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EMERGING DRIFTS BIG DATA ANALYTICS AND ENVIRONMENT SUSTAINABILITY

Are emerging technologies unlocking the potential of sustainable practices in the context of a net-zero economy? An analysis of driving forces

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Abstract

Increasing globalization and climate change have significantly affected business activities. Government and other stakeholders are creating pressure to have a sustainable business model for efficient resource utilization and minimizing negative environmental impact. Many organizations have started focusing on sustainable and cleaner production through the adoption of net-zero economy (NZE) practices. Certain technological advancements are required to put these concepts into practice. Firms have begun to adopt digital technologies (such as big data analytics, artificial intelligence, and internet of things), and have been widely used in practice to achieve NZE. Is digitalization unlocking the potential of sustainable practices in the context of a net-zero economy? This question is still unanswered; therefore, this study aims to identify and analyze the drivers of digitalization that ensure sustainable practices to achieve net-zero economy. Through an extensive literature review and experts' opinions, a list of drivers was identified. An empirical investigation was conducted to validate the identified drivers and further understand the influencing relationship among the drivers, Pythagorean fuzzy decision-making trial and evaluation laboratory (PF-DEMATEL) was employed. The findings of the study show that "*high degree of automation*," "*enhancing the flexibility in the manufacturing process*," and "*real-time sensing capability*" are the main influencer drivers among all cause group forces. The present study can be a source for industrial practitioners and academia that can provide significant guidance on how the adoption of digitalization can unlock the potential to achieve CE, which can lead us toward net-zero.

Keywords Emerging technologies · Sustainable practices · Net-zero economy · Circular economy · Drivers · Pythagorean fuzzy DEMATEL

Introduction

Changing climate over the globe has significantly disrupted the ecosystem and it has become hazardous for human life. Hence, it is a serious issue for various stakeholders across

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the globe (D'Amato et al. 2017; Sofuoğlu and Kirikkaleli 2022). The air pollutants from greenhouse gas emissions have resulted in the death of 4.2 million people (Mishra et al. 2022). As a result, minimizing emissions has become a major concern and responsibility of the entire nation (Kovacikova et al. 2021). Notably, the United Nations (UN) has come up with sustainable development goals (SDGs) that ensure a healthy society, environment, and economy. To ensure SDGs, different business sectors are striving to shift their linear traditional economy to a low-emission economy to ensure sustainable production and consumption (Tumilar et al. 2020).

Various business ventures around the globe are keen to adopt circular economy principles, especially firms in the European Union (EU) (Hong Nham and Ha 2022). In one of the reports of the European Commission, it is estimated that with the adoption of circular economy (CE) practices in manufacturing, economic gains of $ 600 billion could be achieved per year in the EU (Korhonen et al. 2018). The rapidly growing research on natural resources of energy and fossil-free fuel energy helps in reducing climate change by minimizing greenhouse gas emissions (Shahsavari and Akbari 2018; Yan et al. 2022). Also, some countries like Sweden, France, and Denmark are committing to achieving a net-zero economy by 2050 (IEA 2020). The net-zero concept is defined as "*the balance between the amount of greenhouse gas produced and the amount removed from the atmosphere*" (Ku et al. 2021).

Enormous action plans have been considered to achieve SDGs, such as investing in renewable sources of energy, minimizing fossil fuel consumption, and adopting digital technologies to optimize resource consumption (Kristoffersen et al. 2020). Achieving sustainability across various sectors is highly significant to sustain in the competitive market (Rejeb et al. 2022). To ensure sustainable development across industrial sectors, it is very much important to develop a net-zero economy infrastructure (Stern and Valero 2021). In this regard, a business model of a net-zero economy would be needed to achieve sustainability in the business unit (Bonsu 2020).

The shift from linear economy, i.e., the take-make-waste approach toward a CE, is increasing and becoming a strategic approach across the world. The concept of circular economy and net-zero economy are replacing linear approaches with recycling, reusing, and reducing approaches (Chauhan et al. 2022). Multiple barriers are restricting the adoption of CE practices, including but not limited to "challenges in taking back" (Govindan and Hasanagic 2018), lack of awareness in society (Tura et al. 2019), and limited technology for recycled material (Bilal et al. 2020).

