Socially Responsible Operations in the Industry 4.0 Era:

Post-COVID-19 Technology Adoption and Perspectives on Future Research

Abstract

Purpose: As focal firms in supply networks reflect on their experiences of the pandemic and begin to rethink their operations and supply chains, there is a significant opportunity to leverage digital technological advances to enhance socially responsible operations performance (SROP). This paper develops a novel framework for exploring the adoption of Industry 4.0 technologies for improving SROP. It highlights current best-practice examples and presents future research pathways.

Design/methodology: This viewpoint paper argues how Industry 4.0 technology adoption can enable effective SROP in the post-COVID-19 era. Academic articles, relevant grey literature, and insights from industry experts are used to support the development of the framework.

Findings: Seven technologies are identified that bring transformational capabilities to SROP, i.e. big data analytics, digital twins, augmented reality, blockchain, 3D printing, artificial intelligence, and the Internet of Things. It is demonstrated how these technologies can help to improve three sub-themes of organisational social performance (employment practices, health and safety, and business practices) and three sub-themes of community social performance (quality of life and social welfare, social governance, and economic welfare and growth).

Research limitations/implications: A research agenda is outlined at the intersection of Industry 4.0 and SROP through the six sub-themes of organisational and community social performance. Further, these are connected through three overarching research agendas: *"Trust through Technology", "Responsible Relationships"* and *"Freedom through Flexibility"*.

Practical implications: Organisational agendas for Industry 4.0 and social responsibility can be complementary. The framework provides insights into how Industry 4.0 technologies can help firms achieve long-term post-COVID-19 recovery, with an emphasis on SROP. This can offer firms competitive advantage in the "new normal" by helping them build back better.

Social implications: People and communities should be at the heart of decisions about rethinking operations and supply chains. This paper expresses a view on what it entails for organisations to be responsible for the supply chain-wide social wellbeing of employees and the wider community they operate in, and how they can use technology to embed social responsibility in their operations and supply chains.

Originality: Contributes to the limited understanding of how Industry 4.0 technologies can lead to socially responsible transformations. A novel framework integrating SROP and Industry 4.0 is presented.

Keywords: Operations management, Social responsibility, Industry 4.0, COVID-19, Sustainability, Digital

Paper Type: Viewpoint

1. Introduction

The resilience of global operations has been tested throughout the COVID-19 pandemic, which has forced many organisations into rapidly shutting down or scaling back their operations and caused one of the worst economic crises of modern times (Bai *et al.*, 2021; PwC, 2020; Sarkis, 2020a). While shutting down was relatively straightforward, the process of restarting extended, fragmented and global supply networks has been much more complex (KPMG, 2020; Trybula and Newberry, 2020). As companies think about what their post-COVID-19 global operations should look like, we argue it is critical that the social responsibilities that organisations have towards people are kept at the forefront of decision-making. More specifically, firms should consider both their internal employees and the safety, security, and livelihoods of people external to their organisation, such as at supplier sites and in the wider community. To add to the challenge, suppliers can be situated in distant developing countries with weaker institutional infrastructures and regulations (Huq and Stevenson, 2020; Quayson *et al.*, 2020). Therefore, it is posited that focal firms' capabilities to enhance their socially responsible operations performance (SROP) will be crucial (Huq *et al.*, 2016; Ravindran and Boh, 2020).

Technology can provide significant organisational capabilities for enabling secure and stable remote work (Almeida *et al.*, 2020; Ernst & Young, 2020), and Industry 4.0 technologies such as blockchain, Artificial Intelligence (AI) and Big Data Analytics (BDA) have the potential to drive post-COVID-19 recovery (McKinsey & Company, 2020a; Sarkis, 2020b). For example, blockchain has the capability to significantly enhance supply chain visibility by ensuring the provenance, immutability and chain of custody over products (Cole *et al.*, 2019; Kalla *et al.*, 2020), while BDA coupled with AI can support decision-making capabilities through the analysis of various forms of data in real-time (Khan, 2019; Sarkis, 2020b). Therefore, the advantages provided by Industry 4.0 technologies appear to be very much in line with the capabilities required to ensure socially responsible operations. However, a better understanding of how Industry 4.0 technologies can enable socially responsible transformations is required in order to support organisations in developing this path towards a competitive advantage (Deloitte University Press, 2016). Furthermore, organisations that are able to take advantage of this opportunity will be able to build back better from the pandemic, incorporating the often-neglected social aspect of sustainability (Zorzini *et al.*, 2015).

The central argument in this viewpoint paper is that the pandemic has provided an opportunity for organisations to re-assess their SROP and to build back better using technology to enable their social performance in the post-COVID-19 era. In this paper we present a framework showing how Industry 4.0 technologies can support SROP, including organisational social performance and community social performance. We contend that post-COVID-19 recovery presents an indispensable opportunity to embed socially responsible operations practices in core organisational strategies through technology implementation and business model innovation. The purpose of this paper is therefore to provide an overview of the possibilities for organisations to adopt Industry 4.0 technologies to improve their SROP, to present current best-practice examples, and to outline future research directions, including key research questions relevant to academic research and operations practice through three research agendas.

The paper makes three key contributions. First, it identifies relevant social performance indicators and develops the SROP-Industry 4.0 framework, drawing on academic peer-reviewed articles, grey literature and expert insights. Second, it unpacks the emergent SROP phenomena into two themes – organisational and community social performance – and associates current Industry 4.0 technology adoptions with six, more specific sub-themes. Third, it proposes corresponding avenues for future research based on the six sub-themes, framed through three overarching research agendas, i.e. *"Trust through Technology", "Responsible Relationships"* and *"Freedom through Flexibility"*. The remainder of the paper is structured as follows: *Section 2* contextualises the drivers of socially responsible operations; *Section 3* presents the framework and key illustrative examples from practice; and *Section 4* sets out our proposed future research directions.

2. Change Drivers for Socially Responsible Operations Performance (SROP)

Before discussing the possibilities for adopting Industry 4.0 for SROP in a post-COVID-19 era, the broad drivers for change and the disruptions caused by the pandemic must first be unpacked.

2.1 Global Focus on Sustainability Issues

In addition to growing calls for socially responsible practices, there has been a global focus on holistically developing more sustainable practices, prompted by prominent initiatives such as the United Nations' Sustainable Development Goals (SDGs). Formed in 2015, this initiative is a "call for action" to governments, businesses and individuals through 17 discrete goals and 169 targets to end poverty by 2030 (Hasle and Vang, 2021; Sarkis and Ibrahim, 2022). The initiative considers the environmental, social, and economic aspects of sustainability in an integrated manner to simultaneously improve living standards and protect the planet. Further, as the Inter-governmental Panel on Climate Change (IPCC) highlighted in their recent report, human-induced climate change is causing adverse, irreversible damage to the environment and society across the world, leading to increased scrutiny of organisations' sustainability practices (IPCC, 2022). The IPCC's working group stated that the near-term (until 2040) and mid- to long-term (2041-2100) risks will be multiple magnitudes higher than those currently observed if global warming exceeds 2ºC, resulting in ecosystem extinction and increased global food insecurity (IPCC, 2022). The need to address social inequality and tackle major environmental issues such as deforestation and climate change are therefore catalysts for driving sustainability related changes in industry, with organisations starting to publish annual sustainability reports and engage in compliance initiatives and agreements (Sarkis and Ibrahim, 2022). Governments have also started to exert pressure on organisations to genuinely operate more sustainably through local and regional initiatives such as the European Green Deal (EGD) (Brodny and Tutak, 2021; European Commission, 2019). One of the main objectives of the EGD is for Europe to achieve carbon neutrality by 2050 whilst also being an integral part of achieving the UN's SDGs (European Commission, 2019).

While these initiatives seem to be broad and encompass the wider society and environment, they have direct relevance to operations management. For example, specific SDGs such as SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure) and SDG 12 (Responsible Consumption and Production), and EGD policies such as accelerating the shift to sustainable and smart mobility, are directly related to sustainable operations and supply chain management (Sarkis and Ibrahim, 2022). Meanwhile, the Glasgow Climate Pact agreement made at the UN Climate Change Conference (COP26) highlighted that road transportation accounts for 10% of global greenhouse gas emissions (United Nations, 2021), suggesting that in addition to the EV100 Pledge, which commits to reaching 100% zero-emission transportation fleets by 2030 (United Nations, 2021), re-shoring production could be an effective strategy for reducing carbon emissions (McIvor and Bals, 2021). To this end, the signing of the Glasgow Climate Pact also shows that governments and industries are now taking sustainable development more seriously. With such prominent initiatives being developed, enforced and monitored, operations are now facing intense external pressure to be more sustainable and to create a positive impact. While these initiatives are focussed on holistic sustainability, the environmental dimension of sustainability seems to be more prominent globally, as demonstrated by the COP26 conference and EGD initiative. However, in recent times, SROP is also gaining traction with new legislation coming into place globally and an increasing focus on socially-oriented SDGs (e.g. SDG 8 - Decent Work and Economic Growth).

