medium enterprise; UK, United Kingdom; US, United States of America; UN, United Nations.

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2022 The Authors. Business Strategy and The Environment published by ERP Environment and John Wiley & Sons Ltd.

KEYWORDS

Fourth Industrial Revolution (Industry 4.0), social responsibility, socially responsible human resource, strategic sustainable development, sustainable development

1 | INTRODUCTION

The Fourth Industrial Revolution, or Industry 4.0 (Ind4.0), was first popularised by the German federal government in 2011 (Kang et al., 2016; Lasi et al., 2014). This refers to the development and employment of disruptive technologies aimed at economising and improving efficiencies in industrial capabilities. The manufacturing industry can significantly benefit from Ind4.0 implementation, especially through instantaneous data transmission and tailor-made manufacturing as it encompasses real-time digitised interlinking of humans, objects, machines and systems (de Sousa Jabbour, Jabbour, Foropon, & Godinho Filho, 2018). Ind4.0 is *en route* to aiding sustainable development in the manufacturing industry through automating and digitising technologies including smart manufacturing, cloud manufacturing, the Internet of Things (IoT), cyber-physical systems (CPS), augmented reality (Kang et al., 2016; Pacchini et al., 2019), bulk customisation and servitisation (Oztemel & Gursev, 2020; Wang et al., 2017). Further potential benefits of Ind4.0 digital manufacturing include real-time tracking and traceability of transactions in supply chains (Upadhyay et al., 2021), waste reduction, recycling and facilitating circular economy outcomes (Nascimento et al., 2019). Thereby, exponentially enhancing production agility and cost efficiencies of lean (Buer et al., 2018; Raj et al., 2020; Upadhyay et al., 2020) through digital manufacturing. Notably, PwC¹ reported surplus revenue of 110 billion euro in the European industry through digitisation of goods and services.² Furthermore, McKinsey & Company has predicted a 45% to 55% jump in productivity using Ind4.0 automation technologies (Caylar et al., 2016).

The many evidential and potential benefits have led to high levels of governmental strategic investment, in the long-term sustainable development of Ind4.0 digital technologies in manufacturing industries. Notable governmental investments include the United States, China, South Korea, Japan, Singapore, the United Kingdom, Germany and the European Commission (EC) (Liao et al., 2017; Oesterreich & Teuteberg, 2016). Yet, despite recognition of the benefits, the rate of Ind4.0 adoption has been slow across the sector (Fantini et al., 2020; Nankervis et al., 2021; Raj et al., 2020). Several challenges are emerging in relation to Ind4.0 execution, including impact on social factors (Nascimento et al., 2019), which may account for the slow development. These challenges include implementation complexities, skills gaps and threats to existing jobs (Kamble et al., 2018; Luthra & Mangla, 2018). Arguably, these barriers have social responsibility implications.

Sustainable and socially responsible development is a crucial prerogative for industry. This is strongly evidenced by the United Nations

(UN) 2030 Agenda for Sustainable Development Goals (SDGs) (UN, 2015) and the EC (2011); both emphasising the need to ensure industrial innovation and development (SDG 9), while protecting holistic societal interests including the employment, welfare and well-being of existing and future generations (SDG 8) (Denoncourt, 2020; EC, 2011; International Labour Organization [ILO], 2018; UN, 2015). This presents industry with the conundrum of apparently competing priorities in implementing Ind4.0-based digital manufacturing technology, which can have negative social responsibility repercussions for human employment, skills and decent work. Yet human input remains crucial to the successful integration and operation of Ind4.0 in digital manufacturing (Li et al., 2019), and Ind4.0 can offer significant opportunities for sustainable development (Ghobakhloo et al., 2021). Therefore, it is imperative to find ways to overcome the barriers to Ind4.0 development (Pineiro et al., 2021). Herein, we argue that human resource management (HRM) can act as an enabler in the sustainable development of Ind4.0 digital manufacturing in a socially responsible manner.

Therefore, this article aims to identify and evaluate the human-related barriers to Ind4.0 digital manufacturing and critically explore how HRM can help overcome the barriers with a socially responsible orientation. While there have been some studies on Ind4.0 implementation challenges (Kamble et al., 2018; Luthra & Mangla, 2018; Raj et al., 2020), there is a lack of research on the role of HRM in facilitating socially responsible Ind4.0 sustainable development. This is despite an emerging body of literature on sustainable and socially responsible HRM (Barrena-Martínez et al., 2017, 2019b; Beer et al., 2015; Macke & Genari, 2019; Shen, 2011). This article contributes to bridging this gap through an integrative review of the barriers to Ind4.0 implementation in digital manufacturing and the role of HRM as an enabler, through the social responsibility lens of sustainability.

This article is structured as follows. Following this introduction (Section 1) is the methodology adopted in this study (Section 2). Thereafter, we present the findings and discussion (Section 3) in two parts. First (Section 3.1), we identify and analyse the human-related barriers to digital manufacturing through a content review analysis; thereafter (Section 3.2), we conduct an integrative literature review of the human barriers to Ind4.0 in the digital manufacturing context, Ind4.0 and HRM, socially responsible HRM and socially responsible Ind4.0. Through this integrative analysis, we argue how HRM practices can help overcome the human-related barriers to sustainable Ind4.0 development in digital manufacturing, with a social responsibility orientation. Thereafter, we conclude (Section 4) by discussing future research directions.

2 | RESEARCH METHODOLOGY

2.1 | Review approach and research question

The core of this research adopts an integrative literature review methodology (Torraco, 2005) combined with elements of a systematic review (Denyer & Tranfield, 2009). We employ Denyer and Tranfield's (2009) steps in organising this review: *research question, identifying studies, selecting studies, synthesising studies* and *disseminating outcomes* (Denyer & Tranfield, 2009). Thereafter, in synthesising studies and disseminating the results, we adopt the integrative review approach, critically combining different literature streams (Torraco, 2005). An integrative review is recommended, where rapidly growing, unique emergent bodies of literature are analysed to generate novel thinking, bridging a crucial gap (Post et al., 2020; Torraco, 2016). Therefore, we employ an integrative narrative review as we critically synthesise distinct research streams on the new yet fast-growing literature on Ind4.0 and barriers to digital manufacturing, as well as Ind4.0 and HRM, analysed through the critical lens of social responsibility. Through this review, we address a crucial literature gap, on the following question:

- How can HRM enable overcoming human-related barriers to the sustainable development of Ind4.0 digital manufacturing, in a socially responsible manner?

Therein, this leads to two key objectives for this review. The first objective is to investigate the human-related barriers to the sustainable development of Ind4.0 digital manufacturing. The second objective is to evaluate how HRM practices can help overcome these barriers and enable sustainable Ind4.0 development, in a socially responsible manner.

2.2 | Identifying studies

We searched academic databases including Business Source Premier, Scopus and Science Direct, to identify the relevant studies. Thereafter, we adopted the snowballing technique of identifying relevant articles cited in the articles found through the database search. We surveyed the literature using different combinations of keywords including *industry 4.0, the fourth industrial revolution, 4th industrial revolution, digital manufacturing, barriers, obstacles, challenges, human resource, human resource management, talent development, socially responsible* and *social responsibility*. This helped to achieve the widest coverage of pertinent articles (Denyer & Tranfield, 2009). We retrieved a total 192 relevant articles from the database searches of the different research streams (Table 1).

2.3 | Study selection

To be included in the review, we stipulated that the key search terms would be present in the title, abstract or keywords of the articles. The following clarifies the inclusion and exclusion criteria:

TABLE 1 Database search details

Search	Database searches	No. of articles retrieved
1	Barriers/Challenges to Industry 4.0 and Digital Manufacturing	39
2	Socially responsible Industry 4.0	23
3	Industry 4.0 and Human Resource Management/Talent Development	84
4	Human Resources and Social Responsibility	46
Total		192

- Ind4.0 and digital manufacturing: We included articles which addressed Ind4.0 and digital manufacturing, for example, smart factories and IoT.
- HRM: We include articles, which refer to HRM and human resource (HR) actions using terms like HR development, talent development and competence development. We draw on articles relating to Ind4.0 and being socially responsible.
- Social responsibility: We include Ind4.0 articles, linked with human factors of social responsibility. We also included HRM articles focusing on being socially responsible towards human actors.
- Language: We only included articles written in English.
- Publication type: We included scholarly articles that were peer reviewed. Additionally, we also draw on relevant policy documents (e.g., UN and EC publications). We, however, do not include conference proceedings.