Researchers have suggested that effective adoption of CE practices along with the net-zero economy concept is only possible by integrating digital technologies such as artificial intelligence, big data analytics, cyber-physical system, internet of things, additive manufacturing, and others (Ajwani-Ramchandani et al. 2021; Chauhan et al. 2022; Ha et al. 2022). Thus, many studies have agreed that the adoption of CE practices has a link with digital technologies as it ensures optimized resource utilization, predictive maintenance, tracking of products even after their end of life for recycling purposes, and many more (Chauhan et al. 2021; Kamble et al. 2018a).

Big data analytics can significantly help in achieving sustainability by collecting real-time data and analyzing them for better decision-making (Dubey et al. 2019; Chang et al. 2022). For instance, real-time data can be analyzed to forecast the demand and accordingly maintain the inventory level, which minimizes waste and ensures the shelf life of the product (Ivanov and Rozhkov 2020). Digital technologies also ensure identifying best practices for recycling and refurbishing activities, thereby minimizing or eliminating waste (Khan et al. 2021). For instance, deep learning techniques for image recognition help in improving e-waste recycling practices (Nowakowski and Pamuła 2020). Digital technologies can also be a driver for mass personalization. Artificial intelligence and internet of things (IoT) based technologies enable mass personalization and enhance customer satisfaction (Aheleroff et al. 2020). Predictive maintenance has become easy using these digital technologies to enhance the life cycle of products/machinery (Rymaszewska et al. 2017). In a nutshell, industries that are adopting digital technologies are enhancing their capabilities in production, supply chain, logistics, and recycling practices. Therefore, identifying the drivers of digital technologies to achieve sustainable practices in the context of a net-zero economy is important. Based on the review of literature, this study identifies the digitalization drivers. The identified drivers are then validated using a survey of industry practitioners and academia. Further, the shortlisted drivers were analyzed using a multi-criteria decision-making technique. In these regards, the following research questions are answered in the present study:

RQ1. What are the driving forces of digitalization in achieving sustainable practices in the context of a net-zero economy (NZE)?

RQ2. How these drivers influence each other in the adoption process of sustainable practices in the context of NZE?

To answer these research questions, this study sets some objectives, which are mentioned below:

- To analyze the literature thoroughly to identify the possible drivers of digitalization to achieve sustainable practices in the context of NZE.
- To shortlist the drivers of digitalization through a survey.
- To analyze shortlisted drivers using novel multi-criteria decision-making methods.

This study focused on identifying drivers of digitalization and analyzing them with the help of multi-criteria decision-making techniques. The remaining flow of the study is as follows: in the "Literature review" section, a literature review has been discussed and possible drivers of digitalization have been identified. "Research methodology" section discusses the methodology used in this study. "Analysis and discussion" section discusses the results, and "Implications" section presents the discussion. Finally, "Conclusion" section includes the implications, conclusions, and limitations of the study.

Literature review

Digitalization in the net-zero economy

As per Brundtland and Mansour (1987), sustainable development is the implementation of new business strategies that follows the organizational needs along with the shareholders supporting and securing the resources which are required for future developments. Considerable environmental benefits can be achieved through proper actions for environmental change such as diversified and secured energy. According Sovacool (2016), significant environmental benefits could be attained by taking appropriate environmental actions, such as securing energy for a healthy environment for the future generations. Jenkins et al. (2021) discussed the net-zero structure to satisfy today's needs and those of future generations. For controlling industrial activities, it is always better to create a net-zero infrastructure to satisfy the needs of today and the future by bringing the economy to net zero. Likewise, a net-zero economy framework will always be useful for environmental sustainability. This type of framework will always recognize sustainable development in order to achieve a balance in greenhouse gas emissions, thereby controlling global warming (Kılkış and Kılkış 2018). The definition of a net-zero economy is also addressed by other countries with a growing world population (Sachs et al. 2021; Singh et al. 2022).

Industry 4.0 denotes the fourth revolution of industries. In 2011, the term I4.0 was defined by Hannover Fair in Germany. The most frequently cited definition extracted from the literature is that I4.0 assumes the operation of IT-related connections among people and machines with the exchange of data and information (Patalas-Maliszewska and Skrzeszewska 2018). I4.0 uses the resources from multiple fields that are allowed by the massive sensors with the IoT and big data technologies which leads to modern generations of computing technologies (Wankhede and Vinodh 2022). Okorie et al. (2023) discussed the role of digital technologies in achieving a net-zero economy. The authors adopted resource-based view theory to analyze the competitive advantages achieved by manufacturing firms with a net-zero economy.

