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Analyzing the drivers of smart sustainable circular supply chain for sustainable development goals through stakeholder theory

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Abstract
The concept of sustainable development is becoming incomprehensible and complex in global supply networks, especially in low- and middle-income countries (LMIC) that are most affected by ever-changing industry challenges and standards. Smart technologies emerged by Industry 4.0, sustainability, and circular economy (CE) connection, which remain unexplored, can be integrated into the supply chain as a business strategy to increase collaboration and cooperation between different tiers of the supply chain to achieve sustainable development goals (SDGs) according to LMIC. Therefore, the main objective of this paper is to discover the drivers of a smart sustainable circular supply chain (SSCSC) in achieving the SDGs in LMIC through stakeholder theory. First, a systematic review is employed to identify the drivers of the SSCSC to achieve the SDGs in the LMIC incorporating existing literature on the subject. Second, the Best-Worst Method (BWM) is applied to analyze the identified drivers, and then the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is used to analyze the SDGs. The applicability of the solution methodology was illustrated by providing a numerical example. The results of the study are twofold: firstly, drivers are analyzed by implementation of BWM. The results of the BWM reveal that economic sustainability is the best key driver among the eight drivers in achieving the SDGs, meaning that without financial assistance and support achieving the SDGs becomes ineffective. Secondly, the TOPSIS analysis reveals that SDG 16 (peace, justice, and strong institutions) is the SDG most supported by drivers.

KEYWORDS
circular economy, industry 4.0, low- and middle-income countries, resource efficiency, smart sustainable circular supply chain, stakeholder theory, sustainability, sustainable development goals

1 | INTRODUCTION

As in a linear economy, the standard process of supply chains utilizes the raw materials for the industrial manufacturing process (Goyal et al., 2018) and turns them into waste after consumption. However, the linear economy model is incapable of managing the supply and demand balance in the utilization of natural resources (Rajput & Singh, 2019). In addition to that, innovative manufacturing methods, models, and services as a business strategy aimed at protecting natural resources and the environment have led to increased awareness of climate change and ecosystem deterioration worldwide (Bassetti et al., 2021; Dwyer et al., 2009; Linnenluecke et al., 2012). Therefore,
the source of circular economy (CE) is attributed to supply chains to provide environmentally effective strategies and business responses (Okorie et al., 2018). In this sense, it presents a better alternative to the linear economy, which is widely adopted today (Werning & Spinler, 2020), in terms of environmental management. CE is an economic model that aims efficient use of resources for waste minimization, long-term value retention, elimination of the primary resources, and closed-loop of products, parts, and materials inside of the field of environmental protection, and socio-economic benefits (Morseletto, 2020) and efficient resource, energy, and water use restricting waste that circulates into the atmosphere (Liu et al., 2018). From a broader perspective, a detailed definition of CE is provided by Kirchherr et al. (2017, p. 224) as follows:

“A CE describes an economic system that is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro-level (products, companies, consumers), meso-level (eco-industrial parks) and macro-level (city, region, nation and beyond), to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.”

In the light of this definition, the objective of CE is to add value to the materials and products, to achieve maximum length of the life cycle, and to renew them until their end-of-life (Kouhizadeh et al., 2020). As the supply chain is influenced by this attribution of CE with the increasing cost, complexity, uncertainty, and vulnerability; the managers seek cheaper, faster, and better vertical and horizontal supply chain collaboration.

Developing alternatives to integrate sustainable supply chain collaboration with CE principles has then become necessary (Genovese et al., 2017). Also, the considerable increase in sustainability is being considered as an active response by companies to increased requests and pressure on corporate sustainability for sustainable development by stakeholders (Burritt & Schaltegger, 2010; Dong et al., 2014; Laguir et al., 2019; Qian et al., 2020). Thus, sustainable circular supply chain (SCSC) is generated as an environmental strategy by combining the concepts of sustainability and CE and presents a novel approach and compelling viewpoint to the field in a consideration of forward and reverse supply chain (Guide et al., 2003; Guide & Van Wassenhove, 2009; Kayikci et al., 2021; Murthy & Evans, 2016). It is a restorative and regenerative cycle that is designed relying on circular thinking, and it aims at a zero-waste economy because of CE philosophy (Farooque et al., 2019). The SCSC focuses on the closed-loop system by reversing the product by an external recycler to close the material gap between the company and the consumer (Murthy & Evans, 2016). Thus, CE principles such as reuse, repair, remanufacturing, and recycling are enabled through the SCSC collaboration to sustain value circulation consistently (Batista et al., 2018) by integrating the range of potential CE and supply chain combinations (Masi et al., 2017). Furthermore, economic and business opportunities are also significant drivers for the transition toward SCSC, as well as resource scarcity, global resources concerns, and environmental issues (Jain et al., 2018).