Given the relatively new area of research, with Ind4.0 research commencing in 2011, both theoretical/conceptual and empirical studies were included. Furthermore, socially responsible HRM is also a novel area of research, so both theoretical and empirical studies were reviewed, in synthesising these research streams. After applying the above inclusion and exclusion criteria, and removing duplicates, 76 relevant articles were retained and reviewed.

2.4 | Examination and synthesis of studies

First, all relevant articles were thematically appraised to identify barriers/challenges to implementing Ind4.0 digital manufacturing. Thereafter, we analytically identified and evaluated the key themes emerging in terms of the challenges, arguably entwined with social responsibility issues for the human workforce in manufacturing organisations.

Second, we apply the integrative review approach and critically synthesise the disparate and emerging research streams on 'Ind4.0 and social responsibility', 'human resources and social responsibility' and 'Ind4.0 and human resources' in order develop new perspectives

on how HRM solutions can be applied to facilitate sustainable Ind4.0 development in a socially responsible way (Figure 1).

2.5 | Dissemination of outcomes

This article is the pioneering route to disseminating the findings of this study, to fellow academics and practitioners. The following sections illustrate our analytical findings and discussions on the human barriers to sustainable development of Ind4.0 in digital manufacturing. Thereafter, generate knowledge on how HRM can enable overcoming these barriers with a social responsibility orientation.

3 | FINDINGS AND DISCUSSION

3.1 | Human-related challenges/barriers to sustainable development of Ind4.0

The success of Ind4.0 is highly dependent on human actors (Neumann et al., 2021; Sgarbossa et al., 2020), as these systems are anthropogenic, that is, designed, delivered and dependent on human decisions (Schneider & Sting, 2020). This review evaluates the pertinent human-related challenges and barriers to sustainable Ind4.0 development in digital manufacturing. The literature review points to themes and issues of automation, digital skills gaps, threat to current employment widening socio-economic inequalities, collaboration challenges, leadership and organisational culture. These thematic barriers, which have emerged from the literature, are evaluated below, followed by a critical integrative analysis of how HRM can help overcome these barriers in socially responsible ways in Section 3.2.

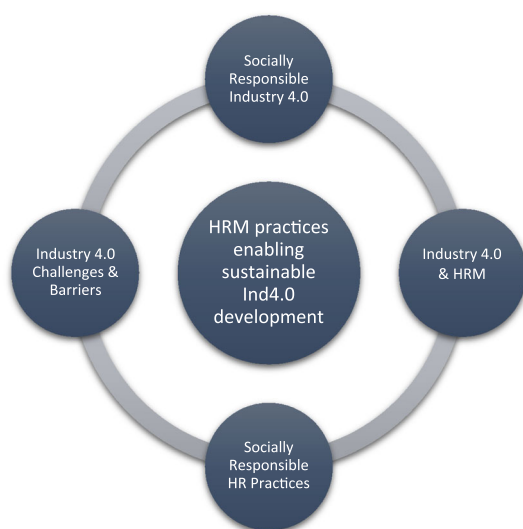


FIGURE 1 Diagrammatic representation of research stream integration [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

3.1.1 | Automation and resistance to change

A central feature of Ind4.0 manufacturing is the automation of work processes using digital technologies like robotics, IoT, big data and blockchain (Awan et al., 2021; Dutta et al., 2020; Upadhyay et al., 2021). Despite the financial and productivity gains (Ghobakhloo & Fathi, 2019), digitisation of processes leads to significant disruption to existing work patterns (Ehret & Wirtz, 2017) and existing jobs fulfilled by human labour (Raj et al., 2020). Artificial intelligence and machine learning are being adopted intensively to augment human-machine interactive collaborations (Huang et al., 2010; Rotatori et al., 2021). This has made it possible to effectively debunch big composite tasks into smaller ones. This involves using digitised systems like robotics to complete and outsource smaller tasks to other parts of the global supply chain, for reduced costs. However, this type of disruptive technology often requires a major overhaul in working processes (Broring et al., 2017; Kamble et al., 2018; Kiel et al., 2017) and requires extensive and risky alterations to existing business models (Herrmann et al., 2014; Müller, Buliga, & Voigt, 2018; Porter & Heppelmann, 2015). This shake-up to the status quo can reveal non-malleable organisational cultures (Rana & Sharma, 2019; Veile et al., 2019; Whysall et al., 2019) resulting in resistance to sustainable development of digital manufacturing (Horváth & Szabó, 2019; Karadayi-Usta, 2020). Moreover, smart manufacturing has a direct impact on the job prospects of existing workers (Frey & Osborne, 2017), making current skills redundant (Rana & Sharma, 2019), leading to visible social concerns and resistance to digitising and changing the processes (Haddud et al., 2017). The resultant impact of threats to employability is a core social responsibility issue for HRM, which we will revisit in this article.

3.1.2 | Digital skills gap

Developing and implementing Ind4.0 in the manufacturing industry requires sophisticated digital expertise. There is a visible gap in the skills needed to develop and implement digital manufacturing (Liboni et al., 2019; Raj et al., 2020). Firms need a workforce able to build the 'smart' infrastructure, to harness the benefits of automation and digitisation (Petrillo et al., 2018). Therefore, their workforce needs new skills, including big data, cloud computing, cybersecurity, robotics and additive manufacturing (Devi et al., 2020; Petrillo et al., 2018). To remain au courant, they will need to update their qualifications and skills perpetually (Herrmann et al., 2014). Policymakers like the EC and EFFRA³ are also recognising this drastic shift in skill-set requirements, emphasising the need for the current and future workforce to specialise in Ind4.0-related skills and technology to survive and capitalise on the Ind4.0 revolution (Fantini et al., 2020; Fareri et al., 2020). Developing a talent pool with high-level skills and qualifications is highly crucial to the sustainable development of digital manufacturing (Dutta et al., 2020; Kazancoglu & Ozkan-Ozen, 2018).

3.1.3 | Threat to existing employment

As stated earlier, redundancies and job losses are a direct and the most significant consequence of developing Ind4.0 digital manufacturing (Frey & Osborne, 2017; Liboni et al., 2019) particularly for middle management and older workers. This goes directly against the SDG principles of socially responsible innovation and decent work for all generations, present and future (UN, 2015). The OECD (2015) has predicted that 47% of American and 30% of British jobs may be lost in the next two decades, while major job losses have been reported across the globe due to the adoption of Ind4.0 technology including job losses in China due to Foxconn replacing manual workers with machines (Liboni et al., 2019; Wakefield, 2016). So the future of work is likely to embody complex and multidimensional transformations (Evangelista et al., 2014), with significant loss of blue-collar jobs (Schneider & Sting, 2020) and significant increases in jobs requiring sophisticated technological skills, previously not encompassed in the disappearing job profiles (Kazancoglu & Ozkan-Ozen, 2018). Hence, on one hand, there is the challenge of a range of existing manual jobs disappearing, while on the other hand, there is an increase in demand for a workforce, who have higher qualifications and skills to design and operate sophisticated smart technology in the manufacturing supply chain (Müller, Kiel, & Voigt, 2018). This poses a major social challenge, risking widening the socio-economic inequalities between the privileged and under-privileged. In this context, it is a crucial social responsibility of industry and HRM to enable digital confidence across all socio-economic sectors of the workforce and enhance the employability of disadvantaged, minority and ageing workgroups (Evangelista et al., 2014).

3.1.4 | Interorganisational collaboration challenges

To effectively harness Ind4.0 technologies, associated manufacturing firms and platforms need to organise themselves appropriately, as these technologies cannot be bought and applied as ready-made products (Porter & Heppelmann, 2015). There is a need for standardisation of practices and models, so that firms can engage in vertical and horizontal integration to reap the rewards of digital manufacturing (Chiarini & Kumar, 2021; Müller, Kiel, & Voigt, 2018; Tortorella et al., 2019) and facilitate sustainable development. A trained workforce is needed to facilitate this holistic integration of process and information flow and identify and resolve associated emergent problems (Agostini & Filippini, 2019). This in turn requires challenging multistakeholder negotiations and collaborations (Fantini et al., 2020). Hence, firms need to be able to effectively manage clients and deliver on multistakeholder collaborations, a key feature of smart manufacturing (CPS); whereby multiple firms and platforms along the supply chain need to come together to work cohesively (Fantini et al., 2020; Liboni et al., 2019; Whysall et al., 2019). Facilitating and coordinating these financially intensive multistakeholder collaborations for sustainable Ind4.0 development are a key human-related challenge for HRM departments too.