Table 1 presents the existing and current research work on digitalization in the CE.

Drivers of digitalization to achieve sustainable practices

CE transformation is a strategic priority for organizations all over the world. It is also an alternative to the traditional linear economy and works on the principle of renewal, using the materials again while reducing the waste and moving toward pollution reduction (Yuan et al. 2008). Thus, CE follows the end-of-life approach with the law of reuse, recycle, reduce, and recover. To address the issues of data unavailability and ecosystem transformation, industries should shift from a linear approach to CE. The researchers argue the key factors for CE transformation move in parallel with the digital revolution, including the utilization of big data, smart sensors, artificial intelligence, fog computing, and automation (Ingemarsdotter et al. 2020; Ajwani-Ramchandani et al. 2021; Chauhan et al. 2021). This is how the academic adoption of CE is integrated with digitalization, which facilitates predictive analytics through the product life cycle of the companies (Chauhan et al. 2021).

Digitalization is also divided into five major categories of big data analytics, IoT, cyber-physical systems, virtual reality, and machine learning (Rüßmann et al. 2016). The combination of methods of managerial skills and technology transfer toward a CE can capitalize on the possibilities. The researchers identified a gap in the literature to present the concept of CE as a basic necessity to sustain life on earth (Ghisellini et al. 2016; Geissdoerfer et al. 2017). Jarrett (2013) demonstrated the CE as a primary requirement to safeguard the resources and sustain life on earth. A CE is also defined as a driver in the economic crisis and an important resource for consumers and manufacturers (Pearce and Turner 1989). Natural resources should always be conserved. The circular system must replace the open-ended system to conserve natural resources. As per Murray et al. (2017), the authors not only identified the CE's background but also provided some optimal solutions for the CE. The argument is that the integration of sustainability and CE will have certain environmental benefits (Yang et al. 2018). CE signifies the green revolution that results in environmental, social, and economic benefits. D'Amato et al. (2017) stated that CE is focused on resources, whereas the green revolution is focused on bio ecological processes. CE also increases the green performance by working on the recreational parts (Kadar and Kadar 2020). Machine learning can accelerate the process of CE at every stage of supply chain management (Kadar and Kadar 2020). Scientists have researched closed-loop supply chains (CLSC) and reverse logistics in connection with CE (Wilson et al. 2022). The closed-loop supply chain enhances the environmental value by returning

Table 1 Current research-related studies

Author	Contribution
Wankhede and Vinodh (2022)	The study focuses on the automotive industry, and the implementation is done using Industry 4.0 technology. And a conceptual framework is drawn to show the significance of I4.0
Singh et al. (2022)	The primary clients for the study are from industries and suppliers, which are the sustainable medium. The external pressures are created by society, the community, consumers, and the government
Kaur et al. (2022)	This study indicates the technological barriers in the blockchain adoption process
Chauhan et al. (2022)	The authors discussed technologies like machine learning and internet of things as beneficial for the CE. Several barriers were identified in the study. As a business model for this study, a product-service system was developed
Hong Nham and Ha (2022)	The authors have presented a non-linear relationship between circularity and digitalization, suggesting some positive impact to reach a certain level
Kristoffersen et al. (2020)	This is a review-based work on CE goals in sustainable production and consumption at the United Nations
Belhadi et al. (2022)	There is a self-assessment model to evaluate the integration level of CE and Industry 4.0 inside the organization. It also provides a relevant framework for industry practitioners
van Schalkwyk et al. (2018)	This article discussed the different types of technologies, from heat to mass transfer, environmental impact, and system simulation, that will lead to knowledge through data
Kumar et al. (2021)	The research identifies the major obstacles to the successful implementation of CE and Industry 4.0. The major obstacles are a lack of policies and a lack of government support
García-Muiña et al. (2022)	The study integrates social organizational life cycle assessment and Industry 4.0 to measure the performance of manufacturing industries
Rejeb et al. (2022)	The study analyzes the current research methods in conjunction with the internet of things and CE as innovative technologies
Mishra et al. (2022)	This study identifies the positive impact of CE, resource optimization, and digitalization on fulfilling the goal of a net-zero economy
Kurniawan et al. (2022)	The authors emphasized that recycled goods through mobile applications and waste recycling can create more job opportunities in a country
Peiró et al. (2021)	This article discussed the digital and standard technologies for CE in terms of a few projects
Dantas et al. (2021)	The study is a critical literature review based upon 50 articles on CE and Industry 4.0 technology
Nandi et al. (2021)	The study is all about multi-level stakeholders in an organizational supply chain. The results lead to sustainable consumption and production
Burmaoglu et al. (2022)	Researchers identified four major areas in business models, industrial manufacturing, additive manufacturing, and sharing economy
Agrawal et al. (2022)	The authors studied digitalization for CE and the consumer's involvement in it

