Reverse supply chains in Industry 4.0

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Abstract
Reverse supply chains (RSC) activities are gaining popularity in the literature and practice due to their contribution to achieving the organizations' sustainable goals and financial indicators. The concept of RSC is forked and representative of many activities. The tasks of RSCs are not limited to recycling waste. Industry 4.0 is a widely used concept that encourages adopting a modern technological and interdependent approach to manufacturing. A working framework has been produced to summarize the contemporary knowledge in the literature and show how Industry 4.0 can potentially support RSC activities.

Keywords: Reverse supply chain, Industry 4.0, Sustainability

1. Introduction
Global challenges are increasing, including those linked to sustainability, while Industry 4.0 technologies may help tackle these challenges (Masood et al., 2021). The challenges such as the economic crisis, international competition and environmental requirements require industry and researchers to improve manufacturing strategies in tackling such challenges. Maintaining raw materials, rationalizing their consumption, and meeting the needs and desires of customers following manufacturing ethics have become the joint responsibility of suppliers, companies, and the consumer. That also highlights the aspects that can improve by different Industry 4.0 technologies (Hernes et al., 2020). To achieve the best benefits for the customer, manufacturing companies and the environment, we aim to produce a framework to integrate RSCs with Industry 4.0 to evaluate the benefits Industry 4.0 can bring to support different activities in RSCs. To achieve this aim, we will present a vision of the RSC that considers the customer preferences, rational use of

raw materials, and issues related to manufacturing ethics as key performance indices. We will show how Industry 4.0 can potentially integrate with RSC activities to understand the customer preferences, rationally use the raw materials and improve the manufacturing ethics.

Reverse supply chains (RSC)

Industrial and scholarly interest in RSC has increased dramatically over the last two decades. Issues like RSC, product recovery, remanufacturing, and reusing have emerged as major areas for development, owing to resource depletion and exhausted landfills in many countries (Mathiyazhagan et al., 2020). That mainly relates to consumers becoming more willing to see environmentally friendly industries. That is also due to legislative pressure (Georgiadis & Besiou, 2010). In addition, with high raw materials prices, recycling becomes more appealing, and RSC can help support competitive advantages (Larsen et al., 2018). Genovese and others (2017) define an RSC as "A process of recovering and reusing or disposing of products that consumers have returned in an environmentally friendly manner". RSCs consist of reverse logistics, de-manufacturing and re-manufacturing stage and the use of recycled or used materials and components in the product's design and the process. Designing an RSC entails several long-term strategic decisions critical to RSC performance (Khalili et al., 2014). Firms should improve the performance measure index to locate the effectiveness of their RSCs thus that they can gather an inserted and overall approach to fulfil the required RSC performance results (Shaharudin et al., 2017). As a result, RSCs are a significant component in enabling the transition to circular economies. RSCs can provide various Advantages to businesses, including increased project competency, public benefits, client satisfaction, and lessened product costs (Doan et al., 2019).

Industry 4.0

Industry 4.0 is a widely used concept that encourages adopting a modern technological and interdependent approach to manufacturing (Masood & Sonntag, 2020; Sharpe et al., 2018). The term "Industry 4.0" is defined as the "fourth industrial revolution that will make the enterprise more agile, aware, efficient, intelligent, safe and sustainable" (Masood & Sonntag, 2020). The impact of Industry 4.0 contributes to meeting market needs and environmental requirements. The smart plant, which represents Industry 4.0 principles, uses technology to integrate business and engineering processes allowing production to operate flexibly, cost-effectively, and resource-efficiently (Masood & Sonntag, 2020; Machado et al.,2019). Industry 4.0 can maximise value and sustainability while minimising waste (Masood & Sonntag, 2020). Industry 4.0 includes technological innovations such as autonomous manufacturing systems, advanced robotics (Malik et al., 2020b), the internet of things (IoT), the cloud, big data analytics, and additive manufacturing. Horizontal and vertical system integration, cybersecurity, augmented reality (AR) (Masood & Egger, 2021), virtual reality (VR) (Malik et al., 2020a), and simulation (Gunal, 2019).

Two significant trends in today's manufacturing system are Industry 4.0 and sustainability. Due to their overlap and interaction may form a distinct industrial wave, which will forever change, global production systems (de Sousa Jabbour et al., 2020). Industry 4.0 features shorter delivery times, more efficient and automated processes, higher quality, production agility, and profitable and customized products (Bongomin et al., 2020). Therefore, the modern technology of Industry 4.0 can contribute to supporting activities of RSC via integrating those to get several benefits for customers,

manufacturers, and manufacturing sustainability. In this paper, the activities of RSC that we focus on are meeting customer preferences, rational use of raw materials and manufacturing ethics. We aim to produce a framework on how Industry 4.0 can potentially support different RSC activities to meet their performance index (i.e. the customer preferences, rational use of raw materials, and manufacturing ethics).