3.1.5 | Leadership and organisational culture barriers

The literature review also suggests that lack of relevant leadership skills and existing organisational cultures are inadvertently posing as impediments to the sustainable development of Ind4.0 digital manufacturing. The deficiency in digital awareness and understanding of the benefits and implications of Ind4.0 appears to extend to leaders at the top (Majumdar et al., 2021; Nankervis et al., 2021). Therefore, there is a lack of clarity in the vision and strategy for digital operations (Luthra & Mangla, 2018; Raj et al., 2020). This in turn tends to directly influence the organisational culture, creating a dearth in digital culture development, which requires interdisciplinary collaboration (Luthra & Mangla, 2018; Whysall et al., 2019). Furthermore, concerns about loss of control and transfer of decision making to floor level can make top management hesitant about the widespread development and implementation of Ind4.0 (Majumdar et al., 2021; Rotatori et al., 2021), thereby impeding the digital culture development, which is crucial for sustainable Ind4.0 development. In addition, the gap between the extant competencies of middle management and the rapidly changing technological competency requirements means experienced middle management talent who can be critical as change agents and lead change sustainably are being overlooked in favour of younger 'emerging leaders' (Whysall et al., 2019). This can also make it extremely challenging to successfully transform the organisational culture and facilitate sustainable and socially responsible Ind4.0 development.

Table 2 provides a summary of all the human-related challenges discussed above.

3.2 | Role of HRM in enabling socially responsible Ind4.0

Having analysed the main human-related barriers to sustainable Ind4.0 development, we conduct an integrated review of the literature on 'Ind4.0 and HRM', 'socially responsible Ind4.0' and 'socially responsible HRM'. The purpose of this is to generate new perspectives on how HRM practices can help overcome the barriers, to enable sustainable Ind4.0 development in a manner, which is socially responsible, employee centric and creates decent work. Socially responsible HRM encompasses practices designed to emphasise social responsibility in all HRM functions, benefit employees and motivate and facilitate socially responsible abilities in the workforce, with humanitarian and people-centric outcomes as the focus (Shen & Zhang, 2019; Shen & Zhu, 2011; Zhao et al., 2021). We argue that HRM has a strategic yet complex role to play in the sustainable development of Ind4.0 smart manufacturing, and as such, the different HR practices argued below will be interconnected and integrated. Based on our integrative review, Figure 2 summarises the key HR practices we recommend. It indicates the interlinkages between the proposed HR practices and the outcomes they can yield, finally leading to sustainable and socially responsible Ind4.0 development.

TABLE 2 Summary of human-related challenges/barriers to Industry 4.0 digital manufacturing with references

Human-related challenges/barriers			
Themes	Subthemes	Details	References
Industry-wide factors	Lack of industry-wide standardisation/collaboration	Including need for vertical and horizontal integration	Fantini et al. (2020); Luthra et al. (2020); Agostini and Filippini (2019); Li et al. (2019); Kamble et al. (2018); Luthra and Mangla (2018); Müller, Buliga, and Voigt (2018); Müller, Kiel, and Voigt (2018); Herrmann et al. (2014)
	Need for digital skills and higher qualifications	Including digital skills gap	Devi et al. (2020); Dutta et al. (2020); Fantini et al. (2020); Fareri et al. (2020); Li et al. (2020); Luthra et al. (2020); Raj et al. (2020); Rotatori et al. (2021); Liboni et al. (2019); Kamble et al. (2018); Kazancoglu and Ozkan-Ozen (2018); Basl (2017); Haddud et al. (2017); Kiel et al. (2017); Oesterreich and Teuteberg (2016); Herrmann et al. (2014)
	Need for the field of education to evolve to effectively prepare workforce for Ind4.0	Including education through the business community, government programmes and traditional education providers	Majumdar et al. (2021); Rotatori et al. (2021); Karadayi-Usta (2020); Whysall et al. (2019)
Knowledge and educational factors	Knowledge sharing challenges	Including multistakeholder collaborations	Nankervis et al. (2021); Li et al. (2019); Rajput and Singh (2019); Kamble et al. (2018)
	Threat/disruption to existing employment	Including loss of blue-collar jobs and impact on older workers	Nankervis et al. (2021); Fareri et al. (2020); Raj et al. (2020); Schneider and Sting (2020); Liboni et al. (2019); Rana and Sharma (2019); Buer et al. (2018); Kamble et al. (2018); Kazancoglu and Ozkan-Ozen (2018); Xu et al. (2018); Frey and Osborne (2017); Haddud et al. (2017)
	Inequality	Including need for higher qualifications and job threats widening the gap in socio-economic status	Xu et al. (2018); Evangelista et al. (2014)
Socio-economic factors	Leadership	Poor leadership in digital operations vision and strategy	Raj et al. (2020); Luthra and Mangla (2018)
		Lack of understanding and commitment of top management/low leadership readiness	Majumdar et al. (2021); Rotatori et al. (2021); Luthra and Mangla (2018)
		Lack of change management competencies or ineffective change management processes	de Sousa Jabbour, Jabbour, Godinho Filho, and Roubaud (2018); Müller, Kiel, and Voigt (2018); Basl (2017); Kiel et al. (2017)
		Lack of awareness of Ind4.0 implications and benefits	Nankervis et al. (2021); Dutta et al. (2020); Kamble et al. (2018); Luthra and Mangla (2018); Müller, Buliga, and Voigt (2018); Basl (2017); Haddud et al. (2017).
	Organisational structure	Inadequate organisational structure	Majumdar et al. (2021); Raj et al. (2020); Basl (2017); Kiel et al. (2017)
	Organisational culture	Including the lack of digital culture and need for culture change	Whysall et al. (2019); Veile et al. (2019); Rana and

TABLE 2 (Continued)

Human-related challenges/barriers			
Themes	Subthemes	Details	References
			Sharma (2019); de Sousa Jabbour, Jabbour, Foropon, and Godinho Filho (2018); de Sousa Jabbour, Jabbour, Godinho Filho, and Roubaud (2018)
	Resistance to change and conflict	Conflicts between workers due to changing working conditions	Kiel et al. (2017)
		Resistance to change	Nankervis et al. (2021); Schneider and Sting (2020); Horváth and Szabó (2019); Luthra and Mangla (2018); Haddud et al. (2017)