2.2 Higher Demand for SROP

SROP focusses on the management of social issues (e.g. working conditions, human rights, safety, etc.) within a firm's internal operations and those of its upstream supply chain partners (Hoejmose *et al.*, 2013; Touboulic and Walker, 2015; Zorzini *et al.*, 2015). Traditionally, SROP has been difficult to measure and track (Nikolakis *et al.*, 2018), and examples of scandals globally prove this point. The recent case of the fast fashion retailer Boohoo.com, where its suppliers sub-contracted work to 'sweatshops' in Leicester, UK (Stevenson, 2021), and the infamous Rana Plaza collapse in Bangladesh (Jacobs and Singhal, 2017) are examples of such scandals in the developed and developing world that have led to a renewed emphasis on social responsibility. This has contributed to stakeholders demanding more disclosure and transparency in supply chain processes (Hasle and Vang, 2021). Stakeholders such as non-governmental organisations that provide external oversight and pressure have the power to promote or boycott brands and play a key role in public opinion formation (Blindheim and Langhelle, 2010). For example, the International Labour Organisation (ILO) developed and enforced the Forced Labour Protocol in 2014 after lobbying to end modern slavery, forced labour and child labour (ILO, 2014). As a result of this legally-binding protocol, governments are required to take preventive actions against modern slavery, forced labour and child labour (Cole and Shirgholami, 2021; Gold *et al.*, 2015; ILO, 2014), thereby demonstrating the power of such external stakeholders. These stakeholders are demanding businesses and governments adopt socially responsible practices and improve disclosure, which has consequently led to local governments and organisations taking the SROP agenda more seriously (Cole and Shirgholami, 2021; Hasle and Vang, 2021). For example, the UK Modern Slavery Act 2015, Australia's Modern Slavery Act 2018 and Norway's

Transparency Act 2021 are local legislations that have already been implemented to tackle socially unethical practices (Walk Free Foundation and The Commonwealth Human Rights Initiative, 2018). Additionally, there are pending legislations yet to be implemented, such as the German Supply Chain Act (effective 1st January 2023) and the Dutch Child Labour Duty of Care Act (effective mid-2022) (Federal Ministry for Economic Cooperation and Development, 2022; Sedex, 2022) showing that national governments are increasingly involved in improving the governance of socially responsible practices through mandatory compliance. While these legislations demonstrate significant advancement of the social responsibility agenda, they still broadly focus on goods and services produced within a respective country or its sphere of influence. Although this may discourage certain practices, there is no legislation that can actually stop organisations from importing goods made using forced labour (Walk Free Foundation and The Commonwealth Human Rights Initiative, 2018).

2.3 Acceleration of Digitisation and Technology Adoption

Industry 4.0, also referred to as the Fourth Industrial Revolution, has been proposed as a possible solution to developing socially responsible business practices (Bienhaus and Haddud, 2018; Morrar *et al.*, 2017; Wellener *et al.*, 2019). Underpinned by a set of technologies that enable industrial value addition and that blur the physical and digital boundaries (André, 2019; Davidow and Malone, 2020), the notion of Industry 4.0 has its origins in Germany and was initially constructed to improve the manufacturing capabilities of German firms (Morrar *et al.*, 2017). Employing Industry 4.0 technologies has been shown to provide operational benefits, e.g. increasing productivity and competitiveness (Wellener *et al.*, 2019). Therefore, adopting the latest digital technology has become a business imperative for organisations globally in order to maintain or extend their competitive advantage (Upadhyay *et al.*, 2021; Verbeke and Hutzschenreuter, 2021).

An added benefit of adopting the latest digital technologies is that they have the capability to address social challenges in complex supply chains by improving transparency and traceability through technological characteristics such as proof of provenance, data immutability, the ability to track the chain of custody, and real-time data exchange (Cole *et al.*, 2019; Friedman and Ormiston, 2022; Nikolakis *et al.*, 2018). Various Industry 4.0 technologies have been piloted across industries, including in construction, oil and petrochemical refineries, and mineral sourcing (van der Brink *et al.*, 2019; Osterreich and Teuteberg, 2016; Yuan *et al.*, 2017); but there are very few integrated industrial adoptions of these technologies, especially from a social sustainability perspective (Cole *et al.*, 2019; Helmi *et al.*, 2021). Thus, there remains limited understanding of how to exploit these technological advances to improve SROP (Bai *et al.*, 2022; Beltrami *et al.*, 2021; Kamble *et al.*, 2018; Morrar *et al.*, 2017), including knowing which Industry 4.0 technologies should be adopted to improve specific aspects of SROP (Beltrami *et al.*, 2021; Cole *et al.*, 2019; Paul *et al.*, 2021). Therefore, the implications of Industry 4.0 for SROP need to be further investigated to better understand how Industry 4.0 technologies improve SROP and in order to prevent unintended social consequences from adoption.

2.4 Operations Disruptions due to COVID-19

The emergence of the COVID-19 pandemic has shown that social responsibility is as important as operational efficiency. Production was halted globally as local public health measures were enacted globally to reduce the spread of the virus, and these 'lockdowns' resulted in shortages of goods and services (Fearne *et al.*, 2021; van Hoek and Loseby, 2021; Schleper *et al.*, 2021). Supply chain risk is a widely researched concept (van Hoek and Dobrzykowski, 2021), with many well-established best practices evident in the literature, such as multiple sourcing (Manuj and Mentzer, 2008), maintaining flexible suppliers (Tang, 2006), inventory buffers (Vanpoucke and Ellis, 2020) and constant information exchange (Rao and Goldsby, 2009). Despite such best practices, the majority of modern manufacturing is globally dispersed, which has caused complex challenges for operations managers during the pandemic (Paul and Chowdhury, 2020). Yet, organisations have adapted to, and adopted measures in response to, the pandemic. Many of these measures have been dependent on technology adoption in one form or another, from simple video-calling solutions to more complex virtual reality scenarios (Ernst & Young, 2020), demonstrating that the "new normal" is likely to be very much reliant on technology. For example, within organisations, firms have implemented new practices such as technology-enabled "one-way" walk systems, contactless shift handovers, and working-from-home initiatives (Fahrni *et al.*, 2020). From a broader community perspective, initiatives such as the Ventilator Challenge (Fearne *et al.*, 2021; van Hoek and Loseby, 2021) and the 3D printing of face-masks (Huang *et al.*, 2021; Illinois MakerLab, 2020) helped firms contribute back to society.

Similarly, technology-enabled socially responsible practices may form part of the solution for dealing with disruptions and humanitarian logistics challenges during the ongoing conflict in Europe. In addition to unstable political relations, the conflict has also caused major global disruptions in everyday commodities including fuel, gas, sunflower oil and wheat, as the majority of these items are exported by the impacted countries (BBC, 2022). Learnings from the pandemic can be adapted to this latest scenario; for example, ramping up re-shoring capabilities using 3D printing and using AI and BDA to find alternative supply sources for essential goods whilst simultaneously ensuring ethical practices are followed (Oyedijo, 2022; Simchi-Levi and Haren, 2022). From a community SROP perspective, technologies such as BDA and blockchain can help in identity management for refugees and crowdsourcing funds to ensure basic quality of life and social welfare is not impacted. While these are conceptual ideas, it is evident that the opportunities provided by Industry 4.0 technologies from longer-term SROP are quite significant.

In summary, SROP has been an often-neglected aspect of sustainability but, as described through the above drivers, it has gained immense significance from the COVID-19 pandemic. Further, Industry 4.0 technologies have proven to be capable of improving SROP and economic sustainability (Bienhaus and Haddud, 2018), which we argue presents an opportunity for organisations to invest in technologies and embed SROP in their core strategy to manage new disruptions in the post-COVID-19 era. We discuss these possibilities in the following section where we develop our framework.

3. Conceptualisation of the SROP-Industry 4.0 Framework

To conceptualise the SROP-Industry 4.0 framework, we first identified and thematically analysed key academic articles in the social responsibility literature through a narrative literature review, as the aim was to explore extant literature in socially responsible operations and derive themes (Aguinis *et al.*, 2020; Snyder, 2019). In contrast to systematic reviews, which have very specific boundaries and inclusion/exclusion criteria, a narrative review offers greater latitude. The narrative review method provides greater potential for academic insight and permits opportunities to highlight the core thrust of the view being put forward (Snyder, 2019). The composition of articles considered different aspects of operations management, including sourcing, manufacturing and logistics, ensuring coverage of as many social performance indicators as possible. Through our thematic data analysis, we built the initial framework consisting of SROP themes, sub-themes and social indicators.