Supply chains are also required to be smarter to overcome the aforementioned challenges (Butner, 2010; Wu et al., 2016) and also to provide sustainable output (Zouari et al., 2021) and reduce human–machine interaction for easier adoption of sustainability practices to facilitate CE principles (Yadav et al., 2020). For this purpose, Industry 4.0 (I4.0) technologies bring the “smart concept” and generate smart SSCSC to be flexible and versatile, rendering them responsive (Butner, 2010; Gupta et al., 2019; Kayikci et al., 2021) with transparency and sustainable collaboration (Duan et al., 2021) as seen in Figure 1. SSCSC consists of multi-tiers and multiple stakeholders within a vertical and horizontal collaboration. Thus, the processes within the supply chain need the assistance of information technologies. In that sense, supply chains promise an ideal playground for the convergence of sustainability, CE, and I4.0 technologies. SSCSC performs better not just traditional financial performance indicators but also social and environmental indicators. These indicators help measure performance in ensuring long-term sustainability by considering key factors (Gozacan & Lafci, 2020). As part of the 2030 Agenda, sustainable development goals (SDGs) were formed in 2015 as a “blueprint to achieve a better and more sustainable future for all” consisting of 17 interlinked global goals (UN, 2016). The SDGs are designed for the implementation of mechanisms to bring various actors together to actively align their efforts with a common goal (Fowler & Biekart, 2017). This idea critiques economic growth as the only bottom line and it underlines the necessity of balancing economic, ecological, and social development in moving toward a sustainable economy and society (Qian et al., 2020). SDGs mostly address low- and middle-income countries (LMIC). For this reason, the implementation of SDGs in LMIC with the vertical and horizontal collaboration SSCSC proposes is of great importance. From this point of view, CE principles may be utilized as a toolbox to achieve a wide variety of SDGs (Schroeder et al., 2019) as a part of SSCSC. Most importantly these smart circular activities are required to reach the collaboration of multi-tier supply chains (Fabbe-Costes et al., 2011). To the best of our knowledge, sustainability, CE, and I4.0 dimensions have not been extensively studied together until now due to the recent emergence of the interaction between them. In addition, the interaction between supply chain, sustainability, CE, and I4.0 has not been examined in the literature. Also, considering SDGs, the vertical and horizontal effects of these three dimensions on collaboration in LMICs have never been studied in the literature. All these aspects reveal a research gap. To close this research gap, more comprehensive management models and strategies that recognize the complexity of sustainable development and promote collaborative action and partnerships are required to prevent negative effects and optimize positive benefits across all social sectors, public, private, and civil society sectors (van Zanten & van Tulder, 2021; van Tulder & Keen, 2018). Based on this research gap, the objective of this study is to investigate the drivers within the concept of SSCSC to achieve the SDGs in LMIC through stakeholder theory. Therefore, the main contribution of this study is to provide an SDG guideline for LMIC by integrating the sustainability, circularity, and smartness perspectives into the supply chain within the concept.
of SSCSC, as effective implementation of SDGs is a great challenge for LMIC. In this sense, this paper aims to fill this gap by providing both proactive and reactive solutions and contributions to this issue. The novel approach is accomplished by applying a Systematic Literature Review (SLR) to identify drivers, followed by the Best-Worst Method (BWM) for the analysis of these drivers, and then the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) for the analysis of SDGs. This paper contributes to the literature by proposing a roadmap for the practitioners and academicians by presenting drivers and analyzing the interrelationships between them in terms of the implementations of SSCSC for SDGs in LMIC. Research questions (RQs) are generated stepwise in line with the motivations mentioned to accomplish the analysis of the overall objective of the research. RQs are shown clearly in Table 1.

The organization of the paper, seen in Figure 2, is as follows: collaboration for sustainable development with the lens of stakeholder theory is explained and the drivers of the SSCSC are identified by conducting an extensive SLR in Section 2. In Section 3, solution methodology is given to analyze the relationships between drivers using BWM and SDGs using TOPSIS method. In Section 4, a numerical example is given to demonstrate the results. Section 5 includes a discussion on findings. Section 6 presents the implications of this study. Finally, Section 7 concludes the paper with the limitations and future direction of research.

2 | COLLABORATION FOR SUSTAINABLE DEVELOPMENT: STAKEHOLDER THEORY

Supply chain management is critical in adopting sustainable manufacturing and improving the performance of the organization (Kumar et al., 2020; Shi et al., 2017; Wu et al., 2016). Integrating the concept of sustainability with key business activities related to supply chain management, such as procurement, logistics, and knowledge management, has resulted in a vital and multidisciplinary subject known as sustainable supply chain management (Morali & Searcy, 2013). Because of the rising complexity of global supply networks, sustainable development is gaining traction (Li & Mathiyazhagan, 2018) among organizations, multinational corporations, and various tiers of supply chains to achieve sustainable development. However, sustainable development adoption necessitates collaboration across all levels of the business, from multinational corporations to small and medium enterprises (Li & Mathiyazhagan, 2018) since sustainable supply chain management is an action that contributes to the achievement of sustainable development (Diabat et al., 2014).

SDGs were established in 2015 as part of the 2030 Agenda, including 17 interconnected global goals to balance social, economic, and environmental sustainability (UN, 2016). Middle-income countries are significant partners in the implementation of the 2030 Agenda and have much to share from their efforts to achieve the SDGs, including with the low-income countries (UN, 2018). To ensure that the development is sustained and sustainable, it is needed to improve the international competitiveness and access to newer technologies which is the main challenge since it is the limited capacity to absorb and develop technologies, given their infrastructural and institutional bottlenecks (UN, 2018). A key objective of the agenda is also to highlight the focused and enhanced support, including improved coordination that the United Nations development system, the international financial institutions, regional organizations, and other stakeholders can extend to middle-income countries (UN, 2018) and low-income countries.