the materials to the producers (Wilson et al. 2022). Value recovery in a CLSC includes only the organization's supply chain and never includes other channel participants (Chauhan et al. 2022).

Digital technologies are considered to be the major enablers of CE by checking the components, products, data available, and materials used to improve decision-making in any industry culture (Antikainen et al. 2018; Nobre and Tavares 2020). Digital technologies are an inevitable part of information exchange for the circular economy of natural resources. For example, the IoT (internet of things) can enable the tracking of natural capital. Similarly, big data analytics encourages several aspects of CE waste material to be resource recycled for industrial benefits. Data analytics is used as a tool to predict the accuracy of any product, the maintenance time, and to optimize the consumption of energy (Porter and Heppelmann 2014). Cardinali and de Giovanni (2022) explore the intersection of responsible digitalization and green practices. The authors argue that responsible digitalization can be achieved by adopting green practices, which can help mitigate the negative environmental impacts of digital technologies. The authors argue that responsible digitalization is an approach to digital technology that prioritizes the ethical, social, and environmental impacts of technology, in addition to its economic benefits. The authors also note that responsible digitalization is becoming increasingly important as the use of digital technologies continues to grow and the negative impacts of these technologies become more apparent.

All these signify the contribution of CE to many business strategies, from recycling to reuse through their design process. In a nutshell, 20 prominent drivers of digitalization were identified through an extensive literature survey and have been presented in Table 2.

Table 2 Drivers of digitalization for sustainable practices

Drivers	Description	References
Availability of financial resources	Financial resources are an important need adopting digital technologies for sustainable production and consumption	(Kamble et al. 2018b; Ghobakhloo 2020)
Support from top management	Commitment from top management toward the adoption of digital technologies makes the transaction process smooth	(Kagermann 2015; Hecklau et al. 2016; Ghobakhloo 2020)
Cost reduction	An earlier prediction of machine failure helps reduce maintenance-related costs	(Calabrese et al. 2021; Fatorachian and Kazemi 2021)
Improve time to market	Additive manufacturing-based digital technologies help in quick product development and improve time to market	(Stentoft et al. 2021; Wankhede and Vinodh 2022)
High degree of automation	With digital technologies such as AI and ML, a high degree of automation can be achieved	(Karekla et al. 2021; Raimo et al. 2022)
Real-time sensing capability	IoT devices help in collect data from machines and enhance real-time sensing capabilities	(Rachinger et al. 2019; Singh et al. 2021)
Efficient resource utilization	With digital technologies, the resource can be allocated more intelligently, thereby enabling sustainable production and consumption	(Tiwari 2021; Zhang et al. 2022)
High degree of safety	Digitalization with sound data about process input and output ensures quality and safety	(Raimo et al. 2022; Wankhede and Vinodh 2022)
Enhanced resilience of the system	Adoption of digital technologies enhances the sustainability and resilience of the system	(Yang et al. 2021; Wankhede and Vinodh 2022)
Increased customization of product	Product customization can be easy with the adoption of 3D printing	(Stentoft et al. 2021; Karekla et al. 2021)
Remote monitoring	IoT and big data help in remote monitoring, which enables a person to monitor all activity remotely as well	(Raimo et al. 2022; Wankhede and Vinodh 2022)
Decentralization of tactical decision-making	It may relieve the pressure on managers, so they allowing them to devote more time to strategy	(Schneider 2018; Marques et al. 2017)
High computing power	Advanced manufacturing simulations and predicting maintenance issues can be smoothly done with high computing power	(Ghobakhloo 2020; Yang et al. 2021)
Digital culture	Digital culture ensures better time management and improves communication between teammates	(Borchard et al. 2022; Grover et al. 2022)
High degree of security	A high degree of security using digital technologies reduces security breaches and cyber-attacks	(Raimo et al. 2022; Wankhede and Vinodh 2022)
Enhanced life cycle of equipment	A machine learning algorithm helps predict the health of equipment, thereby enhancing the life of the equipment	(Sakao et al. 2021; Aheleroff et al. 2020)
Reduced energy consumption	Digital technologies include smart lighting and a smart thermostat, which in turn reduce energy consumption and ensure sustainable production and consumption	(Hong Nham and Ha 2022; Kristoffersen et al. 2020)
High-quality product	Industries are using digital technologies such as process automation to maximize production, improve quality, and minimize resource consumption	(Belhadi et al. 2022; Yang et al. 2021)
Enhancing the flexibility in manufacturing process	Adoption of digital technologies such as process automation and 3D printing ensures flexibility in the manufacturing processes as well as enables mass personalization	(Burmaoglu et al. 2022; Kristoffersen et al. 2020)