2. Methodology

According to the search protocol in Table 1, for consistency with objectivity and reliability. Scopus database users import potential data and other approved databases relevant to our research topic for literature review.

Table 1. Protocol of systematic literature review.

	Research Protocol	Description
The base plan of search	Databases Publication type Language Years Publication	Scopus database and other approved databases. Journals indexed by Scopus, Google Scholar. English. Focus on published in the last decade.
Search features	Search terms Search terms in titles, keywords, abstracts	Titles, abstracts, keywords. RSCs and Industry 4.0.
The researched sample topic.	Inclusion criteria Exclusion criteria	Research variables, relationship between them. Articles do not focus on the content of the
Analysis	Data collection, Analysis, and synthesis	Detailed analysis and statement of relationship, linkage and integration.

All references for this research were selected from accredited international scientific publishing, Scopus databases. Using keywords related to the research topic, such as RSCs, Industry 4.0 of a research topic and its branches, and then focusing on research papers that deal with the relationship between them. The researcher faced challenges in the lack of studies dealing with the integration between RSC and Industry 4.0. Therefore, we extended the search to include keywords such as Industry 4.0 and circular economy and logistics, in which RSCs are among their activities.

3. Findings

By highlighting the previously published literature, limited contributions were noted to the interface of RSCs and Industry 4.0. Researchers have made several contributions in the field of Industry 4.0 and circular economy and logistics, in which RSCs are among their activities. There were also previous studies representing Industry 4.0 and sustainability. As can notice in Table 2.

Table 2. Summarized literature review of Industry 4.0 in a circular economy, reverse logistics and sustainability.

Authors	Model /Framework	Methodology/ Technique	Findings
Garrido-Hidalgo et al., (2019).	End-to-end solution for (reverse supply chain management) based on cooperation between	Use IoT devices and sensors to inventory monitoring of	Communication bottlenecks need addressing to enhance the

Authors	Model /Framework	Methodology/ Technique	Findings
	different Industry 4.0 technologies.	WEEE through embedded sensors.	reliability of large-scale (IIoT) networks.
Abdul-Hamid et al., (2020)	A framework of challenges to Industry 4.0 in circular economy in practices.	The fuzzy Delphi Method is to screen out the less-important attributes.	Contributes to unveiling what challenges Industry 4.0 in CE faces for operational decision-making.
Zhou et al., (2020).	A framework of economy driving forces under Industry 4.0 and circular economy.	Economic growth	The industrial policy works well on structural co-localization and regional economy.
Bag, S., & Pretorius, J. H. C. (2020).	Review of Industry 4.0, sustainable manufacturing and circular economy.	Qualitative research. Integration with Industry 4.0, sustainability and CE.	Integrating three contemporary concepts (Industry 4.0, CE and Manufacturing sustainably) in the context of SCM.
Ćwiklicki, M., & Wojnarowska, M. (2020).	Identify the relationships between the CE and Industry 4.0.	The most promising digitalisation tools of Industry 4.0 are the (IoT) and Big Data Analytics.	Industry 4.0 leads to a CE, two-way relationship, indicating between these concepts.
Yavas, V., & Ozkan-Ozen, Y. D. (2020).	Transformation of logistics centres in Industry 4.0.	Fuzzy multi-criteria decision-making methodology.	The result is helpful for logistics centre professionals in the transition process.
Dev et al., (2020)	A roadmap for sustainable RSC by the joint implementation of principles Industry 4.0 and Resolve model of circular economy (CE) approaches.	Taguchi's experimental design topic has been used for the analysis.	The integration of Industry 4.0 and CE represents a real-time decision model for the sustainable RL system.
Yadav et al. (2020).	Technology Industry 4.0 with sustainability.	Method (RBWM) is utilised to recognize the intensity of the effect of each enabler.	Managerial, economic and environmental enablers possess a strong contribution toward sustain-ability adoption.
Saniuk et al.,(2021)	Development of Industry 4.0 with human resources.	Literary analysis and the conducted survey of selected industrial enterprises.	Required knowledge and skills of workers essential to implement the Industry 4.0 concept.
Enyoghasi, C., & Badurdeen, F. (2021)	Implementation of sustainable manufacturing facilitated or enhanced by using Industry 4.0.	Comparative analysis of individual Industry 4.0 technologies and their potential	The opportunities of Industry 4.0 are limited in the literature.