The fact that sustainability management and stakeholder theory both contain a long-term point-of-view is justified by their strategic planning similarities (Hörisch et al., 2014; Figge et al., 2002; Freeman, 1994). The stakeholder theory becomes one of the most powerful and widely utilized theoretical tools for value creation (Tapaninaho & Heikkinen, 2022) by numerous academics, and it resulted in significant progress in dimensioning sustainability (Khosravi & Izbirak, 2019; Barić, 2017; Alves & Rodrigues, 2019; Carroll & Brown, 2018; Clark et al., 2015) since the objective of stakeholder theory is to establish mutual benefit for all stakeholders.
(Freeman, 1994) as in the 2030 Agenda. This wide concept of value is explicitly embraced by stakeholder theory, which deliberately extends further defining value in a mere money perspective (Hörisch et al., 2014). According to Hörisch et al. (2014), the necessity to establish innovative approaches in the framework of sustainability management that improves the quality of life (Gladwin et al., 1995) corresponds to stakeholder theory, which is more engaged with quality of life than simply monetary goals (Freeman et al., 1994). Therefore, the stakeholder theory is being considered as the most formidable framework for measuring sustainability and the vast majority of scholars agree that social sustainability and stakeholder theory are compatible (Bellantuono et al., 2016; Collier et al., 2014; Herazo & Lizarralde, 2016; Khosravi & Izbirak, 2019; Perrini & Tencati, 2006; Khosravi & Izbirak, 2019). Because of the high involvement of various tiers of the supply chain, their cooperation and collaboration are needed (Savage et al., 2010) for achieving SDGs in LMIC. Collaborative or proactive strategies toward sustainability incorporate sustainable development throughout basic company concepts as well as seek to interact productively with confrontational or disengaged stakeholders, demoralized staff, inefficient activities, including reduced market share (Perey et al., 2018). Stakeholder theory suggests that companies that want to conduct successful business must consider the opinions and expectations of their stakeholders (Freeman, 1994). Therefore, high involvement, long-term commitment, and collaboration of various tiers of the supply chain are needed for supply chains to achieve SDGs in LMIC. Supply chains offer collaborative platforms for addressing responsibility by internalizing environmental and social externalities (Carter & Jennings, 2002; Chien & Shih, 2007; Morali & Searcy, 2013; Roberts, 2003; Sarkis et al., 2010). In such a competitive environment, which is composed of various stakeholders, each organization and stakeholder must respond to the pressure and take appropriate action (Meherishi et al., 2019) collaboratively. To manage and maintain these collaborations in supply chain networks, the stakeholder theory has a lot to offer to supply chains. Because it is critical to understand each stakeholder’s role and how it may be expanded to allow the shift from a linear to a CE (Meherishi et al., 2019) in supply chains and accomplish SDGs in LMIC. Therefore, investigating these collaborative interactions, particularly social partnerships, calls into question parts of both descriptive and instrumental stakeholder theory (Savage et al., 2010).

Sustainable development in LMIC and other countries requires a collaborative system that starts recycling the materials used in manufacturing processes and adds these materials to the smart closed-loop system as in SSCSC. For this reason, the implementation of SDGs in LMIC with the vertical and horizontal collaboration SSCSC proposes is of great importance as stakeholder theory suggests. In this context, circular practices are recognized as a means to advance toward sustainable development, resource efficiency, and a low-carbon economy (Wright et al., 2019) as a part of SSCSC since the reason underneath for expediting and driving the willingness to embrace circular principles arisen from the need to decrease negative unsustainable environmental consequences that occurred due to the existing linear supply chains such as resource scarcity, waste disposal, destruction of natural resources, and energy consumption. Thus, as a toolkit for achieving a broad variety of SDG goals, CE principles can be utilized (Kayikci et al., 2021; Schroeder et al., 2019). Within SSCSC, the circular principles are supported by the relationship between I4.0 and sustainability. Therefore, manufacturing industries cannot disregard the influence of I4.0 on supply chains and sustainability necessity (Fallahpour et al., 2017; Liao et al., 2017; Luthra et al., 2020; Quezada et al., 2017; Thornton, 2017) because I4.0 technologies are hastening manufacturing digitalization and correspondingly reshaping the whole value chain (Merkel et al., 2017; Queiroz et al., 2020). I4.0 can be defined as an integration of digitization into business operations and procedures for intelligence and has a wide range of applications in many fields (Lin et al., 2017; Luthra et al., 2020). However, implementation of I4.0 technologies is currently in its early stages, particularly in developing countries (Luthra & Mangla, 2018) as LMIC and it is important to highlight that the adoption of I4.0 in the manufacturing industry is simpler in developed economies than in developing economies (Fettermann et al., 2018; Luthra et al., 2020).
2.1 Systematic literature review

There is a substantial number of papers in the current literature investigating prominent SCM issues such as sustainability, CE, I4.0, and SDGs. However, a holistic approach that combines these concepts in a theoretical and practical manner is missing in literature and requires immediate attention. Since the main purpose of this paper is to present, identify, and analyze the key drivers of SSCSC to achieve SDGs in LMIC, search strings were established for the searching process in Web of Science (WoS) as seen in Figure 3. The search string of SLR is as follows:

- **Search strings. TITLE-ABS-KEY {**

<table>
<thead>
<tr>
<th>Search dimensions</th>
<th>Search string</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply chain</td>
<td>(“supply chain” OR “green supply chain” OR “sustainable supply chain” OR “green manufacturing” OR “sustainable manufacturing”) AND</td>
</tr>
<tr>
<td>Sustainability</td>
<td>(“sustainable development goals” OR “SDG” OR “sustainability” OR “sustainable development” OR “environmental sustainability” OR “social sustainability” OR “economic sustainability” OR “corporate sustainability”) AND</td>
</tr>
<tr>
<td>Circularity</td>
<td>(“circular economy” OR “green economy” OR “circularity” OR “reuse” OR “reduce” OR “recycle” OR “repair” OR “remanufacture” OR “repurpose” OR “recycle” OR “recover” OR “rethink” OR “9R”) AND</td>
</tr>
<tr>
<td>Smartness</td>
<td>(“industry 4.0” OR “I4.0” OR “manufacturing 4.0” OR “digital”” OR “internet” OR “big data” OR “Blockchain” OR “internet of things” OR “IoT” OR “sensors” OR “machine learning” OR “cyber-physical systems” OR “artificial intelligence” OR “AI” OR “cognitive computing” OR “virtual reality” OR “augmented reality” OR “VR/AR” OR “3D printing” OR “4D printing” OR “additive manufacturing” OR “cloud computing” OR “edge computing” OR “mobile devices” OR “5G” OR “robotics” OR “unmanned aerial vehicle” OR “UAV” OR “nanotechnology” OR “self-driving vehicles” OR “automated guided vehicles” OR “AGV” OR “radio frequency identification” OR “RFID” OR “near field communication” OR “NFC” OR “M2M”) AND</td>
</tr>
<tr>
<td>LMIC</td>
<td>(“LMIC” OR “low and middle-income countries” OR “low-income countries” OR “middle-income countries”) AND</td>
</tr>
<tr>
<td>Drivers</td>
<td>(“drivers” OR “success factors”)]. Limit to: Doctype (article and review)</td>
</tr>
</tbody>
</table>

