

Editorial

Achieving Sustainability in Supply Chain Operations in the Interplay between Circular Economy and Industry 4.0

1. Introduction

Circular economy (CE) is an emerging industrial paradigm in manufacturing supply chains (Ellen MacArthur Foundation, 2012; Urbinati et al., 2017). CE, in manufacturing supply chains, emphasises a circular approach to energy and materials for providing economic, environmental and social benefits of “triple bottom line” (Geissdoerfer et al., 2017). CE reconciles the outlook for a nation's economic growth with the environmental and social benefits, while, at an enterprise level, it aims to create superior value (Henley, 2013). CE addresses some of the issues relating to ecological degradation and resource scarcity in the business context (Vladimirova, 2017). Supply chain managers can improve resource efficiency and profitability of manufacturing facilitates through effective CE mechanisms and minimise the negative impacts of production operations.

Manufacturers adopt modern technologies, such as 3D printing, Internet of Things (IoT) and other Industry 4.0 technologies to enhance operational performance (Ghobadian et al., 2020). An appropriate alignment of the Industry 4.0 goals with the enterprises' long-term strategic objectives is essential to improve the overall performance of the manufacturing supply chains. For example, manufacturing firms like Caterpillar (Caterpillar Energy Solutions GmbH, 2017) and Renault have adopted Industry 4.0 to enhance efficiency and reduce costs. BMW, Jaguar Land Rover, Rolls-Royce, GE and Philips have implemented Industry 4.0. In the food sector, for example, Mondelez – the owner of many prominent brands like Cadbury, Milka, Oreo and Toblerone etc. – at their Global Centre of Excellence for chocolate in Bournville, UK, has adopted Industry 4.0 based smart factories (Mondelez International, 2017) aiming to improve process efficiency in their supply chains through manufacturing and packaging waste reduction and productivity improvement. Nestlé has participated actively in the Industry 4.0 agenda in Germany to improve their resource efficiency, reduce the environmental impact of packaging wastes and enhance productivity through the digitalisation of operations.

Industry 4.0 acts as one of the accelerators of sustainable energy that aims to enhance environmental performance (UNIDO, 2017). Therefore, effective integration of some smart Industry 4.0 technologies with sustainability agenda can propel an efficient operational control of the manufacturing system that aims to achieve some aspects of the CE focused operations. The use of Industry 4.0 can have disparate sustainability implications, such as optimal use of

resources and technology etc. (Liao et al., 2017). CE-focused Industry 4.0 can assist manufacturers to enhance resource and energy efficiencies (Fatorachian and Kazemi, 2018).

The Courtauld Commitment 2025 of the United Kingdom views CE as the condition for sustainability (WRAP, 2020). Courtauld 2025 aims to improve the sustainability aspect in the UK's food and drink sector through enhanced resource efficiency and more waste reduction. Manufacturers participating in both Courtauld 2025 and Industry 4.0 agendas strive to reduce waste, improve packaging and reduce carbon footprint. Examples are Cadbury, Mars Nestlé, Heinz, Premier Foods and Kerry Noon, and grocery retailers, such as Asda and Morrisons.

Sustainability, circular economy and digitalisation (i.e. Industry 4.0) have been researched separately in manufacturing supply chains. Broadly the contribution of the research is limited within resource efficiency. A distinct knowledge gap seeks to explore studies on Industry 4.0 driven sustainable manufacturing supply chains in a circular economy context and its implications on manufacturing supply chain operations. Therefore, this Special Issue entitled '*Achieving Sustainability in Supply Chain Operations in the interplay between Circular Economy and Industry 4.0*' aims to collate recent research on Industry 4.0 driven sustainable circular supply chains. The articles in this Special Issue identify the growing needs of sustainability-oriented supply chain operations through Industry 4.0 and circular economy. These articles reveal new knowledge and findings by addressing at least one of the following research questions in understanding the interplay between circular economy-oriented Industry 4.0 agenda and sustainable supply chain operations:

- a) How does digitalisation enhance productivity and resource/energy efficiency in circular supply chain operations?
- b) What are the key drivers and barriers of digitalisation within a circular economy context for achieving sustainable supply chain/logistics operations?
- c) How do the innovative capabilities of sustainable supply chains/logistics mediate between Industry 4.0 and circular economy practices from an operations management perspective?