Authors	Model /Framework	Methodology/ Technique	Findings
		impact on sustainability.	
Awan et al., (2021)	Identify Industry 4.0 stakeholders' interests and expectations regarding how the IoT.	various stakeholders	IoT tools for dealing with the circular economy.
Mastos et al. (2021)	CR models and solutions are assisted by Industry 4.0 technologies to transform products at the end of the life cycle into new products with a different use.	Dimensions of the Resolve model.	Industry 4.0 supports the improvement of CE processes.
Rajput, S., & Singh, S. P. (2021)	Integrate the CE and RL in the existing supply chain to foster environmental and economic growth.	Mixed-integer linear programming (MILP) model of Industry 4.0 to achieve a CE includes RL.	Optimize cost and maximize the products' end-of-life to establish an Industry 4.0 facility.
Devi et al., (2021)	Sustainability in the global markets in shadow Industry 4.0 and the circular economy.	An integrated path comprises Analytical Hierarchy Process (AHP).	Develop an active and integrated strategic approach to foster sustainable operations in Industry 4.0 and the circular economy.

As can be noticed from Table 2, although some research discussed the role of Industry 4.0 in improving the suitability and encouraging the move to circular economy, there is limited research exploring how the role of Industry 4.0 in supporting different RSCs activities. That encouraged the researchers to explore RSCs and industry 4.0 to rationalize the use of raw materials, sustainable manufacturing, and meet customer preferences with a commitment to preserving the environment.

4. How Industry 4.0 supports RSC: A framework

In most supply chains, the customer is the final step in the process. On the other hand, returns processes are part of the RSC (Covaci, 2019). As a result, RSCs are now a revenue opportunity for manufacturers. With this development in the industry field, Industry 4.0 technology will enable independent processing decisions and algorithms that will allow the transition from traditional RSCs to digital RSCs in the future through simulation systems that will allow this. Manufacturing flexibility provided in the Industry 4.0 helps adapt activities for RSCs, the speedy response to changing opinions customers and meeting them, quality, and efficiency required, and adding customer value based on foundations manufacturing ethics. It also reflects the rational use of raw materials and their preservation, with the RSC activities that evaluate, monitor and feed information to Industry 4.0 to integrate between them to obtain the best performance, improving the manufacture. Figure 1, shows that the framework of Industry 4.0 supports RSCs.