As a result of the SLR, Figure 4 shows the yearly distribution and the number of publications. Year 2018 is the year that has the highest number of publications on the SSCSC concept with 17. This declined to 15 in 2019 and 13 in 2020. Figure 5 displays the yearly distribution of the publication in terms of journals. The top five most preferred journals were classified as follows: *Journal of Cleaner Production* (21), *Resources, Conservation and Recycling* (5), *Production Planning and Control* (5), and *Sustainability* (4).

2.2 Drivers of the smart sustainable circular supply chain

In this part of the article, the available literature is reviewed to find the addressed drivers of SSCSC for SDGs in LMIC. As a result, the literature on drivers for achieving SDGs in LMICs has been evaluated and compiled in Table 2 to answer RQ1. The explanations of the drivers were also presented in the table for further understanding of the drivers and their interactions with the paper.

3 SOLUTION METHODOLOGY

In this study, BWM and TOPSIS methods were used as a solution methodology. BWM is a comparative multi-criteria decision-making method (MCDM) that compares the best criterion to all other criteria before comparing all other criteria to the worst criterion (Zhao et al., 2018). The objective of this technique is to use a basic optimization model to discover the best weights and consistency ratio (Zhao et al., 2018). The approach was chosen because it offers numerous benefits over other MCDM methods, such as analyzing small group pairwise comparisons in this method rather than the entire pairwise comparison matrix in other MCDM methods (Agrawal & Vinodh, 2021). Additionally, utilizing expert opinions is a beneficial strategy in the presence of uncertainty generated by technological innovations since experts have a stronger comprehensive understanding of cause-effect relationships. BWM is easy and precise because the implementation of secondary comparisons is not necessary (Haseli et al., 2021; Ghoushchi et al., 2019; Rezaei, 2015a). Also, TOPSIS is utilized to analyze SDGs since TOPSIS aims to identify the best alternative that is both the closest to the positive ideal solution and the most far away from the negative ideal solution (Karim & Karmaker, 2016). TOPSIS has several benefits, including its ease, rationality, and comprehensibility, as well as its high processing performance and potential to quantify the relative performance per each alternative in a simple mathematical format (Roszkowska, 2011).
FIGURE 3  Data collection process

FIGURE 4  Yearly distributions of the publications

FIGURE 5  Distribution of the journals
<table>
<thead>
<tr>
<th>Drivers</th>
<th>Explanation</th>
<th>References</th>
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<tbody>
<tr>
<td>D1 Economic sustainability</td>
<td>Potential to increase sustainable, committed, and strong employment in circular practices by providing employees financial assistance. This driver also includes the concentration of environmental costs, such as expenses associated with the current or future deterioration of natural resources due to economic activity of smartness and circular supply chain ecosystem vertically and horizontally.</td>
<td>Dantas et al. (2021); Chen et al. (2020); Elia et al. (2020); Fatimah et al. (2020); Tura et al. (2019); Diabat et al. (2014); Gabzdylova et al. (2009); Carter and Rogers (2008)</td>
</tr>
<tr>
<td>D2 Policy and regulations</td>
<td>Effective and supportive government regulations and policies on cyber security and circular activities are necessary to eliminate threats and weaknesses while planning smart circular operations of the supply chain ecosystem vertically and horizontally following the existing regulations. In addition, pricing, taxes, and financial subsidies are beneficial strategies for guiding people's consumption behaviors in the direction of sustainable circularity.</td>
<td>Nasir et al. (2021); Chen et al. (2020); Tura et al. (2019); Bag et al. (2018); Bonilla et al. (2018); Luthra and Mangla (2018); Dong et al. (2016); Hermann et al. (2016); Ilić and Nikolić (2016); Witjes and Lozano (2016); Bai et al. (2015); Kagermann (2015); Velis and Vrancken (2015); Diabat et al. (2014); Yu et al. (2014); Stahel (2013); Faisal (2010); Brown (2009); Gabzdylova et al. (2009); Marshall et al. (2005); Zhu et al. (2005); Desrochers (2001)</td>
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<tr>
<td>D3 Supply chain connectivity</td>
<td>Considering organizational policy in implementing 4.0 technologies and escalating supply chain sustainability entails international cooperation and collaboration among vertical and horizontal members of the supply chain ecosystem while increasing the satisfaction of the environmentally sensitive consumer with circular and sustainable products and processes with the boost of smartness.</td>
<td>Badraoui et al. (2021); Nasir et al. (2021); Elia et al. (2020); Tura et al. (2019); Luthra and Mangla (2018); Müller et al. (2018); Pfohl et al. (2017); Reddy et al. (2016); Türk (2015); Diabat et al. (2014); Hussain (2011); Faisal (2010); Lee (2008); Cox et al. (2007); Jamison and Murdoch (2004); Geffen and Rothenberg (2000); Innes &amp; Booher (2000); Brandenburger and Nalebuff (1996)</td>
</tr>
<tr>
<td>D4 Social sustainability</td>
<td>Reducing harmful substances or using non-chemical circular materials and processes with proper standards for sustainable health and safety for employees. Also, a smart circular sustainable supply chain ecosystem reduces the consumption of hazardous materials in the vertical and horizontal supply chain operations to provide a pollution-free environment while increasing globalization and global awareness of the need for sustainability.</td>
<td>Fatimah et al. (2020); Tura et al. (2019); Luthra and Mangla (2018); Murray et al. (2017); Wolf (2017); Diabat et al. (2014); Waheed et al. (2009); Carter and Rogers (2008); Carter et al. (2007)</td>
</tr>
<tr>
<td>D5 Organizational competency</td>
<td>Detection, identification, and management of supply chain risks, diverse emissions, and their origin activities can be discovered due to the integrated sustainability, circularity in the harmonized supply chain ecosystem, and advanced cooperation and collaboration via transparency that is driven by smart technologies. Moreover, high support, commitment, and involvement of top management provide innovation, infrastructure to improve circular practices and increase their performance. This driver also prioritizes organizational learning, smart circularity for the sustainable welfare of people, and is ethical and supportive vertically and horizontally.</td>
<td>Nasir et al. (2021); Elia et al. (2020); Bag et al. (2018); Luthra and Mangla (2018); Müller et al. (2018); Pfohl et al. (2017); Savtschenko et al. (2017); Wan et al. (2016); Faisal (2010); Swee et al. (2010); Carter and Rogers (2008); Klimley (2005); Rice (2003); Roberts (2003); Zsidisin and Siferd (2001); Zsidisin and Hendrick (1998); Walton et al. (1998)</td>
</tr>
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TABLE 2 (Continued)