In terms of SROP, we have identified two overarching themes: (1) *organisational social responsibility (OSP)*; and (2) *community social responsibility (CSP)*, to reflect the internal and external social practices employed, respectively. This conceptualisation of social performance is in line with the extant literature, which states that social responsibility can be broadly classified into means of avoiding internal social failures and ways of improving community welfare (Huq *et al.*, 2016; Klassen and Vereecke, 2012; Yawar and Seuring, 2017). A key difference in our conceptualisation of social performance when compared to existing studies is that we consider the upstream supply chain to be within the organisational remit. This is because supply chains have now evolved into more collaborative functions and, more importantly, the focal firm holds responsibility for upstream practices, and therefore it falls within the scope of an organisation's business practices (Hartmann and Moeller, 2014; Kim *et al.*, 2018; Marshall *et al.*, 2019). To this end, we define OSP as the theme considering all social practices focused on an organisation's employees and supplier management practices (i.e. *employment practices, health and safety,* and *business practices*). *Employment practices* focuses on social indicators such as workplace diversity, human rights, job satisfaction and quality, child labour and flexible working (Bai and Sarkis, 2010; Huq *et al.*, 2016; Mani *et al.*, 2016; Marshall *et al.*, 2015). *Health and safety* (H&S) encompasses social indicators, including H&S practices implemented, the number of H&S incidents (Bai and Sarkis, 2010; Huq *et al.*, 2016; Mani *et al.*, 2016) and a newer type of H&S social indicator which emerged due to the pandemic, social safety practices. The latter includes traditional H&S practices for mitigating the spread of occupational diseases as well as novel practices for mitigating the spread of infections. Finally, *business practices* includes social indicators focused on relationships with suppliers through supplier development and management practices to ensure ethical procurement standards, fair margins and both anti-corruption and bribery. This sub-theme also includes supplier ethical issues such as fair wages for supplier employees (Chardine-Baumann and Botta-Genoulaz, 2014; Huq *et al.*, 2016; Mani *et al.*, 2016; Marshall *et al.*, 2015).

Meanwhile, CSP encompasses social practices external to the organisation but within its scope of impact that focus on community health and improvement (i.e. *quality of life and social welfare, social governance,* and *economic welfare and growth*). *Quality of life and social welfare* includes social indicators such as public H&S through general community welfare, training and the social impacts of products or services provided by the focal firm in that environment to mitigate against a negative organisational social footprint (Bai and Sarkis, 2010; Büyüközkan and Karabulut, 2017). *Social governance* covers social indicators such as stakeholder relations and corporate social responsibility practices to ensure that the community is supported in effective projects and has an influence on decisions made through empowerment (Bai and Sarkis, 2010; Li *et al.*, 2019; Mani *et al.*, 2016). Lastly, *economic welfare and growth* looks at social indicators such as job and wealth creation in the community through local sourcing and local talent hiring, including disabled workers, as well as societal investment in the form of access to essential services and general social acceptance (Chardine-Baumann and Botta-Genoulaz, 2014; Huq *et al.*, 2016).

Next, we performed a keyword search of *"social responsibility"* AND *"operations"* AND *"Industry 4.0"* and related synonyms on the Web of Science database within the time span of 1995 to 2022. This search generated 13 results, of which only 8 were academically peer-reviewed articles. Further, we could not identify any real use-cases in these articles, possibly due to the highly novel nature of this impactful topic. Therefore, we incorporated relevant grey literature to build the second part of the framework, on technologies and their links with SROP, and ensure relevance to both practitioners and academics (Adams *et al.*, 2017). To maximise relevance and legitimacy, the search criteria were company reports from "The Gartner Supply Chain Top 25 for 2021" and research reports from reputed strategy consulting firms such as McKinsey & Company, Deloitte, Ernst & Young, KPMG and PricewaterhouseCoopers that discuss current use cases of Industry 4.0 technologies, which we read with a critical eye. Through this extensive review, different applications of Industry 4.0 technologies for SROP emerged across industries such as manufacturing, healthcare, and public procurement. Based on this, we were able to associate predominant Industry 4.0 technologies with the SROP framework's themes to integrate practitioners' views into the academic framework (Adams *et al.*, 2017).

This analysis of literature identified BDA, Digital Twins (DT), Augmented Reality (AR), blockchain, 3D Printing (3DP), AI and the Internet of Things (IoT) as the most prominent Industry 4.0 technologies capable of aiding in the improvement of SROP. These seven technologies are briefly defined and their key characteristics identified in Table I. While other technologies, such as robotics and 5G were also identified, the seven technologies presented here have been shown to have more than a broad conceptualised link with social responsibility. More specifically, we were able to identify studies that discuss specific Industry 4.0 technologies in a post-COVID scenario; for example, Kalla *et al.* (2020) and Quayson *et al.* (2020) described how blockchain can help improve socially responsible operations post-COVID; Siriwardhana *et al.* (2020) discussed the potential benefits of using IoT in fighting against the pandemic and accelerating a return to normality; and Naghshineh *et al.* (2021) explored the social impacts of 3D printing. However, except for Quayson *et al.* (2020), who provided a few industry examples, the other studies were predominantly conceptual. In contrast, we provide real examples of industry use-cases where each technology has led to improvements in a specific social performance indicator, or at least where the technology has been trialled in a pilot project. The purpose here is not to provide an exhaustive list of technologies aiding socially responsible operations, but rather to highlight current adoptions and show pathways for future research. There is also the potential to use combinations of technologies, but this is not considered here for two reasons: (1) it would not be practically feasible to illustrate all the possible combinations of technologies; and, (2) the multi-technology examples that we identified were at a conceptual stage and therefore did not fit within the scope of this article.

Table I Description and Key Characteristics of Technologies Identified

Technology	Brief Definition	Key Characteristics	Sources
Big Data Analytics (BDA)	Technologies, techniques, practices, systems, methods and applications that can analyse large volumes and varieties of business-critical data to support organisations in understanding the market better and in making timely and effective decisions.	• Volume: large amount of data generated and collected. • Velocity: the rapid pace at which data is generated, flows within a supply chain, and made available for analysis. • Veracity: identifying uncertainty, noise and anomalies present in data. • Variety: collects data from multiple sources of structured and unstructured data. • Value: the generation of insights that will benefit supply chains.	(Khan, 2019; Popovič *et al.*, 2018)
Digital Twins (DT)	Seamless connectivity between digital and physical worlds through a digital representation to enable guided interactions, cognitive services and artificial intelligence.	• Simulation: digital simulation of real-world changes in virtual space. • Human-Machine Collaboration: real-time connectivity through intelligent services to simulate models such as predictive maintenance, product development and emergency situations.	(Srai and Lorentz, 2019; Wang *et al.*, 2019)
Augmented Reality (AR)	Technology that allows users to interact with a physical environment through an overlay of digital information, enhancing connections between users and smart environments, where users can interact with resources in real-time.	• Wearable Devices: devices such as smart glasses that capture and interact with the surrounding environment in real-time and that overlay information, providing users with more information in 3D than they can physically see for themselves. • Intelligent: devices that are context-aware, responsive and provide a continuous AR experience.	(Grubert *et al.*, 2017; Wang *et al.*, 2020)
Blockchain	Electronically distributed ledger system recording data regarding transactions and other information governed by consensus of participants.	• Distributed Ledger: facilitates information sharing across multiple stakeholders. • Immutability: transactions entered into the blockchain and agreed upon cannot be altered, which provides proof of provenance. • Smart Contracts: when pre-specified conditions are met, the system verifies and enforces negotiated terms of the contract, removing the need for an intermediary.	(Cole *et al.*, 2019; Nikolakis *et al.*, 2018)
3D Printing (3DP)	A form of additive, rather than subtractive, manufacturing where material is consecutively added in order to "print" a physical model based on a digital model developed using 3D modelling software.	• Distributed: digital models can be electronically shared and physically printed in a different physical location. • Co-creation Community: users can share, update and revise designs based on intellectual property rights to co-create products. • Low Investment: lower capital required in comparison to setting up a modern factory, and the ramp-up speed is considerably faster.	(Hannibal and Knight, 2018; Rayna and Striukova, 2014)
Artificial Intelligence (AI)	Technology comprising machines, systems, algorithms and programs that seek to understand and imitate human intelligence to create knowledge and solve problems.	• Data sharing and exchange: facilitates transparency information exchange for better data management, integration and weak link identification among stakeholders and within businesses. • Self-Learning: can learn from datasets, human intelligence and other information to generate insights without human interference to continuously improve and reduce error in predictions and insights.	(Dora *et al.*, 2021; Modgil *et al.*, 2021)
Internet of Things (IoT)	Devices enabling the connection of humans, machines, products and equipment for real-time data collection through networks.	• Continuous data collection: devices, such as sensors, log and collect data continuously in real-time to generate insights for multiple scenarios such as machine failure and temperature control. • Interconnected: allows data exchange between multiple entities including machines, humans and products to enable continuous monitoring whilst providing autonomy.	(Bienhaus and Haddud, 2018; Strandhagen *et al.*, 2017)

--*Insert Table I here*--

The above process was supplemented by insights gained from six industry experts from organisations operating in a variety of sectors, including Fast Moving Consumer Goods (FMCG), Information Technology (IT) and electronics. The organisations have turnovers ranging from £50 million to £50 billion, including two Fortune-500 companies. The experts included, among others, the Social and Human Rights Manager of a global FMCG organisation, the Social and Environmental Responsibility Manager of a global IT manufacturer, the Global Sourcing Manager of a 3D printing technology service provider (TSP), and the Director of Strategy and Foresight for a global TSP providing multiple technology solutions. The experts' inputs, which were derived from semi-structured elite interviews based on Solarino and Aguinis (2020), further solidified our views and provided insight into the usefulness of the framework from an industry perspective.