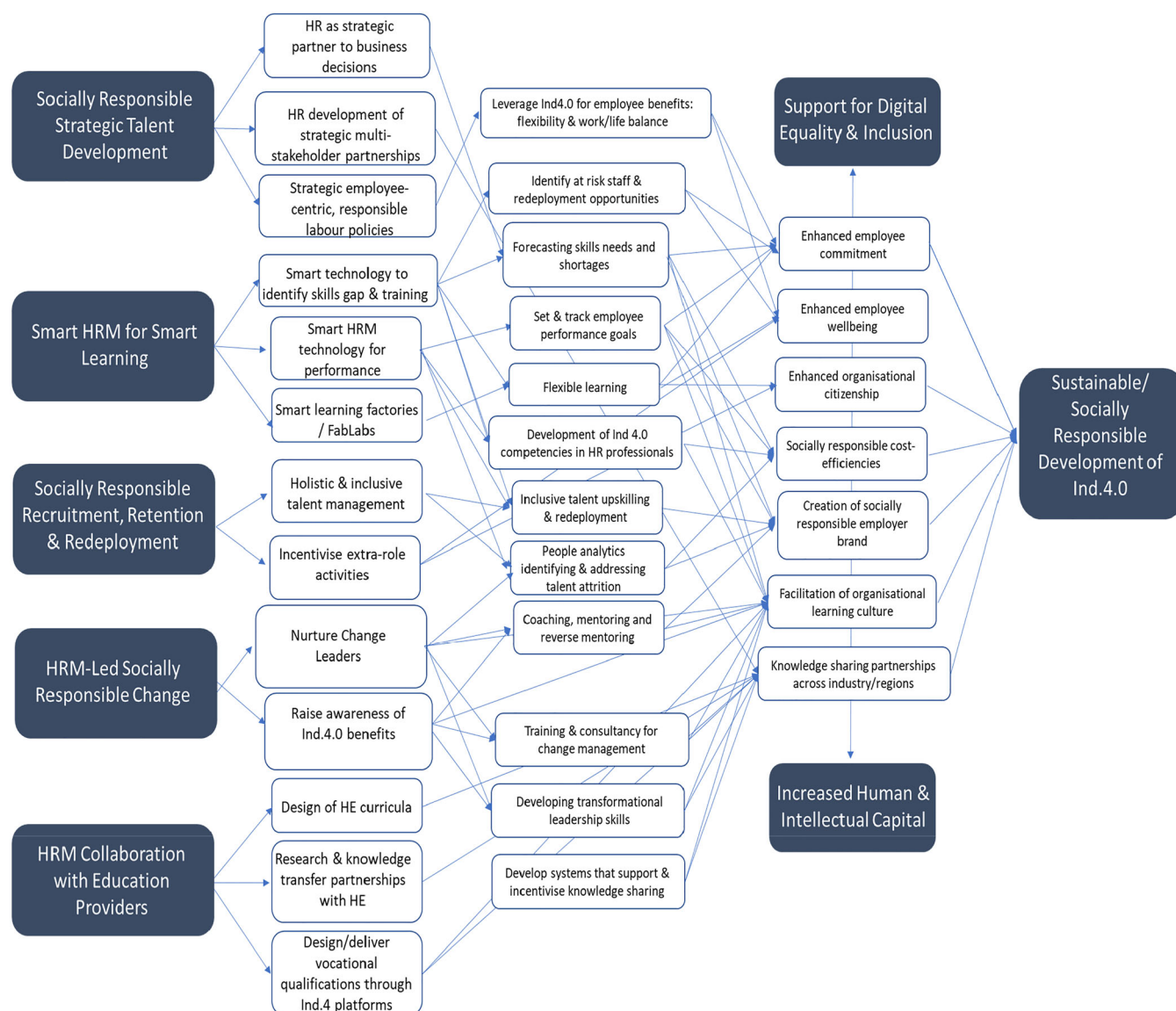


FIGURE 2 HR practices to enable Ind4.0 sustainable development in a socially responsible manner. Source: Developed from integrative review [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

3.2.1 | Strategic HRM leading to socially responsible strategic talent development

HRM can facilitate sustainable development by adopting a strategic approach to implementing digital manufacturing in a socially responsible manner. Moreover, this entails a long-term vision and extended planning with all strategic partners and stakeholders, including the workforce. HR professionals can play a strategic role in navigating the challenges of multistakeholder strategic partnerships, with collaborating and competing firms, and government bodies (Brunetti et al., 2020; Galang & Osman, 2016), facilitating vertical and horizontal integration in the digital supply chain.

Furthermore, HR departments need to be a strategic business partner to business decisions (Galang & Osman, 2016), so that socially responsible decisions are made in implementing Ind4.0 technology, causing the least possible disruption to employment. They need to find ways to establish responsible labour policies that create value for employees (Sorribes et al., 2021), to encourage collective adoption of sustainable Ind4.0 digital manufacturing. For example, HR can aid the step change to smart factories by incentivising socially responsible solutions (He et al., 2020) like retrofitting technology to old machines (Arnold et al., 2016; Müller, Kiel, & Voigt, 2018), so that employees can benefit (Jia et al., 2019) through job retention as existing workers can still operate them with nominal upskilling.

3.2.2 | HRM led socially responsible change for Ind4.0

HR specialists can contribute significantly by becoming an effective change agent (Long et al., 2013) and by equipping manufacturing firm managers and leaders with change management (Sony & Naik, 2020) and transformational leadership skills (Bag et al., 2021) through appropriate training and consultancy. HR professionals can also focus on developing digital awareness and competencies of management, so that they can effectively lead as role models. Change generates fear (Majumdar et al., 2021), hence generating awareness (Dutta et al., 2020) and providing socially responsible opportunities for employee training (Shen & Benson, 2016) can enhance employee commitment (Shen & Zhu, 2011) and thereby play a crucial role in advancing sustainable digital manufacturing. Hence, HR departments can contribute by generating awareness of the benefits and trends in Ind4.0 digitalisation for manufacturing and highlight the drawbacks and threats of not adapting to Ind4.0 changes. In this vein, they can also contribute via identifying and nurturing agile and ethically responsible leaders (Herold, 2016), as well as leaders who demonstrate systemic thinking and emotional sensitivity (Whysall et al., 2019), to champion digital manufacturing (Narula et al., 2020).

Sustainable development of Ind4.0 in a socially responsible way will require HR to facilitate a change in organisational culture (Rana & Sharma, 2019; Whysall et al., 2019) and the cultural mindset (Long

et al., 2013) of employees, while safeguarding the well-being of the workforce. Interpersonal relationship building skills and open channels of communication will be crucial for effectively implementing this change (Agostini & Filippini, 2019; Baran et al., 2019). HR departments can achieve sustainable and socially responsible changes by leveraging the Ind4.0 benefits whereby the technology allows for flexibility, mobility and work-life balance of employees (Rana & Sharma, 2019).

HRM can also aid sustainable and socially responsible digital development by facilitating a learning culture and developing knowledge sharing processes and networks within manufacturing firms and the industry. Knowledge sharing by the workforce can be crucial to Ind4.0 implementation (Li et al., 2019), yet role ambiguity and threat to jobs can deter knowledge sharing and create distrust (Jia et al., 2019; Wang et al., 2014). Therefore, socially responsible HRM centred on generating value for employees will build trust, respect and knowledge sharing (Jia et al., 2019). Developing a learning organisation will foster much needed value cocreation (Li et al., 2020). This can help quicken the pace of change in an inclusive and sustainable manner. A core function of HR departments is to foster team learning (Rana & Sharma, 2019), and HR professionals can enable this, by developing systems that support and reward knowledge sharing among the workforce (Nankervis et al., 2021). A learning organisation can effectively permeate new knowledge and learning at all levels within the firm including the individual, team and organisational level (Marsick & Watkins, 1999). HR professionals can help develop this approach to facilitate a learning culture leading to effective and sustainable transitions to Ind4.0 smart manufacturing.

3.2.3 | Smart HRM for smart learning

There is increasing recognition that generations Y and Z will make up an increasing percentage of the workforce, a generation that has grown up with IT and smart technology. Furthermore, continuous upskilling will be imperative for employees in digital manufacturing firms to remain competitive and technologically au courant (Herrmann et al., 2014). HR professionals themselves need to become digitally competent and current (Rana & Sharma, 2019; Ulrich et al., 2017). Therefore, HR departments can make use of smart technology itself and harness data analytics for effective and continuous talent development (Herrmann et al., 2014). For example, AI and big data can be employed to spot skills gap in workforce talent profiles for training, augmented reality can be designed to deliver online and simulated training (Herrmann et al., 2014) and IoT and blockchain technology can be used to set and track individual performance goals, which staff can self-monitor. Thereby, smart technology itself can help spot expertise shortages in advance, identify staff at risk of losing employment and invest in upskilling staff in implementing, operating and maintaining digital manufacturing technology in smart factories. This will help achieve sustainable Ind4.0 development in an efficient and socially responsible way.

Furthermore, human talent can be developed by investing in both physical and digital 'learning/teaching factories' as well as fabrication laboratories (FabLabs) which can be used for designing, testing and knowledge sharing across the industry and regions (Herrmann et al., 2014). The technique of using smart technology to identify and offer necessary training to individuals in the workforce will also facilitate socially responsible equality (Nie et al., 2018). This will also increase human and intellectual capital (Barrena-Martínez et al., 2019a; Mahmood & Mubarik, 2020) and support equality and diversity (Barrena-Martínez et al., 2019b) which is imperative to sustainable and socially responsible Ind4.0 implementation.

Moreover, socially responsible HRM can play a vital role by providing employee-oriented in-house learning, development coaches, targeted mentoring and external consultancy support. They can also facilitate reverse mentoring, where generation Y and Z employees can mentor the older workforce in becoming digitally competent (Brunetti et al., 2020). These socially responsible employee-centric HR practices will in turn generate employee commitment and organisational citizenship (Barrena-Martínez et al., 2019b; Newman et al., 2016) contributing to the vision of sustainable development of Ind4.0.