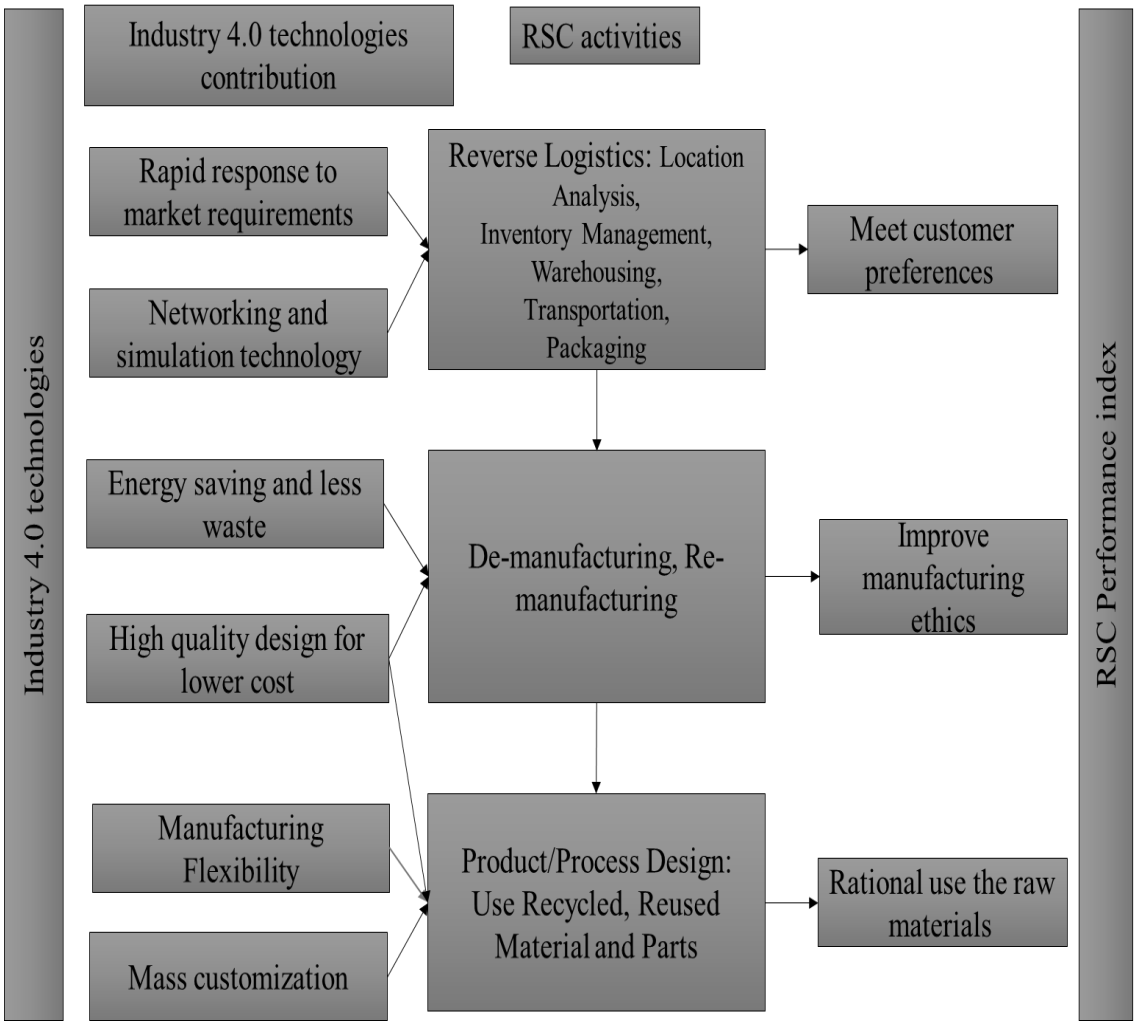

Figure 1: RSC and Industry 4.0 Framework

The RSC represents the flow of products and information from customers to manufacturers. ARSC is challenging because it must manage every stage where products must handle and distributed to manufacturers, with multiple recovery options and data analysis to benefit customers (Garrido-Hidalgo et al., 2019). From an economic standpoint, Industry 4.0 technology's flexible operations lead to long-term developments in manufacturing or remanufacturing (Dev et al., 2020). Despite the fourth generation of the industry's enormous potential, it must be regularly evaluated and achieved. To get the most out of Industry 4.0, we need to connect it to RSCs. RSC and Industry 4.0 simulations help industrial companies meet customer needs while increasing profits. Unsold and obsolete goods are on the rise due to Industry 4.0's technological advancements. Therefore, the need to plan products according to the rational use of raw materials reflects reducing manufacturing costs and preserving the environment and sustainability. Industrial companies face great challenges in addition to production processes.

Operations managers can benefit from Industry 4.0 technologies in various ways, including reducing product-processing time, lowering manufacturing costs, improving value chain coordination, increasing process flexibility, improving customer service, and increasing product customisation (Fettermann et al., 2018). In addition, the closed-loop has become a contemporary topic in the supply chain (SC) domain. The forward and RSCs combine in a closed-loop supply chain, which preserves and recovers value from used products while generating as little waste as possible through the de-manufacturing

and re-manufacturing. Adoption of some industry 4.0 technologies in the closed-loop supply chain, which includes the returns processes, makes RSCs a revenue opportunity rather than a cost-cutting strategy for manufacturers (Covaci, 2019).

5. Conclusion and discussion

This paper explored how RSC can benefit from Industry 4.0 technologies based on a literature review. Industry 4.0 technologies may be the answer to meet the customers' preferences, rationalise the use of raw materials and improve the manufacturing ethics where the rapid development in manufacturing creates more obsolete and unsold products. Industry 4.0 can support reverse supply chains in several areas. In the processes of remanufacturing and recycling, Industry 4.0 possesses flexible, high technology in remanufacturing and other processes, which enables it to support the RSCs in remanufacturing and recycling optimally. The technology Industry 4.0 is characterized by high-tech, high-speed networks and accurate electronic simulation systems that enable it to support RSC by linking the customer with companies and suppliers. That will provide information that allows the possibility of benefiting from feedback from customers, evaluating goods, and stating their preferences. That will help suppliers and producers to know the actual customer preferences to satisfy them in quantity and quality. As for the environmental aspect, Industry 4.0 can lead to greener processes by saving energy and reducing pollution. Through the Industry 4.0 obtains accurate information from RSC.

Capabilities of Industry 4.0 in the speed of response and adaptation to market requirements can lead to better utilization of the information in reverse logistics to meet the customer needs. As well, Industry 4.0 can lead to high flexibility 4.0 in manufacturing will significantly influence mass customization, meeting customers' preferences and rationalization of using raw materials. In this paper, we tried to reflect on how industry 4.0 can how RSC activities can benefit from Industry 4.0 technologies by producing a framework that shows the linkages. In our future work will develop this framework further using empirical evidence. We will also reflect on how specific industry 4.0 technologies can support the reverse supply chain activities we reported. We will investigate their impact on meeting customer preferences, improving manufacturing ethics, and rationalising the use of raw materials.

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