The first phase of developing our framework involved looking within OSP and CSP, and this identified six sub-themes of SROP. Each sub-theme has its own social indicators and, through analysis of the use-cases, has been linked to Industry 4.0 technologies that dominate in terms of applications for achieving SROP. In the second phase, we looked for cross-cutting agendas that were independent of any specific sub-theme or of OSP and CSP. Here, we suggest three future research agendas from our viewpoint, linked directly with technology adoptions and SROP (Table II). The three agendas allow for the sub-themes to be viewed at a granular level of detail while also relating the overarching themes of OSP and CSP to technology. These agendas will be returned to in Section 4 as the basis for our final proposed research directions.

Table II Future Research Agendas Linking SROP and Technology

Research Agenda	Definition	Link to Technology	Link to SROP
"Trust through Technology"	Technology-enabled trust through transparency and awareness.	Technology integrates upstream SC and for transparency.	Ensure ethical practices which improves trust in technology, leading to trust through technology.
"Responsible Relationships"	Stakeholder management to ensure fair value chains and inclusion of stakeholders.	Technology used to ensure inclusion of internal (OSP) and external (CSP) stakeholders. Wider range of data sources can be used.	Reduced bias, collective voice, decision influence potential and inclusion of SMEs/ marginalised suppliers; organisations are more responsible and consider all stakeholders.
"Freedom through Flexibility"	The socio-economic link; improved flexibility in managing disruptions through technology while keeping SROP at the core of operations strategy.	Technology provides operational flexibility and efficiency in disruption scenarios to minimise risk and ensure continued operations.	As SROP is embedded in operations strategy, social responsibility does not have to be addressed separately in disruptions as economic benefits are now built around these practices.

--*Insert Table II here*--

The final framework (Figure 1) aids managers in two ways: (1) in understanding which technologies can help to improve SROP prior to technology adoption; and (2) in understanding which social performance indicators can be targeted for improvement if a specific technology has already been implemented for an operational efficiency purpose. Tables III and IV support the framework by providing specific examples of how Industry 4.0 technologies have improved various social indicators under each of the sub-themes. Further, in the following sub-sections we offer a detailed discussion of at least one selected industry example of how Industry 4.0 technology has enabled social performance for each of the six sub-themes.

--*Insert Figure 1 here*--

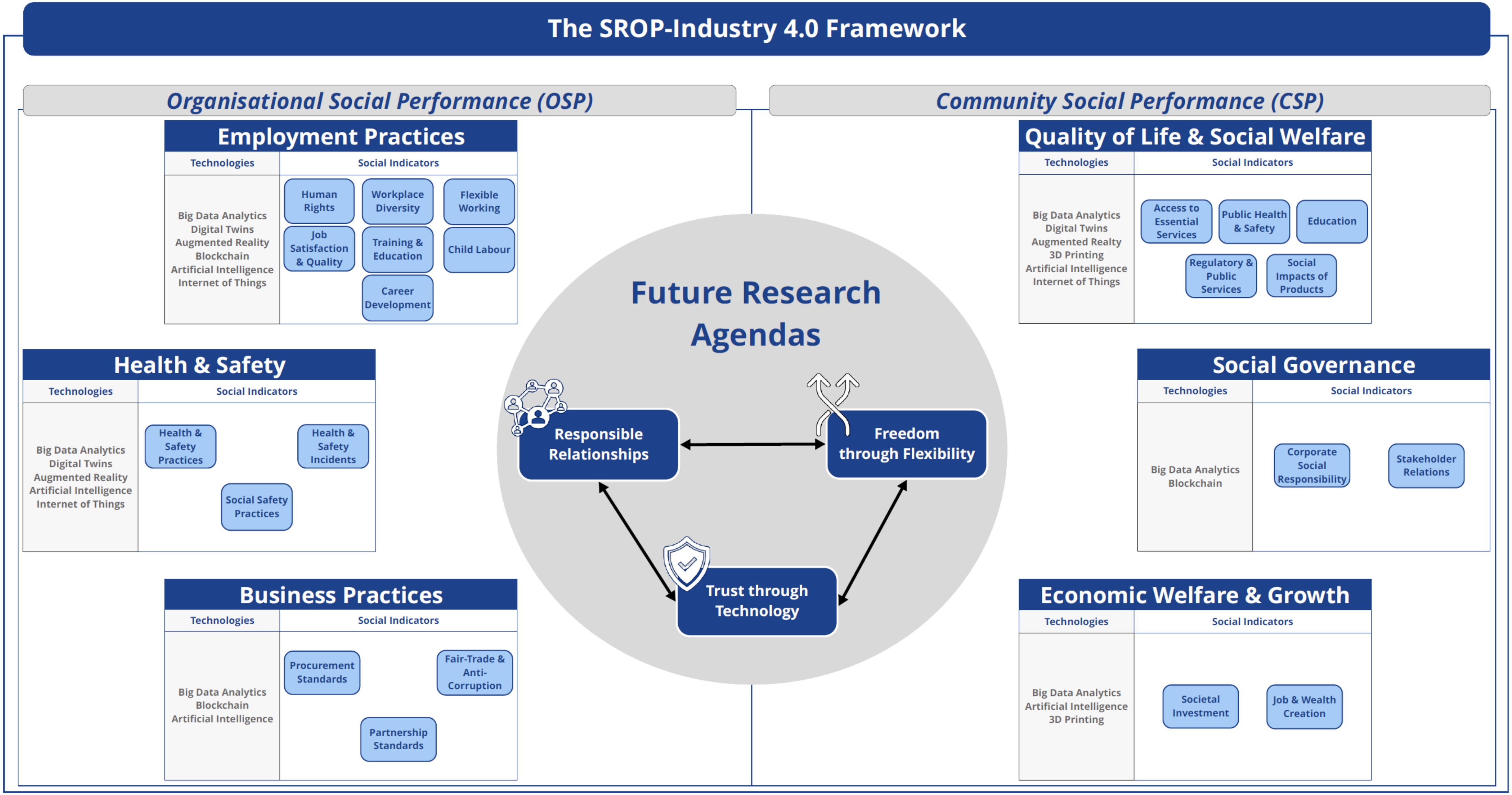

Figure 1 The SROP-Industry 4.0 Framework

Table III Illustrative Examples of how Industry 4.0 Technologies can Improve Organisational Social Performance (OSP)