3.2.4 | HRM collaboration with education providers

To enhance the sustainable development of Ind4.0, HR professionals also need to collaborate with higher education (HE) provision in designing inclusive and innovative curricula, which prepares the future graduate for digital manufacturing and smart factories. They can also contribute through research collaborations (Majumdar et al., 2021) and knowledge transfer partnerships with universities. These may include development of sophisticated cobot or collaborative robot systems facilitating safe close working between people and robots (Chiarini, 2021; Franklin et al., 2020) and fostering coproduction and codesign among practitioners and academics, of sustainable Ind4.0 pathways (Massaro et al., 2021) in a socially responsible way. Whysall et al. (2019) found that it takes 2 years for university graduates to become useful to the hiring firm. There is increasing recognition of this lack of work readiness, and education content and delivery styles are being altered to remain au courant with Ind4.0 (Xu et al., 2018). HR professionals also need to work with HE in designing and delivering learning and vocational training through Ind4.0 platforms, learning factories and FabLabs. Moreover, HR professionals can work with educational providers and professional and policymaking bodies in designing new Ind4.0 relevant National Vocational Qualifications. The future of digital manufacturing rests on higher order skills of technicians, engineers and doctorates who excel at research, design and manufacturing and need to be part of the digital manufacturing supply chain. Hereby, addressing the needs of the future graduate, the industry and the wider society will help meet the sustainable development and social responsibility imperatives. Furthermore, HR professionals will also benefit by collaborating with HE and professional bodies in upskilling and developing their own Ind4.0 competencies (Nankervis

et al., 2021) (i.e., people data analytics), which they can then utilise in talent spotting and talent development.

3.2.5 | Socially responsible holistic recruitment, retention and redeployment policies

Ind4.0 implementation is leading to the need for new recruitment and selection criteria. Alongside focusing on recruiting talent with multi-disciplinary digital and engineering skills, HRM can help by moving from 'lateral hiring' of talent from competitors to addressing the over-all shortage in the new type of talent needed, through investing in holistic talent management (Whysall et al., 2019). This can help sustainable development of Ind4.0 competencies. Therefore, HR departments need to create internal systems to upskill new recruits internally to make them work ready, while simultaneously working with education providers in developing new skills needed for graduates to be work ready for digital manufacturing (Section 3.2.4). Moreover, HR departments need to recruit trainers, dedicated to reskilling and upskilling existing staff through training, coaching and learning factories, to minimise job losses due to changing job profiles and engage in socially responsible redeployment efforts and decent employment. Furthermore, socially responsible HR requires the development of inclusive talent development and retention practices, focusing on ensuring internal redeployment and job opportunities for middle managers and the ageing workforce (Sgarbossa et al., 2020; Whysall et al., 2019). Such socially responsible HR practices will in turn create a socially responsible employer brand, attracting high calibre candidates (Barrena-Martínez et al., 2019b). This will enable holistic socially responsible recruitment and retention of talent and create a diverse talent base, leading to sustainable Ind4.0 development.

Moreover, HR professionals can help by strategically forecasting the need for new skills and proactively training and equipping staff with the skills needed for digital manufacturing, including middle managers, older workers and blue-collar workers (Lin-Hi et al., 2019; Whysall et al., 2019). This type of strategic talent management will help ensure socially responsible advancement towards Ind4.0, whereby staff will feel valued and protected from fears of external risks (He et al., 2020) to their job security. HRM can also help by identifying redeployment opportunities for staff in job profiles, which will potentially become redundant with further digitisation in manufacturing.

Furthermore, HR professionals can employ Ind4.0 people analytics technology to speed up recruitment and selection by using cobots to sift through job applications and curriculum vitae (CVs), as well as track individual performance, training access, competency development, experience and performance feedback to identify attrition risks (Fareri et al., 2020). This can help in increasing talent retention in digital manufacturing, through HR identifying internal redeployment opportunities. Furthermore, socially responsible HRM rewards extra-role activities and organisational citizenship, information, which could be, retrieved through people analytics. These HR initiatives will help

achieve socially responsible cost efficiencies, enhance employee satisfaction and well-being (Abdelmoteleb & Saha, 2020; Celma et al., 2018) and thereby advance the sustainable development of Ind4.0.

4 | CONCLUSIONS, LIMITATIONS AND FUTURE DIRECTIONS

To conclude, this paper contributes to knowledge and practice, by analysing and organising the key people-related challenges and barriers to the sustainable development of Ind4.0. This article is the first of its kind to propose key solutions to how HR tools and practices can help to overcome these barriers, while ensuring socially responsible employee welfare and decent work. Firms and HR professionals can accelerate the pace of digital manufacturing development by applying the HR practices argued in this study. The present study shows that these HR practices will foster employee commitment to the vision of sustainable Ind4.0 development by enabling collective advancement in Ind4.0 implementation, thereby benefiting multiple stakeholders, including the employers, the workforce, customers and the wider industry. Hence, we show HRM can be a crucial enabler for sustainable Ind4.0 development through socially responsible HR programmes. These include strategic multistakeholder collaborations, holistic talent management, change leadership, inclusive knowledge sharing, sponsoring education research and codesigning curricula, smart technology for upskilling and rewarding inclusive Ind4.0 ideas. Thereby, implementing these practices will also help sustainable development by improving talent retention and reducing turnover. Overall, in facilitating sustainable development of Ind4.0, these HR practices will significantly support socially responsible aspirations of equality, diversity, inclusion, intellectual capital generation, inter-generational value cocreation, decent employability and socio-economic protection.

A limitation of this study is that it was unable to specifically differentiate between HR prerogatives for sustainable Ind4.0 development, in developed and developing economies. Future studies exploring the differences between the challenges for developed and developing countries will be beneficial. This is particularly relevant as technological replacement of human processes has a huge impact on the livelihood of people in developing countries, where a disproportionate number of people survive by providing cheap labour. Furthermore, disseminating inclusive digital education is an extremely costly prospect in developing countries, where the inequalities between the rich and the poor are very stark.

Moreover, this study has not distinguished between large manufacturing organisations and small and medium enterprises (SMEs). Digital manufacturing development is, understandably, being pioneered by large, financially secure organisations in the industry. However, these firms are entwined with numerous SMEs in their supply chains. Although SMEs are becoming aware of the benefits of Ind4.0 (Dutta et al., 2020), they still have a long distance to cover as

they navigate the impact and role of Ind4.0 in their businesses (Li et al., 2019). SMEs find it very expensive to change business models and need more standardisations in the sector (Müller, Buliga, & Voigt, 2018; Müller, Kiel, and Voigt (2018)), to catch up with global competition (Dutta et al., 2020). Therefore, more research in this field, and how HRM could specifically aid this transformation, will be valuable to the sector.

HR as a profession is significantly guided and informed by legislative frameworks in different countries. Investigating this aspect in relation to Ind4.0 development was beyond the scope of this article. However, to facilitate sustainable and socially responsible development of Ind4.0, it would be helpful to comprehend the nature of legislative frameworks needed (Ghobakhloo et al., 2021). Therefore, future studies focusing on this aspect will be highly beneficial for governance and regulatory authorities, to appropriately guide and govern sustainable Ind4.0 development.

ORCID

Sumona Mukhuty  <https://orcid.org/0000-0003-2408-7123>

Arvind Upadhyay  <https://orcid.org/0000-0002-6906-5369>

ENDNOTES

- ¹ Price Waterhouse Coopers.
- ² <https://www.infopulse.com/blog/the-main-benefits-and-challenges-of-industry-4-0-adoption-in-manufacturing/>; <https://i4-0-self-assessment.pwc.nl/i40/study.pdf>.
- ³ European Factories of the Future Research Association.

REFERENCES

- Abdelmoteleb, M., & Saha, S. K. (2020). Socially responsible human resources management, perceived organizational morality, and employee well-being. *Public Organization Review*, 20(2), 385–399. <https://doi.org/10.1007/s11115-019-00447-3>
- Agostini, L., & Filippini, R. (2019). Organizational and managerial challenges in the path towards Industry 4.0. *European Journal of Innovation Management*, 29(6), 910–936. <https://doi.org/10.1108/EJIM-02-2018-0030>
- Arnold, C., Kiel, D., & Voigt, K.-I. (2016). How the industrial Internet of Things changes business models in different manufacturing industries. *International Journal of Innovation Management*, 20(08), 1640015. <https://doi.org/10.1142/S1363919616400156>
- Awan, U., Stroufe, R., & Shahbaz, M. (2021). Industry 4.0 and the circular economy: A literature review and recommendations for future research. *Business Strategy and the Environment*, 30(4), 2038–2060. <https://doi.org/10.1002/bse.2731>
- Bag, S., Yadav, G., Dhamija, P., & Kataria, K. K. (2021). Key resources for Industry 4.0 adoption and its effect on sustainable production and circular economy: An empirical study. *Journal of Cleaner Production*, 281, 125233. <https://doi.org/10.1016/j.jclepro.2020.125233>
- Baran, B. E., Filipkowski, J. N., & Stockwell, R. A. (2019). Organizational change: Perspectives from human resource management. *Journal of Change Management*, 19(3), 201–219. <https://doi.org/10.1080/14697017.2018.1502800>
- Barrena-Martínez, J., López-Fernández, M., & Romero-Fernández, P. M. (2019a). The link between socially responsible human resource management and intellectual capital. *Corporate Social Responsibility and Environmental Management*, 26(1), 71–81. <https://doi.org/10.1002/csr.1658>