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<thead>
<tr>
<th>Drivers</th>
<th>Explanation</th>
<th>References</th>
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<tr>
<td>D6 Human resources competency</td>
<td>Increasing workforce knowledge, training, and expertise in the supply chain ecosystem by providing appropriate technology, and public awareness of circularity education and sustainability concepts drive thoughts to act responsibly to environmental issues vertically and horizontally.</td>
<td>Liboni et al. (2019); Lopes de Sousa Jabbour et al. (2018); Fettermann et al. (2018); Luthra and Mangla (2018); Lin et al. (2017); Schuster et al. (2016); Faisal (2010); Brown (2009); Geldermann et al. (2007); McKeown et al. (2002); Wright (2002)</td>
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<tr>
<td>D7 Information technology competency</td>
<td>A fully equipped facility with the adoption of emerging technologies IT-based technologies and infrastructure provides the required network, connectivity, sustainable compatibility, and traceability of the information across the vertical and horizontal circular and sustainable supply chain ecosystem.</td>
<td>Nasir et al. (2021); Tseng et al. (2021); Chen et al. (2020); Elia et al. (2020); Tura et al. (2019); Lopes de Sousa Jabbour et al. (2018); Luthra and Mangla (2018); Ghsisellini et al. (2016); Lacy and Rutqvist (2015); Ellen MacArthur Foundation (2013); Hofmann et al. (2012); Mathews and Tan (2011); Zhijun and Nailing (2007)</td>
</tr>
<tr>
<td>D8 Environmental sustainability and circularity</td>
<td>Environmental responsibility for environmental sustainability is an immense concern to consumers. Thus, products and services of circular eco-design are designed via smart operations with the minimum amount of detrimental environmental effect as a result of cooperation in the supply chain ecosystem vertically and horizontally.</td>
<td>Dantas et al. (2021); Nasir et al. (2021); Fatimah et al. (2020); Tura et al. (2019); Ghsisellini et al. (2016); Andrews (2015); Lacy and Rutqvist (2015); Linder and Willander (2017); Murray et al. (2017); Diabat et al. (2014); EC (2014); Moreno et al. (2014); Ellen MacArthur Foundation (2013); Kok et al. (2013); Hofmann et al. (2012); Vojdani and Lootz (2012); Gabzdylova et al. (2009); Bhaskaran et al. (2006)</td>
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3.1 Best-Worst Method

In MCDM methods, the process starts with $n$ criteria and it is intended to perform a pairwise comparison on a scale of 1/9 to 9 as seen below,

$$
A = \begin{bmatrix}
  a_{11} & a_{12} & \ldots & a_{1n} \\
  a_{21} & a_{22} & \ldots & a_{2n} \\
  \vdots & \vdots & \ddots & \vdots \\
  a_{n1} & a_{n2} & \ldots & a_{nn}
\end{bmatrix}
$$

(1)

where $a_{ij}$ indicates the relative preference of criterion $i$ to criterion $j$. Here, $a_{ij} = 1$ indicates that $i$ and $j$ are of identical significance. $a_{ij} > 1$ indicates that $i$ is more significant than $j$. If $a_{ij} = 9$, there is an extreme significance of criterion $i$ to criterion $j$. Similarly, the significance of $j$ to $i$ is indicated by $a_{ij}$. $a_{ij}$ is required to be equal to $1/a_{ij}$ so it can be reciprocal (Rezaei, 2015a). BWM consists of two parts, which are reference pairwise comparisons and secondary pairwise comparisons (Rezaei, 2015b). In this way, the necessary number of pairwise comparisons can decrease to $2n – 3$ which includes pairwise comparisons of best criteria to other criteria ($n – 2$), pairwise comparisons of other criteria to the worst criterion ($n – 2$) and pairwise comparisons of the best criterion to the worst criterion ($n – 1$) (Guo & Zhao, 2017). Rezaei (2015a, 2015b) explains BWM as follows:

Step 1. Identify the decision-makers and the decision-making criteria: $\{C_1, C_2, \ldots, C_m\}$ is considered as a set of criteria and $\{DM_1, DM_2, \ldots, DM_n\}$ is considered as a set of decision-makers.