Sub-Theme	Social Indicator	Technology	Illustrative examples of how Industry 4.0 technologies can improve Organisational Social Performance	Source
Employment Practices	Human Rights	Big Data Analytics	Employing BDA can create actionable insights for governments and policymakers where vulnerable groups are targeted. Modern slavery, forced labour and wage disparities within organisations can also be identified.	(de Assis, 2018)
		Blockchain	Automotive companies including the Volkswagen Group and Ford have formed a consortium with LG Chem, Huayou Cobalt and RCS Global to track and trace raw material supply on a blockchain platform developed by IBM in an attempt to identify and reduce human rights violations, such as forced labour across plants in DR Congo, Korea and the United States. The Organization for Economic Cooperation and Development (OECD) provides platform governance to ensure that raw materials are sourced and processed ethically, thus helping to meet compliance requirements through immutable audit trails.	(IBM, 2019a)
	Workplace Diversity	Big Data Analytics	Existing diversity gaps can be identified using data analytics through the ability to gain a holistic understanding of the current workforce in terms of gender, age, ethnicity, etc. BDA can be used to analyse and create equitable compensation structures, thereby closing the gender pay gap. Also, by highlighting key metrics, BDA can help to improve diversity retention.	(McKinsey & Company, 2017)
		Artificial Intelligence	Daivergent, an organisation dedicated to the autistic and neurodiverse community, trains and manages a candidate pool of diverse talent. The Daivergent platform, in collaboration with an SAP module, uses AI to match neurodiverse candidates to vacancies, thereby helping client companies to hire and manage a diverse workforce.	(SAP, 2020)
	Job Satisfaction & Quality	Digital Twins	Through digital twins, production and warehouse facilities can be mapped interactively, thereby determining the shortest paths required for on-floor breakdowns, maintenance and logistics processes. This leads to more effective time utilisation where employees perform value-adding tasks.	(Mussomeli *et al.*, 2020)
		Augmented Reality	Using AR in training for job specific situations, the US Department of Agriculture's Food Safety and Inspection Service has been able to improve retention rates of inspectors prior to graduating from training into the actual role. Using this technology, the organisation claims they are able to provide better training and placement leading to improved job satisfaction for inspectors.	(Deloitte, 2018)
		Artificial Intelligence	In their 2020 Sustainability Report, the Volkswagen Group have committed to digitisation as a key enabler, with the use of AI helping in different business areas. They state that, in an effort to improve cognitive ergonomics, the Group will increase the use of AI to remove repetitive administrative tasks so that employees can spend more time on preparing for final decisions, which will improve job quality.	(Volkswagen, 2021a)
	Training & Education	Augmented Reality	AR can provide step-by-step visual training for employees, thereby reducing errors and training times. This improves the quality of training while reducing costs attributed to a lack of in-house skills and errors in the learning curve. The approach is particularly useful for new hires and seasonal employees, where short training times are critical.	(Porter and Heppelmann, 2017)
		Artificial Intelligence	Indonesian mining organisation, Petrosea, has embraced digital transformation for survival and adopted AI based technologies in one site to help source raw materials such as copper, nickel and lithium faster and more efficiently. To address the re-training needs of a low-literacy workforce, the organisation used an AI based gamification app to engage and train employees, which enabled the creation of a digital mind-set and improved profits.	(McKinsey & Company, 2020b)
	Flexible Working	Augmented Reality	Off-site assistance can be provided to on-site technical engineers through AR devices, such as smart glasses and cameras. With online meetings having become the norm relevant, stakeholders can use AR technology to provide real-time updates while working from home.	(Deloitte, 2017)
		Internet of Things	IoT devices combined with Manufacturing-Execution Systems have been adopted by a US tier-one firm surveyed by consulting firm McKinsey & Co. to gather real-time data on the shop floor processes and production. The consulting firm further states that even though most managers are not physically present on the shop floor, the real-time data enables relevant and informed discussions during videoconferences.	(McKinsey & Company, 2020b)
	Career Development	Big Data Analytics	Employees' performance management over the years can be tracked more effectively via the use of more detailed, complex data sources such as metrics including time to close an open job. BDA can also aid in finding vacant positions that would be best matched for enabling job rotations and upskilling as part of employee development based on employees' training records and performances.	(Peakon, 2019)
	Child Labour	Blockchain	Tony's Chocolonely, an Amsterdam based chocolate manufacturer, has collaborated with Chainpoint and Accenture to build "BeanTracker" – a blockchain platform to trace cocoa in their chocolate supply chain. The platform collects and verifies data from sources in Ghana and Cote d'Ivoire until the chocolate bar has been produced and wrapped in Europe. Through this project, the organisation states that they are moving towards their vision of 100% slave free chocolate by establishing upstream traceability and mitigating instances of child and forced labour by identifying all stakeholders involved.	(Forbes, 2019)

Health & Safety	Health and Safety Practices	Big Data Analytics	Past incidents can help provide valuable information on potential accident hotspots. These can then be monitored or modified if possible and BDA can be used for predictive purposes, i.e. the possibility of accidents occurring and their impact based on likelihood and severity matrices.	(IBM, 2019b)
	Health and Safety Incidents	Digital Twins	Corrective actions can be taken prior to accidents occurring, through real-time simulations. This has the potential to reduce incidents and improve practices by identifying hotspots, root causes and troubleshooting.	(SAP, 2019)
		Artificial Intelligence	Lloyd's Register has used AI innovatively to perform deep analyses of health and safety data for a professional consulting firm offering services in marine, energy and manufacturing industries. By identifying, segregating and analysing complex datasets, the organisation has been able to generate insights on 78,000 incidents which were previously not categorised, thereby improving health and safety incident data and providing management with better root case analyses and actions.	(Lloyd's Register, 2019)
		Internet of Things	IBM, in collaboration with Mitsufuji, developed innovative solutions through their Maximo® Worker Insights which uses IoT devices to constantly measure and analyse employee heart rate, location and related health data to prevent health and safety incidents before they occur. The data collected from the wearable workwear fabric is shared with an employee on their smartphone in case of dangerous situations (e.g. heat stress) to increase awareness of their surroundings.	(IBM, 2019b)
	Social Safety Practices	Big Data Analytics	BDA is useful for collecting, analysing, tracking and forecasting the spread and impact of infectious diseases. BDA can be a source of contact tracing, producing a detailed medical history based on travel and contacts, leading to the reduction of hotspot formation. Hotspots can be predicted and early warnings can be issued to implement the required measures.	(Wu *et al.*, 2020)
		Augmented Reality	The use of AR in combination with engineering principles has helped the NHS during the COVID-19 pandemic where experts remotely provided instructions, inspected processes and supported in the manufacture of ventilators. Due to the widespread impact of the virus, these experts could not physically be present on the shop floor; however, they were able to guide the production process remotely, which created and distributed knowledge more efficiently than previously when they relied on paper documentation.	(Institution of Mechanical Engineers, 2021)
		Internet of Things	Libelium, an IoT solutions provider, worked with Equimodal, an organisation specialising in secure access gateways, to implement the Libelium FeverKit which measures employees' temperatures through IoT devices in real-time as they enter and sanitise themselves. This data is then shared with on-site managers to create awareness in case high temperatures are detected, indicating COVID-19 symptoms. Libelium further state that the solution is applicable in multiple other scenarios such as turnstiles and walkways.	(Libelium, 2020)
Business Practices	Procurement Standards	Blockchain	Blockchain makes it mandatory for each supply chain actor to input transaction details (such as cost, origin, lead time, etc.) throughout the supply chain, from origin to consumer outlets. This enables end-to-end transparency and traceability for safety critical products, mitigating product tampering and counterfeits. It also helps organisations in audits and in checking Code of Conduct conformance for future performance evaluations.	(MediLedger, 2020)
		Big Data Analytics	SAP deployed their analytics tools to support Air Canada's operations in approximately 220 airports spanning six continents in an effort to streamline procurement spend. In addition to reducing costs and improving agility and automation, Air Canada was able to gain improved visibility of their procurement processes and control spend effectively. This ultimately led to a better experience for suppliers as well, in addition to enhancing procurement compliance.	(SAP, 2021)
	Partnership Standards	Big Data Analytics	SAP's spend analysis software works in collaboration with Dun and Bradstreet's market intelligence to support customers in obtaining as much insights as possible before contracting a vendor. This information consists of numerous sources such as supplier credit reports and social media news, updated and analysed in near real-time using machine learning algorithms to offer client customers' valuable insights, such as sustainability indicators on prospective and current suppliers.	(SAP, 2022)
		Artificial Intelligence	Volkswagen, Porsche and Audi have partnered with AI organisation Prewave to analyse supplier related news from public and social media source in more than 50 languages and 150 countries in an effort to proactively identify supplier breaches of sustainability requirements set out by the manufacturers. The AI algorithm monitors over 4,000 suppliers to transparently provide data, which could be helpful in targeting sustainability risks early on before they occur, thereby reducing risk occurrences and improving compliance.	(Volkswagen, 2021b)
	Fair-Trade and Anti-Corruption	Blockchain	FairChain Foundation is working with coffee farmers in Ethiopia to bring about transparency in the coffee supply chain though blockchain. In addition to digitising the supply chain and providing proof of provenance through an immutable audit trail, the organisation is aiming to transparently drive value back to the farmer and provide access to credit which will ultimately aid in improving living standards. Through transparency and traceability, the entire value chain is visible to all stakeholders, ensuring profits are distributed equally.	(FairChain Foundation, 2019)

--*Insert Table III here*--

Table IV Illustrative Examples of how Industry 4.0 Technologies can Improve Community Social Performance (CSP)