- Barrena-Martínez, J., López-Fernández, M., & Romero-Fernández, P. M. (2017). Socially responsible human resource policies and practices: Academic and professional validation. *European Research on Management and Business Economics*, 23(1), 55–61. <https://doi.org/10.1016/j.iedeen.2016.05.001>
- Barrena-Martínez, J., López-Fernández, M., & Romero-Fernández, P. M. (2019b). Towards a configuration of socially responsible human resource management policies and practices: Findings from an academic consensus. *The International Journal of Human Resource Management*, 30(17), 2544–2580. <https://doi.org/10.1080/09585192.2017.1332669>
- Basl, J. (2017). Pilot study of readiness of Czech companies to implement the principles of Industry 4.0. *Management and Production Engineering Review*, 8(2), 3–8. <https://doi.org/10.1515/mp-2017-0012>
- Beer, M., Boselie, P., & Brewster, C. (2015). Back to the future: Implications for the field of HRM of the multistakeholder perspective proposed 30 years ago. *Human Resource Management*, 54(3), 427–438. <https://doi.org/10.1002/hrm.21726>
- Broring, A., Schmid, S., Schindhelm, C.-K., Khelil, A., Kabisch, S., Kramer, D., Le Phuoc, D., Mitic, J., Anicic, D., & Teniente, E. (2017). Enabling IoT ecosystems through platform interoperability. *IEEE Software*, 34(1), 54–61. <https://doi.org/10.1109/MS.2017.2>
- Brunetti, F., Matt, D. T., Bonfanti, A., De Longhi, A., Pedrini, G., & Orzes, G. (2020). Digital transformation challenges: Strategies emerging from a multi-stakeholder approach. *The TQM Journal*, 32(4), 697–724. <https://doi.org/10.1108/TQM-12-2019-0309>
- Buer, S.-V., Strandhagen, J. O., & Chan, F. T. S. (2018). The link between Industry 4.0 and lean manufacturing: Mapping current research and establishing a research agenda. *International Journal of Production Research*, 56(8), 2924–2940. <https://doi.org/10.1080/00207543.2018.1442945>
- Caylar, P.-L., Noterdaeme, O., & Naik, K. (2016). *Digital in industry: From buzzword to value creation* (pp. 1–9). McKinsey & Company. <http://www.oecd.org/dev/Digital-in-industry-From-buzzword-to-value-creation.pdf>
- Celma, D., Martinez-Garcia, E., & Raya, J. M. (2018). Socially responsible HR practices and their effects on employees' wellbeing: Empirical evidence from Catalonia, Spain. *European Research on Management and Business Economics*, 24(2), 82–89. <https://doi.org/10.1016/j.iedeen.2017.12.001>
- Chiarini, A. (2021). Industry 4.0 technologies in the manufacturing sector: Are we sure they are all relevant for environmental performance? *Business Strategy and the Environment*, 30(7), 3194–3207. <https://doi.org/10.1002/bse.2797>
- Chiarini, A., & Kumar, M. (2021). Lean Six Sigma and Industry 4.0 integration for Operational Excellence: Evidence from Italian manufacturing companies. *Production Planning and Control*, 32(13), 1084–1101. <https://doi.org/10.1080/09537287.2020.1784485>
- 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. *Technological Forecasting and Social Change*, 132, 18–25. <https://doi.org/10.1016/j.techfore.2018.01.017>
- de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Godinho Filho, M., & Roubaud, D. (2018). Industry 4.0 and the circular economy: A proposed research agenda and original roadmap for sustainable operations. *Annals of Operations Research*, 270(1–2), 273–286. <https://doi.org/10.1007/s10479-018-2772-8>
- Denoncourt, J. (2020). Companies and UN 2030 Sustainable Development Goal 9 Industry, Innovation and Infrastructure. *Journal of Corporate Law Studies*, 20(1), 199–235. <https://doi.org/10.1080/14735970.2019.1652027>
- Denyer, D., & Tranfield, T. (2009). Producing a systematic review. In D. A. Buchanan & A. Bryman (Eds.), *The Sage handbook of organizational research methods*. Sage.
- Devi, K. S., Paranitharan, K. P., & Agniveesh A, I. (2020). Interpretive framework by analysing the enablers for implementation of Industry 4.0: An ISM approach. *Total Quality Management & Business Excellence*, 32(13–14), 1494–1514. <https://doi.org/10.1080/14783363.2020.1735933>
- Dutta, G., Kumar, R., Sindhvani, R., & Singh, R. K. (2020). Digital transformation priorities of India's discrete manufacturing SMEs—A conceptual study in perspective of Industry 4.0. *Competitiveness Review: An International Business Journal*, 30(3), 289–314. <https://doi.org/10.1108/CR-03-2019-0031>
- Ehret, M., & Wirtz, J. (2017). Unlocking value from machines: Business models and the industrial Internet of Things. *Journal of Marketing Management*, 33(1–2), 111–130. <https://doi.org/10.1080/0267257X.2016.1248041>
- European Commission. (2011). *A renewed EU strategy 2011–14 for Corporate Social Responsibility*. European Commission.
- Evangelista, R., Guerrieri, P., & Melicani, V. (2014). The economic impact of digital technologies in Europe. *Economics of Innovation and New Technology*, 23(8), 802–824. <https://doi.org/10.1080/10438599.2014.918438>
- Fantini, P., Pinzone, M., & Taisch, M. (2020). Placing the operator at the centre of Industry 4.0 design: Modelling and assessing human activities within cyber-physical systems. *Computers & Industrial Engineering*, 139, 105058. <https://doi.org/10.1016/j.cie.2018.01.025>
- Fareri, S., Fantoni, G., Chiarello, F., Coli, E., & Binda, A. (2020). Estimating Industry 4.0 impact on job profiles and skills using text mining. *Computers in Industry*, 118, 103222. <https://doi.org/10.1016/j.compind.2020.103222>
- Franklin, C. S., Dominguez, E. G., Fryman, J. D., & Lewandowski, M. L. (2020). Collaborative robotics: New era of human–robot cooperation in the workplace. *Journal of Safety Research*, 74, 153–160. <https://doi.org/10.1016/j.jsr.2020.06.013>
- Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, 114, 254–280. <https://doi.org/10.1016/j.techfore.2016.08.019>
- Galang, M. C., & Osman, I. (2016). HR managers in five countries: What do they do and why does it matter? *The International Journal of Human Resource Management*, 27(13), 1341–1372. <https://doi.org/10.1080/09585192.2015.1072099>
- Ghobakhloo, M., & Fathi, M. (2019). Corporate survival in Industry 4.0 era: The enabling role of lean-digitized manufacturing. *Journal of Manufacturing Technology Management*, 31(1), 1–30. <https://doi.org/10.1108/JMTM-11-2018-0417>
- Ghobakhloo, M., Iranmanesh, M., Grybauskas, A., Vilkas, M., & Petraitė, M. (2021). Industry 4.0, innovation, and sustainable development: A systematic review and a roadmap to sustainable innovation. *Business Strategy and the Environment*, 30(8), 4237–4257. <https://doi.org/10.1002/bse.2867>
- Haddud, A., DeSouza, A., Khare, A., & Lee, H. (2017). Examining potential benefits and challenges associated with the Internet of Things integration in supply chains. *Journal of Manufacturing Technology Management*, 28(8), 1055–1085. <https://doi.org/10.1108/JMTM-05-2017-0094>
- He, J., Mao, Y., Morrison, A. M., & Coca-Stefaniak, J. A. (2020). On being warm and friendly: The effect of socially responsible human resource management on employee fears of the threats of COVID-19. *International Journal of Contemporary Hospitality Management*, 33(1), 346–366. <https://doi.org/10.1108/IJCHM-04-2020-0300>
- Herold, G. (2016). *Leadership in the Fourth Industrial Revolution*. Stanton Chase.