Step 2. Decide which criteria are the most important (best) and which are the least significant (worst): Every decision-maker chooses the best and worst criteria overall.

Step 3. Use the scale of 1 to 9 (see Table 3) to perform pairwise comparisons of the best criterion with other criteria:

$$
A_{bij} = (a_{b1}, a_{b2}, \ldots, a_{bm}) \quad (j = 1, 2, 3, \ldots, m)
$$

(2)

where $a_{biji}$ denotes the relative importance value of the best criterion over criterion $j$.

Step 4. Use the scale of 1 to 9 to perform pairwise comparisons of the worst criterion with other criteria:

$$
A_{wij} = (a_{w1}, a_{w2}, \ldots, a_{wm}) \quad (j = 1, 2, 3, \ldots, m)
$$

(3)

where $a_{wiji}$ denotes the relative importance value of criterion $j$ over the worst criterion.

Step 5. Calculate the optimum criterion weights ($w_1, w_2, \ldots, w_n$) for each group: $a_{bij} = w_b/w_j$ and $a_{wiji} = w_w/w_j$. The calculated weights are non-negative.

$$
\text{minimize } \max \left( \frac{w_b - a_{bij}}{w_j - a_{wiji}} \right)
$$

subject to

$$
\sum_{j=1}^{n} w_j = 1 \quad \text{and } w_j \geq 0 \text{ for all } j
$$

(4)
TABLE 3 1/9 to 9 (Rezaei, 2015a)

<table>
<thead>
<tr>
<th>Equal importance</th>
<th>Somewhat between equal and moderate</th>
<th>Moderately more important</th>
<th>Somewhat between moderate and strong</th>
<th>Strongly more important</th>
<th>Somewhat between strongly strong and very strong</th>
<th>Very strongly important</th>
<th>Somewhat between very strong and absolute</th>
<th>Absolutely important</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

Now, Equation 4 can be written as below and optimal criteria weights for each group and the value of $\xi$, can be calculated.

$$\begin{align*}
\text{minimize} & \quad \xi \\
\text{subject to} & \quad \left( \frac{w_i}{w_j} - a_{ij} \right) \leq \xi, \\
& \quad \left( \frac{w_j}{w_i} - a_{ij} \right) \leq \xi, \\
& \quad \sum_{j=1}^{n} (w_j) = 1
\end{align*}$$

(5)

Step 6. Final weights of each group are calculated using the average weights:

$$w_j = \frac{\sum_{k=1}^{n} (w_{jk} \times n_k)}{N} v_j,$$

(6)

where $n_k$ denotes the number of decision-makers in the $k$th group and $N$ indicates the total number of decision-makers where $N = (n_1, n_2, \ldots, n_n)$.

The consistency ratio which is indicator for the consistent degree of comparisons is calculated using $\xi$ and the consistency index value (Haseli et al., 2021) as below,

$$\text{Consistency ratio} = \xi \bigg/ \text{Consistency index}$$

(7)

Furthermore, Table 4 indicates the consistency index.

Rezaei (2015a) states that inconsistency occurs when $a_{ij} = a_{jw} \neq a_{bw}$. Also, this means $a_{ij} \times a_{jw}$ can be less or more than $a_{bw}$. Maximum consistency is obtained as $a_{ij}$ and $a_{jw}$ have the greatest value (same with $a_{bw}$), which is conducted to $= 0$. In addition,

$$\left( a_{ij} - \xi \right) \times \left( a_{jw} - \xi \right) = (a_{bw} + \xi)$$

(8)

For maximum consistency,

$$\left( a_{bw} - \xi \right) \times \left( a_{bw} - \xi \right) = (a_{bw} + \xi)$$

(9)

Equation 9 can be also written as

$$\xi^2 - (1 + 2a_{bw})\xi + a_{bw}^2 - a_{bw} = 0$$

(10)

3.2 TOPSIS

TOPSIS is a multi-criteria decision analysis method, which was primitive proposed by Hwang and Yoon (1981), which explains the steps as follows:

Step 1: Decision makers rate values for the alternative with respect to criteria on a decision matrix considering Table 3: According to arithmetic mean of pairwise comparisons from decision group, a comparison matrix $A$ is constructed (see Equation 1).

Step 2: Normalize decision matrix:

$$X_{ij} = \frac{X_{0i}}{\sqrt{\sum_{j=1}^{n} X_{0j}^2}}$$

(11)

where $X_{ij}$ is the normalized score and $X_{0ij}$ is the original score.

Step 3: Construct the weighted normalized matrix:

$$v_{ij} = w_i \times X_{ij}, \quad j = 1, 2, 3, \ldots, J, \quad i = 1, 2, 3, \ldots, n$$

(12)

where $w_i$ represents weights.

Step 4: Determine the positive ideal solution (PIS) and negative ideal solution (NIS):

$$A^+ = \{v_{1j}, v_{2j}, \ldots, v_{n_j}^+\} \text{ maximum values (13)}$$

Where $v_{ij}^+ = \{\max(v_{ij})\} \text{ if } j \in J, v_{ij} \text{ if } j \in J^-$

$$A^- = \{v_{1j}, v_{2j}, \ldots, v_{n_j}^+\} \text{ minimum values (14)}$$

Where $v_{ij}^- = \{\min(v_{ij})\} \text{ if } j \in J, v_{ij} \text{ if } j \in J^-$

Step 5: Calculate the distance of each alternative from PIS and NIS:

$$d_j^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{ij}^+)^2}, \quad j = 1, 2, \ldots, J$$

(15)

$$d_j^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{ij}^-)^2}, \quad j = 1, 2, \ldots, J$$

(16)
Step 6: Calculate the closeness coefficient \((CC_i)\) to the ideal solution of each alternative:

\[
CC_i = \frac{d_i}{d_i + d_j}, \quad i = 1, 2, \ldots, J.
\] (17)

Step 7: Rank the alternatives: Alternatives are ordered from most valuable to least valuable depending on the descending values of \(CC_i\).