Sub-Theme	Social Indicator	Technology	Illustrative examples of how Industry 4.0 technologies can improve Community Social Performance	Source
Quality of Life and Social Welfare	Public Health and Safety	3D Printing	Safety critical items with long lead times can be designed and printed in-house. 3D printers have the capability of printing a range of items, from personal protective equipment to ventilator parts, thereby ensuring availability. Ramp-up times are also considerably lower in comparison to full-scale factory set-ups.	(Huang *et al.*, 2021)
		Internet of Things	Southern California Edison, an energy provider in California, has deployed drones equipped with IoT devices to inspect electrical infrastructure in buildings and infrastructure such as towers and transformers. They claim that they are able to improve the speed and quality of inspection in addition to being able to safely inspect hazardous areas such as wild-fire risk zones without the need for human intervention. The organisation is also considering using AI to aid in the analysis of footage to improve turnaround times for issue identification which will improve public safety.	(Deloitte Insights, 2021)
	Education	Digital Twins	By promoting initiatives such as intern and volunteer programs, organisations can use digital twins to educate potential employees on job prospects and career paths. This helps generate interest in supply chain jobs as well as improve the quality of human resource management for the supply chain function, where creative abilities and technical skills are becoming increasingly relevant.	(Scavarda *et al.*, 2019)
	Access to Essential Services	Big Data Analytics	Healthcare facilities can collect and store data based on connected devices and websites, which can be used with BDA and AI to derive actionable insights. Through interactive dashboards that process real-time information, proactive actions can be taken to ensure sufficient access to essential services such as medical supplies, hospital beds and ventilators.	(Gould *et al.*, 2020)
		Internet of Things	As COVID-19 vaccine production increased, logistics had to be scaled up to deliver these globally. The requirement of having to store vaccines at extremely low temperatures increased logistics complexity, in addition to the requirement that the vaccines had to be tamper-proof and tracked. The Hope Consortium, consisting of partners such as Etihad Cargo, SkyCell and Abu Dhabi Ports, ramped up distribution services and ensured digital tracking of shipments. SkyCell provided temperature-controlled containers using IoT devices which monitored temperature in real-time and shipments were tracked using blockchain to reduce counterfeits.	(SkyCell, 2020)
	Regulatory and Public services	Big Data Analytics	Public services, such as transport links, can be analysed using BDA sources to identify which areas need more investment. This will better enable authorities to track peak hours and manage traffic and social safety measures.	(Munné, 2016)
		Augmented Reality	Technology company Crafted Design developed the QueueSight™ device which could be used in any venue where a queue forms, such as airports and retail stores. The device uses AR to help maintain social distancing measures by projecting the distance between people. A sensor tracks this distance and the boundaries change colours to alert proximity. Brands can also advertise regulatory messaging on these projections, which can aid in providing essential information to customers.	(QueueSight, 2022)
	Social Impacts of Products	Artificial Intelligence	Integrating AI into Quality Assurance systems reduces the need for manual quality testing and improves the accuracy of defects testing and rejecting. This is of major importance in pharmaceuticals and related safety critical products and high-value manufacturing supply chains, such as aerospace, where the defect tolerance is very low.	(Smartia Ltd, 2018)
Social Governance	Corporate Social Responsibility	Big Data Analytics	SAP worked with Insurance Australia Group (IAG) to track, analyse and control significant tail spends which were previously untracked due to the use of corporate credit cards. By identifying these spends using BDA, IAG was able to then develop a marketplace with SAP where Aboriginal, women-owned businesses and social enterprises were included to direct the tail spend into community growth. Through this BDA solution, IAG reduced tail spend and invested back into the communities it operated in, while including diverse suppliers in the process.	(SAP, 2020)
	Stakeholder Relations	Blockchain	Through provenance and immutability, Blockchain enables end-to-end transparency and traceability amongst all partners. As the network is decentralised, this is an unbiased "single source of truth" that can be used to benchmark public partnerships through audit trails and to improve strategic stakeholder relationships.	(World Economic Forum, 2020a)
Economic Welfare & Growth	Job and Wealth Creation	3D Printing	3DP can make parts or products with fewer machines thereby reducing high labour cost issues. Manufacturing can be "reshored" leading to reduced transportation costs. As the supply chain remains local or regional, this leads to increasing local employment opportunities. The time from design to market is further reduced, which is an important advantage in safety critical items and in rapidly changing markets more generally.	(KPMG Canada, 2019)
	Societal Investment	Big Data Analytics	Ghost Data and LogoGrab used AI and BDA to measure COVID-19 lockdown violations in Italy using Instagram data. They captured images of public spaces, anonymised location and personal data, and performed analysis to identify statistics such as the cities with the highest number of violations and the locations where violations occurred (e.g. parks). This data can be useful for enforcement authorities to identify violations and ensure preventive mechanisms are in place.	(Migration Data Portal, 2021)
		Artificial Intelligence	Organisations investing in healthcare in local communities can use AI to provide cheaper testing and detailed health risk assessments. This improves community welfare, especially in rural areas in developing countries where the risk of infections is high and access to healthcare is generally low.	(Chaudhuri *et al.*, 2021)

3.1 Organisational Social Performance and Enabling Industry 4.0 Technologies

3.1.1 Sub-Theme 1: Employment Practices

Selected Example: Human Rights

The UN report, "COVID-19 and Human Rights: We are all in this together", stated that the recent rise in unemployment has led to an increase in human rights violations such as domestic abuse and discrimination amongst vulnerable employees (United Nations, 2020; World Economic Forum, 2020b). Alliance 8.7, a global partnership working with partners such as ILO, Walk Free and the International Organisation for Migration (IOM) is working to achieve target 8.7 (reduction of forced labour, child labour, human trafficking and modern-day slavery) in SDG 8 (Decent Work and Economic Growth) in countries where modern slavery, forced labour and child labour are prevalent. The partnership's knowledge platform, Delta 8.7, combines and analyses large datasets of qualitative and quantitative data using language processing algorithms to derive country-specific insights and identify trends in unethical practices (Delta 8.7, 2018). Using such large datasets and targeted insights, local governments have been able to identify and intervene through policy reforms to protect vulnerable groups, thereby reducing incidents of modern slavery and forced labour in organisations (Delta 8.7, 2022; SmartLab, 2022). In addition to using BDA to provide real-time visualisations and dashboards consisting of social Key Performance Indicators (KPIs) that disseminate knowledge on these trends, the platform collates evidence of how technology is being used to tackle *'Human Rights'* issues. For example, the platform showcases best practices adopted, such as using blockchain to identify hidden labour abuses in the agricultural sector in Thailand, and using BDA to track and reduce modern-day slavery in the textile industry in Brazil (Melnyk and Alemany, 2021; SmartLab, 2022).

3.1.2 Sub-Theme 2: Health & Safety

Selected Example: Health & Safety Practices

To enhance knowledge and best practice sharing to improve *'Health and Safety Practices'*, Arizona State University has partnered with the World Economic Forum and many organisations, including IBM, the Rockefeller Foundation and Thermo Fisher Scientific, to collaborate on a "COVID-19 Workplace Commons: Keeping Workers Well Initiative" platform (Arizona State University, 2020a; World Economic Forum, 2020c). This BDA platform collects information from numerous organisations to provide information on workplace safety in light of the pandemic through an interactive dashboard (Arizona State University, 2020a, 2020b). With over 250 case studies across cultures, geographies and industries already in the database, this initiative enables organisations to implement effective strategies and frameworks to resume operations safely (World Economic Forum, 2020c).

3.1.1 Sub-Theme 3: Business Practices

Selected Example: Procurement Standards

Counterfeit products are high risk, especially in safety-critical supply chains such as pharmaceuticals (Marucheck *et al.*, 2011) . The pandemic has seen an increasing trend in counterfeit testing kits, medicines and various medical supplies (European Anti-Fraud Office, 2020; World Economic Forum, 2020d). An enquiry conducted by the European Anti-Fraud Office identified 340 companies trading in COVID-related counterfeits (World Economic Forum, 2020d). These medical supplies are not only ineffective, they are in some cases also extremely dangerous, posing a health risk.

Traceability and transparency have been identified as key factors for eliminating this issue, and experts state that organisations using blockchain are effective in combating counterfeits (McCauley, 2020; World Economic Forum, 2020d). MediLedger is an industry example of such an initiative. MediLedger provides a platform that enables healthcare and pharmaceutical trading partners to collaborate and innovate through blockchain ecosystems that track and trace trading partners' products in real-time (McCauley, 2020; MediLedger, 2020). Through a network of 25 participants, including logistics providers such as FedEx, wholesalers such as Cardinal Health and AmerisourceBergen, retailers such as Walmart and Walgreens, and standards organisations such as GS1, MediLedger conducted a pilot blockchain track and trace initiative (McCauley, 2020; MediLedger, 2020). The entire value chain is now visible to all stakeholders, which ensures provenance and chain of custody, confirming the authenticity of medical products and ensuring compliance with the Drug Supply Chain Security Act (MediLedger, 2020), thereby improving *'Procurement Standards'*.

Selected Example: Partnership Standards

'Partnerships Standards' has been improved during the pandemic by organisations using AI to scout for alternative or secondary suppliers in the event of lockdowns or other disruptions to their existing supply base (Choi *et al.*, 2020; scoutbee, 2020a). For example, scoutbee, a supplier discovery platform founded in 2015, uses an AI-driven platform to connect suppliers with customers and reduce the time involved in strategic sourcing (scoutbee, 2020a). By using this technology, suppliers and customers are globally connected; transparent negotiations are enabled; and supplier and customer sustainability strategies can be matched by analysing vast amounts of data, such as on certifications and awards received, thereby providing detailed supplier insights that drive ethical sourcing decisions (scoutbee, 2020b). The organisation, serving global customers such as Audi, Airbus, and Bosch, made this platform free-of-charge during the pandemic to help customers source essential products and services, such as hazardous material suits and medical supplies. The initiative has been generalised on the platform into "Emergency Sourcing" so that it is ready to respond to future supply chain crises (scoutbee, 2021).