- Herrmann, C., Schmidt, C., Kurle, D., Blume, S., & Thiede, S. (2014). Sustainability in manufacturing and factories of the future. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 1(4), 283–292. <https://doi.org/10.1007/s40684-014-0034-z>
- Horváth, D., & Szabó, R. Z. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change*, 146, 119–132. <https://doi.org/10.1016/j.techfore.2019.05.021>
- Huang, X., Chan, S. C. H., Lam, W., & Nan, X. (2010). The joint effect of leader-member exchange and emotional intelligence on burnout and work performance in call centers in China. *The International Journal of Human Resource Management*, 21(7), 1124–1144. <https://doi.org/10.1080/09585191003783553>
- International Labour Organization. (2018). *Decent work and the sustainable development goals: A guidebook on SDG labour market indicators*. Department of Statistics, ILO.
- Jia, X., Liao, S., Van der Heijden, B. I. J. M., & Guo, Z. (2019). The effect of socially responsible human resource management (SRHRM) on front-line employees' knowledge sharing. *International Journal of Contemporary Hospitality Management*, 31(9), 3646–3663. <https://doi.org/10.1108/IJCHM-09-2018-0769>
- Kamble, S. S., Gunasekaran, A., & Sharma, R. (2018). Analysis of the driving and dependence power of barriers to adopt Industry 4.0 in Indian manufacturing industry. *Computers in Industry*, 101, 107–119. <https://doi.org/10.1016/j.compind.2018.06.004>
- Kang, H. S., Lee, J. Y., Choi, S., Kim, H., Park, J. H., Son, J. Y., Kim, B. H., & Noh, S. D. (2016). Smart manufacturing: Past research, present findings, and future directions. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 3(1), 111–128. <https://doi.org/10.1007/s40684-016-0015-5>
- Karadayi-Usta, S. (2020). An interpretive structural analysis for Industry 4.0 adoption challenges. *IEEE Transactions on Engineering Management*, 67(3), 973–978. <https://doi.org/10.1109/TEM.2018.2890443>
- Kazancoglu, Y., & Ozkan-Ozen, Y. D. (2018). Analyzing Workforce 4.0 in the Fourth Industrial Revolution and proposing a road map from operations management perspective with fuzzy DEMATEL. *Journal of Enterprise Information Management*, 31(6), 891–907. <https://doi.org/10.1108/JEIM-01-2017-0015>
- Kiel, D., Arnold, C., & Voigt, K.-I. (2017). The influence of the Industrial Internet of Things on business models of established manufacturing companies—A business level perspective. *Technovation*, 68, 4–19. <https://doi.org/10.1016/j.technovation.2017.09.003>
- Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, 6(4), 239–242. <https://doi.org/10.1007/s12599-014-0334-4>
- Li, A. Q., Rich, N., Found, P., Kumar, M., & Brown, S. (2020). Exploring product-service systems in the digital era: A socio-technical systems perspective. *The TQM Journal*, 32(4), 897–913. <https://doi.org/10.1108/TQM-11-2019-0272>
- Li, D., Fast-Berglund, A., & Paulin, D. (2019). Current and future Industry 4.0 capabilities for information and knowledge sharing: Case of two Swedish SMEs. *The International Journal of Advanced Manufacturing Technology*, 105, 3951–3963. <https://doi.org/10.1007/s00170-019-03942-5>
- Liao, Y., Deschamps, F., Loures, E. D. F. R., & Ramos, L. F. P. (2017). Past, present and future of Industry 4.0—A systematic literature review and research agenda proposal. *International Journal of Production Research*, 55(12), 3609–3629. <https://doi.org/10.1080/00207543.2017.1308576>
- Liboni, L. B., Cezarino, L. O., Jabbour, C. J. C., Oliveira, B. G., & Stefanelli, N. O. (2019). Smart industry and the pathways to HRM 4.0: Implications for SCM. *Supply Chain Management: An International Journal*, 24(1), 124–146. <https://doi.org/10.1108/SCM-03-2018-0150>
- Lin-Hi, N., Rothenhöfer, L., & Blumberg, I. (2019). The relevance of socially responsible blue-collar human resource management: An experimental investigation in a Chinese factory. *Employee Relations: The International Journal*, 41(6), 1256–1272. <https://doi.org/10.1108/ER-03-2018-0081>
- Long, C. S., Wan Ismail, W. K., & Amin, S. M. (2013). The role of change agent as mediator in the relationship between HR competencies and organizational performance. *The International Journal of Human Resource Management*, 24(10), 2019–2033. <https://doi.org/10.1080/09585192.2012.725080>
- Luthra, S., Kumar, A., Zavadskas, E. K., Mangla, S. K., & Garza-Reyes, J. A. (2020). Industry 4.0 as an enabler of sustainability diffusion in supply chain: An analysis of influential strength of drivers in an emerging economy. *International Journal of Production Research*, 58(5), 1505–1521. <https://doi.org/10.1080/00207543.2019.1660828>
- Luthra, S., & Mangla, S. K. (2018). Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. *Process Safety and Environmental Protection*, 117, 168–179. <https://doi.org/10.1016/j.psep.2018.04.018>
- Macke, J., & Genari, D. (2019). Systematic literature review on sustainable human resource management. *Journal of Cleaner Production*, 208, 806–815. <https://doi.org/10.1016/j.jclepro.2018.10.091>
- Mahmood, T., & Mubarik, M. S. (2020). Balancing innovation and exploitation in the fourth industrial revolution: Role of intellectual capital and technology absorptive capacity. *Technological Forecasting and Social Change*, 160, 120248. <https://doi.org/10.1016/j.techfore.2020.120248>
- Majumdar, A., Garg, H., & Jain, R. (2021). Managing the barriers of Industry 4.0 adoption and implementation in textile and clothing industry: Interpretive structural model and triple helix framework. *Computers in Industry*, 125, 103372. <https://doi.org/10.1016/j.compind.2020.103372>
- Marsick, V. J., & Watkins, K. E. (1999). Looking again at learning in the learning organization: A tool that can turn into a weapon! *The Learning Organization*, 6(5), 207–211. <https://doi.org/10.1108/09696479910299820>
- Massaro, M., Secinaro, S., Dal Mas, F., Brescia, V., & Calandra, D. (2021). Industry 4.0 and circular economy: An exploratory analysis of academic and practitioners' perspectives. *Business Strategy and the Environment*, 30(2), 1213–1231. <https://doi.org/10.1002/bse.2680>
- Müller, J. M., Buliga, O., & Voigt, K.-I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, 132, 2–17. <https://doi.org/10.1016/j.techfore.2017.12.019>
- 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(1), 247. <https://doi.org/10.3390/su10010247>
- Nankervis, A., Connell, J., Cameron, R., Montague, A., & Prikshat, V. (2021). 'Are we there yet?' Australian professionals and the Fourth Industrial Revolution. *Asia Pacific Journal of Human Resources*, 59(1), 3–19. <https://doi.org/10.1111/1744-7941.12245>
- Narula, S., Prakash, S., Dwivedy, M., Talwar, V., & Tiwari, S. P. (2020). Industry 4.0 adoption key factors: An empirical study on manufacturing industry. *Journal of Advances in Management Research*, 17(5), 697–725. <https://doi.org/10.1108/JAMR-03-2020-0039>
- Nascimento, D. L. M., Alencastro, V., Quelhas, O. L. G., Caiado, R. G. G., Garza-Reyes, J. A., Rocha-Lona, L., & Tortorella, G. (2019). Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal. *Journal of Manufacturing Technology Management*, 30(3), 607–627. <https://doi.org/10.1108/JMTM-03-2018-0071>
- Neumann, W. P., Winkelhaus, S., Grosse, E. H., & Glock, C. H. (2021). Industry 4.0 and the human factor—A systems framework and analysis methodology for successful development. *International Journal of Production Economics*, 233, 107992. <https://doi.org/10.1016/j.ijpe.2020.107992>