Articles submitted for consideration of this Special Issue went through a rigorous review process. Nine research contributions presenting new and significant research are accepted. Contributions mainly identify new constructs and approaches that assist enhance sustainable supply chain operations through digitalisation considering circularity in the supply chains.

2. Special Issue Articles

The following five articles of this Special Issue explore some new knowledge and findings focusing on sustainability in the interplay between circular economy and digitalisation. Using semi-structured interviews and fuzzy DEMATEL, Zhang et al. (2021) study the drivers of Industry 4.0-enabled waste management in Chinese firms. The study identifies 11 key drivers for implementing the waste management programme in supply chain operations. The fundamental causal driver identified in this study is the effectiveness of Industry 4.0 technologies for improving operational performance. This study intends to guide Chinese firms at the macro and microlevels.

Based on the data collected from 238 practitioners of Indian manufacturing organisations, Kamble and Gunasekaran (2021) investigate the mediating and moderating roles of CE practices in the relationship between Industry 4.0 technologies and sustainable performance. The study explores how the Industry 4.0 technologies and two dynamic capabilities achieve improved sustainable performance. The study indicates that developing a CE environment is not a prerequisite for implementing the digitalisation technologies.

Based on a case of a Turkish logistics company, Kazancoglu et al. (2021) investigate some CE-related risks associated with the firm's sustainable supply chain considering some Industry 4.0-based responses. The study uses the fuzzy analytic hierarchy process (AHP) and TODIM models in analysing the association between the risks and responses. The study claims to assist managers in mitigating supply chain operational risks.

The study of Bag et al. (2021) reports how manufacturing enterprises in South Africa have used Industry 4.0 technologies in achieving sustainability in supply chain operations. Using a PLS structural equation model with 200 responses from the manufacturing enterprises the study posits the enhancement of sustainable supply chain operations by improving resource consumption rate and reducing waste and pollution through the Industry 4.0 technologies. The study suggests that lower waste disposal and pollution emission rate is positively related to the dynamic remanufacturing capability of the manufacturing enterprises.

Tsolakis et al. (2021) report an empirical study exploring determinants of successful transitions in a framework capturing the interplay between CE and Industry 4.0 towards sustainable supply chains. The study proposes an inclusive hierarchical decision-making framework and a multi-level simulation modelling and optimisation technique in exploring the interplay between digital-enabled circular supply chains and Industry 4.0. A real-life case of blue-green algae, as renewable feedstock, is considered to develop CE perspectives. Results demonstrate enhanced resource utilisation and market dynamics enabled by the adoption of digital operations in the CE context.

The following four articles are related to the theme of this Special Issue. Dr Sachin Kumar Mangla curated these four articles. Using the Scopus database, de Sousa Jabbour et al. (2021) identify and review 52 articles on CE and food waste. The review identifies future research opportunities. The study of Kumar et al. (2021) identifies and analyses 14 critical success factors of the circular supply chain (CSC) and Industry 4.0 using a hesitant fuzzy-DEMATEL model. The study indicates that the adoption of CSC and Industry 4.0 can complement each other while contributing to sustainability. In another study, Kusi-Sarpong et al. (2021) identify some CE-based Industry 4.0 initiatives in sustainable supply chain operations for developing sustainable supplier selection criteria. Illustrating a case of the textile manufacturing industry based in Pakistan, the study evaluates five suppliers and ranks them using the BWM and VIKOR methods. Khanzode et al. (2021) identify 14 enablers of lean Six-Sigma (LSS), assess the influences of the enablers of CE and sustainability and their causal relationships in manufacturing organisations using the classical DEMATEL method. The study mentions that the enablers can assist Indian manufacturing firms in prioritising their resources while implementing Industry 4.0.

3. Acknowledgements

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