3.2 Community Social Performance and Enabling Industry 4.0 Technologies

3.2.1 Sub-Theme 4: Quality of Life and Social Welfare

Selected Example: Public Health & Safety

One prominent example that has been relevant in the pandemic is the "VentilatorChallengeUK", a consortium of global manufacturers, including Airbus, McLaren, and Rolls Royce, that have teamed up to rapidly produce ventilators for the UK's National Health Service (NHS) (Fearne *et al.*, 2021; VentilatorChallengeUK, 2020). Although core engineering principles were also used in this challenge, AR and 3DP technologies sped up the process, enabling firms to learn assembly steps from original equipment manufacturers and to print custom parts, respectively (Institution of Mechanical Engineers, 2020). The consortium was able to produce 14,000 new machines in just 12 weeks (VentilatorChallengeUK, 2020). Other examples of various manufacturing industries using 3DP to produce ventilators and components are present globally, including Ford partnering with 3M and General Electric Healthcare in North America (Ford Motor Company, 2020) and, in Europe, the Italian start-up Isinnova (Hahn, 2020; Tony Blair Institute for Global Change, 2020). These initiatives demonstrate the potential of using Industry 4.0 technologies to improve *'Public Health and Safety'*.

Selected Example: Access to Essential Services

The UK's NHS is one of many healthcare providers that has faced the unprecedented challenge of responding to COVID-19. To gain a better understanding of its real-time requirements for critical equipment, such as ventilators and beds, the NHS partnered with Microsoft, Palantir Technologies UK, Amazon Web Services, Faculty AI and Google to implement a central platform for data collection and analysis (Gould *et al.*, 2020). In addition to helping epidemiologists understand how the virus is spreading, from a supply chain perspective it allows the NHS to proactively improve the distribution efficiency of critical equipment to high-risk areas. The NHS is using this BDA platform in combination with AI to derive real-time, reliable insights, which are presented on a live dashboard to improve *'Access to Essential Services'*.

3.2.2 Sub-Theme 5: Social Governance

Selected Example: Stakeholder Relations

Corruption in public procurement is a global problem that has been escalated during the pandemic. For example, the Guardian UK states that one in five government contracts for PPE kits awarded between February and November 2020 show systemic bias and red flags for corruption (The Guardian, 2021). In an attempt to eradicate corruption and bribery from public procurement, the World Economic Forum has conducted a study towards implementing blockchain-based public procurement in corruption-rife countries, such as Colombia and Brazil through their *'Transparency Project'* (World Economic Forum, 2020a). The study found that widespread corruption leads to a deterioration in public services and a downturn in economic development. The proposed mechanism was to reform policies while investing in a "hybrid" blockchain solution that combines permissioned and permission-less networks involving both supply and customer bases, and was based on existing blockchain based e-procurement systems in the United States, South Korea and Spain (World Economic Forum, 2020a). The pilot adoption project report shared key learnings around challenges including political, legislation and social impacts on adoption but concluded that this system allowed any stakeholder to flag irregularities or suspicious activity, leading to greater accountability and transparency while improving stakeholder engagement (World Economic Forum, 2020a). As all relevant actors are included and engaged in the network, this unbiased, decentralised platform provides an audit trail for benchmarking partnerships through transparency and immutability, thereby improving *'Stakeholder Relations'*.

3.2.3 Sub-Theme 6: Economic Welfare & Growth

Selected Example: Job & Wealth Creation

Automotive companies such as BMW and Honda are moving to 3DP for industrial tools and spare parts in their own factories and dealerships, thereby shortening their supply chains and reducing both their time-to-market and logistics costs (D'Aveni, 2015). While this leads to operational efficiencies, the need for local talent also increases, which creates new domestic jobs. Similarly, General Electric Aviation is producing jet engine parts in-house in its Ohio facility using 3D printers (General Electric, 2018a). This has led to the creation of a new business unit, generating more job opportunities in the region (General Electric, 2018b). Both initiatives are examples of 3DP being used to address *'Job and Wealth Creation'*, which enables organisations to "reshore" operations. This not only reduces transportation costs and time-to-market for new products (Attaran, 2017; Braziotis *et al.*, 2019; D'Aveni, 2015), it also creates highly skilled jobs within the communities where the organisations operate (KPMG Canada, 2019). Further, this is advantageous in a global pandemic as operations are more localised and can continue to function with minimal disruption.

While the typology of OSP and CSP sub-themes and the enabling Industry 4.0 technologies may not be exhaustive, they demonstrate the immense opportunities available to impact business practices and society, in addition to the rich research avenues available to academics, as outlined next.

4. Discussion and Future Research Agenda

This viewpoint paper argues that as firms rethink their operations in the light of the pandemic, there is an important opportunity to make them more socially responsible; and that Industry 4.0 technologies have a key role to play in achieving this vision. Further, it is argued that digitalisation and social responsibility agendas can be complementary. We presented the SROP-Industry 4.0 framework in Figure 1 as a way to explore the use of Industry 4.0 technologies for enabling SROP improvements. The framework provides insights into how Industry 4.0 technologies can help firms with their long-term, post-COVID-19 sustainable recovery. In particular, by building on extant research and current practices, we have shown how seven Industry 4.0 technologies can enhance organisational and community social performance by improving employment practices, health and safety, business practices, quality of life and social welfare, social governance and economic welfare and growth. This will aid operations managers in better understanding what is entailed in being responsible for the supply chain-wide social wellbeing of employees and the wider community they operate in, and how they can use technology to embed social responsibility in their operations. We next suggest future research questions, providing at least one question for each of the six sub-themes across the three research agendas included in the framework.

Employment Practices

While working from home was an option previously trialled by some organisations, this trend has increased exponentially across most industries during the pandemic. In some cases, this appears to be an irreversible trend that has changed the nature of work. Therefore, organisations need to explore innovative methods of enabling flexible working without hindering, for example, employees' career development or job satisfaction (as well as considerations around team cohesion, organisational culture, etc.). The capabilities of Industry 4.0 to support this sub-theme can be viewed through future research questions such as:

Trust Through Technology (3T): "What opportunities does Industry 4.0 offer to reduce bias in employee evaluations through verified real-time data? Further, how can these technologies ensure confidentiality and fair inclusion and diversity in organisations?"

Responsible Relationships (RR): "How can Industry 4.0 technologies aid in developing and monitoring sustainable employment practices to reduce unethical practices, ensure job satisfaction and increase productivity?"

Freedom through Flexibility (FtF): "What operations risk management capabilities do organisations gain by adopting technology for SROP in comparison to non-digitalised organisations?"

Health and Safety

Although health and safety standards exist in organisations, COVID-19 has emerged as a completely new health and safety risk consideration. The role of Industry 4.0 technologies for infectious disease prediction, contact tracing and socially-distanced safety practices, such as contactless shift handovers, presents an area of research opportunity. The role of data ethics, including data ownership, sharing and integrity for organisational health is another gap. This leads to the following suggested future research questions:

3T: "What capabilities do Industry 4.0 technologies possess to mitigate health and safety incidents? Further, how can organisations improve health and safety practices through these technologies to build employees' trust in technology?"

RR: Which technologies can aid in better predictions of organisational and wider community health? Further, how can employees from different socioeconomic backgrounds be included and represented for accurate predictions to reduce operational disruptions?"

FtF: "To what extent can Industry 4.0 technologies aid in predicting the spread of infectious diseases through global and regional supply chains and in prescribing alternative solutions to minimise disruptions?"

Business Practices

There is potential to investigate relationships between social and economic sustainability post-COVID-19. With organisations taking greater responsibility for social responsibility in their supply networks, this sub-theme considers the use of Industry 4.0 technologies for developing fairer and less corrupt supply chains, and ensuring appropriate procurement and partnership standards with suppliers. Further, the transformational capabilities of Industry 4.0 for addressing product counterfeiting and tampering, especially for safety-critical products, can be explored. Another research avenue is how to incorporate small and medium-sized enterprises from the supply network in the adoption of Industry 4.0 technologies for social responsibility, especially given the likely upfront investment costs. This is a critical issue, for example, affected whether or not end-to-end traceability will be achieved. This leads to the following suggested future research questions:

3T: "Given the vast opportunities that Industry 4.0 technologies offer in improving supply chain transparency for efficiency and SROP, why is highly-integrated adoption across different industries still low?"

RR: "How can financially-constrained SMEs in a multi-tier supply chain context be incentivised to implement Industry 4.0 technology to ensure integrated and fair value chains?"

FtF: "*What competitive advantages are gained by organisations adopting Industry 4.0 technology for SROP? Are there impacts on economic and environmental sustainability dimensions?"*

Quality of Life and Social Welfare

As COVID-19 spread rapidly throughout the world there was an acute shortage of essential medical and personal protective equipment, which exacerbated the crisis. Examples such as the VentilatorChallengeUK illustrate how Industry 4.0 has significant potential in disaster management, both in terms of preparedness and recovery, leading to another area of research opportunity. This includes the following future research questions:

3T: "How can Industry 4.0-based training help in improving community awareness and education to build trust in technology? How can this help organisations in the long-term when hiring local talent?"