- Newman, A., Miao, Q., Hofman, P. S., & Zhu, C. J. (2016). The impact of socially responsible human resource management on employees' organizational citizenship behaviour: The mediating role of organizational identification. *The International Journal of Human Resource Management*, 27(4), 440–455. <https://doi.org/10.1080/09585192.2015.1042895>
- Nie, D., Lämsä, A.-M., & Pučetaité, R. (2018). Effects of responsible human resource management practices on female employees' turnover intentions. *Business Ethics: A European Review*, 27(1), 29–41. <https://doi.org/10.1111/beer.12165>
- OECD. (2015). *The Innovation Imperative: Contributing to Productivity, Growth and Well-Being*. OECD. <https://doi.org/10.1787/9789264239814-en>
- Oesterreich, T. D., & Teuteberg, F. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry*, 83, 121–139. <https://doi.org/10.1016/j.compind.2016.09.006>
- Oztemel, E., & Gursev, S. (2020). Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*, 31(1), 127–182. <https://doi.org/10.1007/s10845-018-1433-8>
- Pacchini, A. P. T., Lucato, W. C., Facchini, F., & Mummolo, G. (2019). The degree of readiness for the implementation of Industry 4.0. *Computers in Industry*, 113, 103125. <https://doi.org/10.1016/j.compind.2019.103125>
- Petrillo, A., Felice, F. D., Cioffi, R., & Zomparelli, F. (2018). Fourth Industrial Revolution: Current practices, challenges, and opportunities. In A. Petrillo, R. Cioffi, & F. D. Felice (Eds.), *Digital transformation in smart manufacturing*. IntechOpen. <https://doi.org/10.5772/intechopen.72304>
- Pinheiro, M. A. P., Jugend, D., de Sousa, L., Jabbour, A. B., Chiappetta Jabbour, C. J., & Latan, H. (2021). Circular economy-based new products and company performance: The role of stakeholders and Industry 4.0 technologies. *Business Strategy and the Environment*, 31(1), 483–499. <https://doi.org/10.1002/bse.2905>
- Porter, M. E., & Heppelmann, J. E. (2015). How smart, connected products are transforming companies. *Harvard Business Review*, 93(10), 96–114.
- Post, C., Sarala, R., Gatrell, C., & Prescott, J. E. (2020). Advancing theory with review articles. *Journal of Management Studies*, 57(2), 351–376. <https://doi.org/10.1111/joms.12549>
- Raj, A., Dwivedi, G., Sharma, A., de Sousa, L., Jabbour, A. B., & Rajak, S. (2020). Barriers to the adoption of Industry 4.0 technologies in the manufacturing sector: An inter-country comparative perspective. *International Journal of Production Economics*, 224, 107546. <https://doi.org/10.1016/j.ijpe.2019.107546>
- Rajput, S., & Singh, S. P. (2019). Connecting circular economy and industry 4.0. *International Journal of Information Management*, 49, 98–113. <https://doi.org/10.1016/j.ijinfomgt.2019.03.002>
- Rana, G., & Sharma, R. (2019). Emerging human resource management practices in Industry 4.0. *Strategic HR Review*, 18(4), 176–181. <https://doi.org/10.1108/SHR-01-2019-0003>
- Rotatori, D., Lee, E. J., & Sleeva, S. (2021). The evolution of the workforce during the fourth industrial revolution. *Human Resource Development International*, 24(1), 92–103. <https://doi.org/10.1080/13678868.2020.1767453>
- Schneider, P., & Sting, F. J. (2020). Employees' perspectives on digitalization-induced change: Exploring frames of Industry 4.0. *Academy of Management Discoveries*, 6(3), 406–435. <https://doi.org/10.5465/amd.2019.0012>
- Sgarbossa, F., Grosse, E. H., Neumann, W. P., Battini, D., & Glock, C. H. (2020). Human factors in production and logistics systems of the future. *Annual Reviews in Control*, 49, 295–305. <https://doi.org/10.1016/j.arcontrol.2020.04.007>
- Shen, J. (2011). Developing the concept of socially responsible international human resource management. *The International Journal of Human Resource Management*, 22(6), 1351–1363. <https://doi.org/10.1080/09585192.2011.559104>
- Shen, J., & Benson, J. (2016). When CSR is a social norm: How socially responsible human resource management affects employee work behavior. *Journal of Management*, 42(6), 1723–1746. <https://doi.org/10.1177/0149206314522300>
- Shen, J., & Zhang, H. (2019). Socially responsible human resource management and employee support for external CSR: Roles of organizational CSR climate and perceived CSR directed toward employees. *Journal of Business Ethics*, 156(3), 875–888. <https://doi.org/10.1007/s10551-017-3544-0>
- Shen, J., & Zhu, C. J. (2011). Effects of socially responsible human resource management on employee organizational commitment. *The International Journal of Human Resource Management*, 22(15), 3020–3035. <https://doi.org/10.1080/09585192.2011.599951>
- Sony, M., & Naik, S. (2020). Critical factors for the successful implementation of Industry 4.0: A review and future research direction. *Production Planning and Control*, 31(10), 799–815. <https://doi.org/10.1080/09537287.2019.1691278>
- Sorribes, J., Celma, D., & Martínez-García, E. (2021). Sustainable human resources management in crisis contexts: Interaction of socially responsible labour practices for the wellbeing of employees. *Corporate Social Responsibility and Environmental Management*, 28(2), 936–952. <https://doi.org/10.1002/csr.2111>
- Torraco, R. J. (2005). Writing integrative literature reviews: Guidelines and examples. *Human Resource Development Review*, 4(3), 356–367. <https://doi.org/10.1177/1534484305278283>
- Torraco, R. J. (2016). Writing integrative literature reviews: Using the past and present to explore the future. *Human Resource Development Review*, 15(4), 404–428. <https://doi.org/10.1177/1534484316671606>
- Tortorella, G. L., Giglio, R., & van Dun, D. H. (2019). Industry 4.0 adoption as a moderator of the impact of lean production practices on operational performance improvement. *International Journal of Operations & Production Management*, 39(6/7/8), 860–886. <https://doi.org/10.1108/IJOPM-01-2019-0005>
- Ulrich, D., Kryscynski, D., Ulrich, M., & Brockbank, W. (2017). Competencies for HR professionals who deliver outcomes. *Wiley Periodicals*, 44, 37–44. <https://doi.org/10.1002/ert.21623>
- United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. <https://sustainabledevelopment.un.org/post2015/transformingourworld>
- Upadhyay, A., Mukhuty, S., Kumar, V., & Kazancoglu, Y. (2021). Blockchain technology and the circular economy: Implications for sustainability and social responsibility. *Journal of Cleaner Production*, 293, 126130. <https://doi.org/10.1016/j.jclepro.2021.126130>
- Upadhyay, A., Mukhuty, S., Kumari, S., Garza-Reyes, J. A., & Shukla, V. (2020). A review of lean and agile management in humanitarian supply chains: Analysing the pre-disaster and post-disaster phases and future directions. *Production Planning & Control: The Management of Operations. Ahead of Print*, 1–14. <https://doi.org/10.1080/09537287.2020.1834133>
- Veile, J. W., Kiel, D., Müller, J. M., & Voigt, K.-I. (2019). Lessons learned from Industry 4.0 implementation in the German manufacturing industry. *Journal of Manufacturing Technology Management*, 31(5), 977–997. <https://doi.org/10.1108/JMTM-08-2018-0270>
- Wakefield, J. (2016). Foxconn replaces '60,000 factory workers with robots'. BBC News.
- Wang, S., Noe, R. A., & Wang, Z.-M. (2014). Motivating knowledge sharing in knowledge management systems: A quasi-field experiment. *Journal of Management*, 40(4), 978–1009. <https://doi.org/10.1177/0149206311412192>
- Wang, Y., Ma, H.-S., Yang, J.-H., & Wang, K.-S. (2017). Industry 4.0: A way from mass customization to mass personalization production.

- Advances in Manufacturing*, 5(4), 311–320. <https://doi.org/10.1007/s40436-017-0204-7>
- Whysall, Z., Owtram, M., & Brittain, S. (2019). The new talent management challenges of Industry 4.0. *Journal of Management Development*, 38(2), 118–129. <https://doi.org/10.1108/JMD-06-2018-0181>
- Xu, M., David, J. M., & Kim, S. H. (2018). The Fourth Industrial Revolution: Opportunities and challenges. *International Journal of Financial Research*, 9(2), 90. <https://doi.org/10.5430/ijfr.v9n2p90>
- Zhao, H., Zhou, Q., He, P., & Jiang, C. (2021). How and when does socially responsible HRM affect employees' organizational citizenship behaviors toward the environment? *Journal of Business Ethics*, 169(2), 371–385. <https://doi.org/10.1007/s10551-019-04285-7>

How to cite this article: Mukhuty, S., Upadhyay, A., & Rothwell, H. (2022). Strategic sustainable development of Industry 4.0 through the lens of social responsibility: The role of human resource practices. *Business Strategy and the Environment*, 1–14. <https://doi.org/10.1002/bse.3008>