### 4 | NUMERICAL EXAMPLE

The textile industry was selected to study SDG access in LMIC by applying a supply chain concept that manages to combine CE, I4.0, and sustainability. The reason underneath of choosing the textile industry for the implementation of this study is because of the direct effect of the textile industry on the SDGs in LMIC because the textile industry has a unique position that includes industries such as agriculture and engaged cross-cutting activities. Hence, these integrated industries are also affected by the attention made to the textile industry. The numeric examples of this study obtained through examining the SSCSC drivers identified in the previous section. Numeric data were obtained and evaluated through a questionnaire by the 16 decision-makers from the textile industry. The average work experience of experts is 16 years in the textile industry. In addition, the educational background of the participants is at least at the undergraduate level. Nine experts have bachelor's degrees, five experts have master's degrees, and two experts have doctorate degrees. The distribution of the experts according to the tiers from downstream to upstream of the textile supply chain is shown in Figure 6. It is important to note that some respondents indicated that they are involved in more than one tier of the textile supply chain. This study was pursued between April 1 and July 31, 2021.

The interaction among the drivers in SC for SDGs in LMIC was analyzed by using BWM and TOPSIS method. Using questionnaire, the 16 participants defined the most and least significant driver, as well as the best and worst criteria. Obtained data from the questionnaire have been used to identify the best and worst drivers to achieve SDGs in LMIC. In this context, Table 5 illustrates the best and worst drivers. Later, using a 1–9 scale, participants were requested to express their choice for the best criterion over all other criteria. With the same measurement scale of 1–9, respondents were also required to assess the preference rate of all criteria over the least important criterion through a questionnaire.

Table 6 represents the final findings of the BWM application. The findings can be utilized to develop strategic management decisions. The maximum criterion weight is 0.130 for D1 (economic sustainability). When it comes to achieving SDGs in LMICs, economic
sustainability is the most important driver. D8 (environmental sustainability and circularity) and D3 (supply chain connectivity) ranked next, with criteria weights of 0.128 and 0.122, respectively. This conclusion for LMIC suggests that economic sustainability necessitates the highest and most immediate managerial focus to contribute to the achievement of enhanced SDGs overall. Once economic sustainability is established and executed, it will serve as a foundation for the adoption and improvement of the other criteria, ultimately contributing to the advancement of the SDGs as a whole. D5 (organizational competency) is the least important driver, with a weight of 0.065.

As the final step of BWM, the prioritization result of SSCSC drivers for SDGs in LMIC is as seen below:

\[ D_1 > D_8 > D_3 > D_2 > D_7 > D_6 > D_4 > D_5 \]

After the drivers were analyzed with BWM, the effects of drivers on SDG were examined with TOPSIS. While examining the importance of drivers on SDGs in the survey, participants were first asked the Yes–No question to find out whether drivers are important for SDGs. As a result of this question, all drivers and all SDGs were found important. Afterward, the evaluation was performed using a 1/9–9 scale. The driver weights to be used in the TOPSIS process were obtained from the BWM method. As a result of taking the arithmetic average of the decision-maker evaluations (Karim & Karmaker, 2016), the decision matrix shown in Table 7 was obtained. The normalized matrix calculated in the next step based on this matrix is also seen in Table 8.

Table 9 shows the answer of RQ2 via the ranking based on PIS \( (S_i^{+}) \) and NIS \( (S_i^{-}) \). As can be seen in this table, the importance of the identified drivers is greatest on SDG 16 (peace, justice, and strong institutions) with 0.76. This is followed by SDG 9 (industry, innovation, and infrastructure) with 0.67. SDG 15 (forests, desertification, and biodiversity) is in the third ranking with 0.61. If we look at the last three SDGs, SDG 2 (zero hunger) is ranked last with 0.29. SDG 8 (Decent Work and Economic Growth) was second to last with 0.39. SDG 1 (No Poverty) is seen with 0.42 before SDG 8.

### 5 | DISCUSSION

Inequalities have risen dramatically in many nations, while the environment has been severely damaged on an unprecedented scale (Sachs, 2015). To deal with these inequalities, maintain sustainability, and eliminate detrimental effects on the environment, creating solutions to combine SSCSC became required. SDGs are crucial strategies for maintaining continuous sustainability in the ever-changing market conditions in LMIC and these SDGs have the capabilities to create a solution to these challenges confronted by the supply chains. Therefore, achieving SDGs has great importance for LMIC, and integrating-smart technologies into the supply chain assist the transition from linear to CE more smoothly and swiftly. For that reason, circularity, and smartness (the role of technologies) of the supply chain are vital to achieving the SDGs. In this context, this paper contributes to the literature by depicting and emphasizing the important points of drivers to focus on to achieve SDGs in LMIC. However, achieving SDGs in LMIC requires additional effort rather than emerging economies. In this context, CE and I4.0 technologies can be considered as a promoter to achieve various SDGs in LMIC.