RR: "How can organisations use Industry 4.0 technologies for welfare-based new product development, integrating SROP and wider sustainability to promote the positive social impacts of products (e.g. through product life cycle analysis)?"

FtF: "What predictive capabilities do Industry 4.0 technologies offer for proactive disaster management from an organisational and community perspective to reduce economic impacts and ensure continued operations for economic survival?"

Social Governance

While organisations budget for and spend on Corporate Social Responsibility (CSR) initiatives, the use of Industry 4.0 technologies for identifying projects and allocating funds effectively is yet to be studied. This can help in a post-COVID-19 scenario to support community-relevant CSR projects, such as erecting quarantine centres and socially-distant communal spaces. The capabilities of Industry 4.0 in this sub-theme can be viewed through our three research agendas with the following future research questions:

3T: "How effective are Industry 4.0 technologies in identifying and prescribing the most beneficial CSR projects from a community perspective? What factors should be considered to ensure the spend is effective?"

RR: "To what extent can Industry 4.0 technologies be used by organisations to integrate external stakeholders and ensure collective voices are accounted for when making community-based decisions? Does this help or hinder any traditional community influence on CSR projects undertaken by organisations?"

FtF: "What is the relationship between using Industry 4.0 technology-based CSR spend and organisational growth? Does this benefit the community positively in comparison to existing CSR spend allocations?"

Economic Welfare and Growth

Organisations have reconfigured supply chains during the pandemic to minimise disruptions and attempt to ensure the continued supply of essential products and services. In some cases, operations that were previously globally outsourced due to the high cost of labour could now be "reshored" following the advent of Industry 4.0 technologies, as it may be possible to significantly reduce manufacturing costs. This leads to increased job opportunities in local communities and, consequently, a higher standard of living. The capabilities of Industry 4.0 in this sub-theme can be viewed through our three research agendas as follows:

3T: "How can Industry 4.0 technologies aid in creating job opportunities for community development and growth? What skills and training are required to improve local talent hiring and retention?"

RR: "What opportunities do Industry 4.0 technologies offer in improving local sourcing from SMEs, marginalised suppliers, women-owned businesses and social enterprises to develop economic growth and community standards of living?"

FtF: "To what extent can Industry 4.0 technologies be employed to reshore and localise supply chains? Which technologies are best suited to achieve this transition with minimum negative economic impact?"

The pandemic has disrupted operations globally, and economies are still recovering from the devastating impact. COVID-19 has also exposed a lack of resilience and the poor risk management capabilities of some firms (van Hoek and Loseby, 2021). The unique nature of the pandemic has had particular effects for social performance within organisations and wider communities, prompting many firms to now include SROP as a core part of their strategy. Given the vast opportunities and capabilities provided by Industry 4.0 for improving SROP, organisations can gain competitive advantage through the adoption of relevant technologies. We have illustrated this through real use-case examples and shown how organisations can capitalise on social sustainability, as summarised in the SROP-Industry 4.0 framework in Section 3. In Section 3, we also suggest three overarching research agendas based on our viewpoint, which we believe will enable scholars and practitioners to better manage future disruptions. For academics, the three research agendas outlined represent a call to arms for fellow scholars in the field. Many of the research questions we identify can be approached using action-oriented methods, such as action learning (Powell and Coughlan, 2020), action research (Touboulic and Walker, 2016) and other interventionist approaches (Hasle and Vang, 2021) to both test and build theory (Oliva, 2019). These methods can help in improving processes through engaged research and making changes in a forward-looking "real time" manner to build theory (Coughlan and Coghlan, 2002; Touboulic *et al.*, 2020). For managers, these research agendas provide a direct link to technology and SROP, which can aid in improving understanding of technology adoptions from a SROP perspective, as many of the questions posed have direct practical relevance. Therefore, these research agendas can support organisations in building back better with SROP-centric business models in the post-COVID-19 era.

To date, however, there have been relatively few fully-integrated implementations, and there remains only limited empirical academic evidence on the impact of Industry 4.0 technologies on SROP. This could be attributed to the lesser understood "dark side" of digitalisation (Son *et al.*, 2021; Verbeke and Hutzschenreuter, 2021), especially in an SROP context. For example, SROP standards such as ISO 26000 are voluntary, meaning organisations have discretionary power over whether or not they adopt them (Son *et al.*, 2021). Further, inequitable access to information and technology, especially in developing economies where it has been argued unethical practices are most prevalent (Almeida *et al.*, 2020; LeBaron, 2021; Linkov *et al.*, 2018), adds to adoption complexity. From a data management perspective, the ethical standards for private data collection, especially when organisations operate in multiple regions governed by different laws, have to be adhered to, and employees need to be aware of what data is being collected in order to protect employee privacy and rights (Corbett, 2018; Gozman and Willcocks, 2019) and prevent employee exploitation through data misuse (Raut *et al.*, 2019; Stock *et al.*, 2018). These SROP-specific issues are in addition to other wider technology-related challenges, such as regarding cybersecurity and data breaches (Khan, 2019); the cost of technologies, which is a barrier for some financially-constrained supply chain partners (Kiel *et al.*, 2017); and resistence to technology implementation for fear of greater employee monitoring and job losses as a result of automation (Fawcett and Waller, 2014).

Therefore, even though Industry 4.0 technologies have been hyped to bring about positive outcomes, there exists a distinct possibility of unintented consequences from technology adoption, and this "dark side" of digitalisation also needs to be studied in depth to prevent any social repercussions. Despite this, we posit that, post-COVID-19, the implementation of Industry 4.0 technologies and their use for improving SROP will be vital, and thus accelerated. To this end, our paper provides a plaftorm for exploring the opportunities of Industry 4.0 technologies for SROP in a post-COVID-19 world.

Table V Future Research Questions (FRQs) based on Overarching Research Themes

--*Insert Table V here*--

Sub Theme	Trust through Technology FRQs	Responsible Relationships FRQs	Freedom through Flexibility FRQs
Employment Practices	"What opportunities do Industry 4.0 offer to reduce bias in employee evaluations through verified real-time data? Further, how can these technologies ensure confidentiality and fair inclusion and diversity in organisations?"	"How can Industry 4.0 technologies aid in developing and monitoring sustainable employment practices to reduce unethical practices, ensure job satisfaction and increase productivity?"	"What operations risk management capabilities do organisations gain by adopting technology for SROP in comparison to non-digitalised organisations?"
Health & Safety	"What capabilities do Industry 4.0 technologies possess to mitigate health and safety incidents? Further, how can organisations improve health and safety practices through these technologies to build employees' trust in technology?"	Which technologies can aid in better predictions of organisational and wider community health? Further, how can employees from different socioeconomic backgrounds be included and represented for accurate predictions to reduce operational disruptions?"	"To what extent can Industry 4.0 technologies aid in predicting the spread of infectious diseases through global and regional supply chains and prescribing alternative solutions to minimise disruptions?"
Business Practices	"Given the vast opportunities that Industry 4.0 technologies offer in improving supply chain transparency for efficiency and SROP, why is highly-integrated adoption across different industries still low?"	"How can financially constrained SMEs in a multi-tier supply chain context be incentivised to implement Industry 4.0 technology to ensure integrated and fair value chains"?	"What competitive advantages do organisations adopting Industry 4.0 technology for SROP gain? Are there impacts on economic and environmental sustainability dimensions?"
Quality of Life & Social Welfare	"How can Industry 4.0-based training help in improving community awareness and education to build trust in technology? How can this help organisations in the long-term when hiring local talent?"	"How can organisations use Industry 4.0 technologies for welfare based new product development by integrating SROP and wider sustainability to promote positive social impacts of products (e.g. through product life cycle analysis)?"	"What predictive capabilities do Industry 4.0 technologies offer for proactive disaster management from organisational and community perspectives to reduce economic impacts and ensure continued operations for economic survival?"
Social Governance	"How effective are Industry 4.0 technologies in identifying and prescribing the most beneficial CSR projects from a community perspective? What factors will be considered to ensure the spend is effective?"	"To what extent can Industry 4.0 technologies be used by organisations to integrate external stakeholders and ensure collective voices are accounted for when making community-based decisions? Does this help or hinder any traditional community influence on CSR projects undertaken by organisations?"	"What is the relationship between using Industry 4.0 technology-based CSR spend and organisational growth? Does this benefit the community positively in comparison to existing CSR spend allocation?"
Economic Welfare & Growth	"How can Industry 4.0 technologies aid in creating job opportunities for community development and growth? What skills and training are required to improve local talent hiring and retention?"	"What opportunities do Industry 4.0 technologies offer in improving local sourcing from SMEs, marginalised suppliers, women-owned businesses and social enterprises to develop economic growth and community standards of living?"	"To what extent can Industry 4.0 technologies be employed to reshore and localise supply chains? Which technologies are best suited to achieve this transition with minimum economic impact?"

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