Given the several similarities among countries, an internationally coordinated effort to create an open knowledge platform containing

<table>
<thead>
<tr>
<th>TABLE 7</th>
<th>Decision matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drivers</strong></td>
<td><strong>0.163</strong></td>
</tr>
<tr>
<td><strong>SDG 1</strong></td>
<td>9</td>
</tr>
<tr>
<td><strong>SDG 2</strong></td>
<td>8</td>
</tr>
<tr>
<td><strong>SDG 3</strong></td>
<td>9</td>
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<tr>
<td><strong>SDG 4</strong></td>
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<td><strong>SDG 5</strong></td>
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<tr>
<td><strong>SDG 6</strong></td>
<td>8</td>
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<tr>
<td><strong>SDG 7</strong></td>
<td>8</td>
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<tr>
<td><strong>SDG 8</strong></td>
<td>8</td>
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<tr>
<td><strong>SDG 9</strong></td>
<td>8</td>
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<tr>
<td><strong>SDG 10</strong></td>
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<tr>
<td><strong>SDG 11</strong></td>
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<tr>
<td><strong>SDG 12</strong></td>
<td>8</td>
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<tr>
<td><strong>SDG 13</strong></td>
<td>8</td>
</tr>
<tr>
<td><strong>SDG 14</strong></td>
<td>8</td>
</tr>
<tr>
<td><strong>SDG 15</strong></td>
<td>8</td>
</tr>
<tr>
<td><strong>SDG 16</strong></td>
<td>8</td>
</tr>
<tr>
<td><strong>SDG 17</strong></td>
<td>8</td>
</tr>
</tbody>
</table>
systematic and robust analysis of the SDGs and their interactions, as well as how they might play out in different contexts, could greatly advance national SDGs implementation (Nilsson, 2017). The adoption of the 2030 Agenda for Sustainable Development (UN, 2016) signaled a paradigm change in global development policy and collaboration (Nilsson, 2017). As a result, sustainable development has become the central focus of global collaboration (Sachs, 2015). Therefore, the role of vertical and horizontal supply chain collaboration is becoming substantial for supply chains to eliminate the fragility, uncertainty, and complexity toward achieving SDGs.
The results demonstrate that D1 (economic sustainability) is the best driver that plays a vital role in accomplishing SDGs between all eight drivers, implying that attaining SDGs is becoming useless without financial aid as well as support. As a result, organizations must pay close attention to financial elements to make a real effect on LMICs because economic sustainability is vital to alleviate the detrimental impact of global inequality while simultaneously enhancing countries’ acceptance of the SDGs (Van Niekerk, 2020). This driver is directly connected with SDG 8 (UN, 2016), which focuses on sustaining inclusive and sustainable economic growth with productive and decent working conditions for all, and this target connects country-level economic sustainability to individual-level work dignity (Leal Filho et al., 2019). Therefore, we can claim that achieving economic sustainability is the building block for realizing the other SDGs. Furthermore, D8 (environmental sustainability), D3 (supply chain connectivity), and D2 (policy and regulations) were found as the following important drivers after D1 (economic sustainability), respectively. The transition to SSCSC will have a significant positive impact on environmental sustainability since the cradle-to-cradle system of CE refuses the industrial paradigm of “take-make-dispose” (Averina et al., 2021; Blomsma & Brennan, 2017). Even though most of the SDGs address climate change and environmental sustainability challenges directly or indirectly, SDG 13 focuses specifically on tackling climate change and its consequences (Leal Filho et al., 2019; UN, 2016). Also, supply chain connectivity, which increases the productivity of the systems, operational efficiency, data management, continuous production, energy waste elimination, and so on (Kayikci, Kazancoglu, Lafci, Gozakan-Chase, & Mangla, 2021), is substantial for realizing SDGs. Particularly, an open and connective platform enabling a network through international cooperation as well as collaboration across vertical and horizontal supply chain participants is an essential supporter of SDG achievement. In this context, companies need to focus on SC connectivity as a driver to achieve SDGs because it is becoming more effective, efficient, reactive (Luthra et al., 2020), and intelligent because of upcoming smart technology breakthroughs. Furthermore, policies and regulations that forced companies to adopt smart technologies and sustainability principles for circularity purposes in the supply chain are a requirement for SDG achievement. Policies, subsidies, regulations, and incentives pursued by the government are required for the adoption of SDGs and their effective implementation at a local, regional, and global level.

The results of this study contribute to the literature by providing a holistic understanding of achieving SDGs in LMIC and providing vertical and horizontal supply chain collaboration for this purpose.
Identifying, analyzing, and ranking the eight drivers and the SDGs affected by these factors facilitate industry practitioners to identify which drivers they should adopt to achieve a specific SDG and take required remediation action. Therefore, this study assists industry experts, practitioners, and managers to understand which drivers should be adopted by organizations to support SDGs in LMIC. Also, effective, and supportive government regulations, policies, conductive legal systems, effective executions related to environmental regulations, and so on are some of the key drivers for setting a roadmap to achieve SDGs for industry experts, practitioners, and managers. Moreover, some policies and regulations related to consumer consumption habits toward sustainability behaviors, tax reductions, and financial subsidies can be influential for organizations to direct them to adopt SDGs. The limitations of this research, the presented study focuses only on Turkey as LMIC and only the textile industry is considered as a numerical example. Future research can focus on this topic with a broader scope. By defining the drivers, this research concentrates on only the WoS database which can be also defined as a limitation. Furthermore, the drivers can be also analyzed by using Total Interpretive Structural Modelling to construct a hierarchical model by analyzing the contextual interrelationships between the identified drivers as the next step. Moreover, another multiple-criteria decision-making method, DEMATEL can be utilized to discover the cause-effect relationships between the drivers.

ACKNOWLEDGEMENT

The first author, Dr. Yasanur Kayikci, gratefully acknowledges the support provided by the Scientific and Technological Research Council of Turkey under the grant number 1929B021800620 for this research.

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