Table 2 (continued)

Drivers	Description	References
Increased tracking	Using IoT sensors, real-time monitoring and tracking of processes and products is possible, and it ensures safe working conditions	(Hong Nham and Ha 2022; Stentoft et al. 2021)

Research gaps

IoT can be better implemented with the combination of big data analytics, cloud computing, and artificial intelligence technologies. The concept of CE can be technologically and ecologically feasible here (Sousa-Zomer et al. 2018; Tseng et al. 2018). The main role of big data is to enable the CE to act scientifically to utilize IoT and big data for the benefit of industries that are moving toward CE (Bressanelli et al. 2021). It is specifically meant to make a smart product with additional challenges to maintain security issues. IoT can benefit in overcoming all the issues with the integration of all the technologies at the organizational level. Hence, it is a requirement to understand the potential of IoT with the integration of other technologies for CE in the organizational aspect (Rejeb et al. 2022). A net-zero economy employs sustainable manufacturing, which is in high demand and will become increasingly popular in the coming years. The circular capabilities of CE boost sustainable manufacturing. The themes introduced worldwide are to increase the sustainability of the environment. Net-zero economy and sustainability include the subthemes of CE, IoT, big data, and cloud computing. To achieve this sustainability goal, an integrated framework combining the technologies from the basic level is required. Sustainability can be defined as the combination of people, planet, and profit (Sehnem and Oliveira 2017; Zeng et al. 2017; Manninen et al. 2018; Tseng et al. 2018; Wehner et al. 2021).

Organizations should shift from a linear economy to CE which gives different values for different resources. Wastage of resources, CO_2 emissions, and misuse of energy can be minimized a lot by slowing down the processes. Renewable energy usage, technology innovation, and recycling should be highly promoted for maintaining a sustainable environment. Sustainability is seen as a symbol of a company's social responsibility to the environment and people by reputable companies (Shevchenko et al. 2016; Geissdoerfer et al. 2017; Fernando et al. 2022). To maintain sustainability, the net-zero economy plays an important role in closing the gaps. It brings CE to a place for recycling and reuse.

Research methodology

The flow of the present research study is shown in Fig. 1. First, a list of drivers of digitalization was identified from the literature review and is presented in Table 1 of the "Literature review" section. Next, the shortlisting of identified drivers and validating their relevance for the study was done using a survey-based study. A list of questionnaires was prepared corresponding to each driver and was sent to several manufacturing industries, including small-scale, medium-scale, and large-scale industries. The respondents were asked to provide a rating in the form of a Likert scale, which varies from 1 to 5 where 1 indicates strongly disagree and 5 indicates strongly agree. The survey was administered using Google Forms, and the link to the Google Form was emailed to all firm respondents on 03 May 2022. The respondents were asked to fill out their responses within a month and, after a month, a reminder mail was sent to all those firms from which responses had not yet come. Then finally, we received responses from 33 firms. Out of 33 responses, 1 response was inadequate, so 1 response was deleted, and only 32 responses were considered for further study. The profile of respondents who participated in the survey is presented in Table 3.

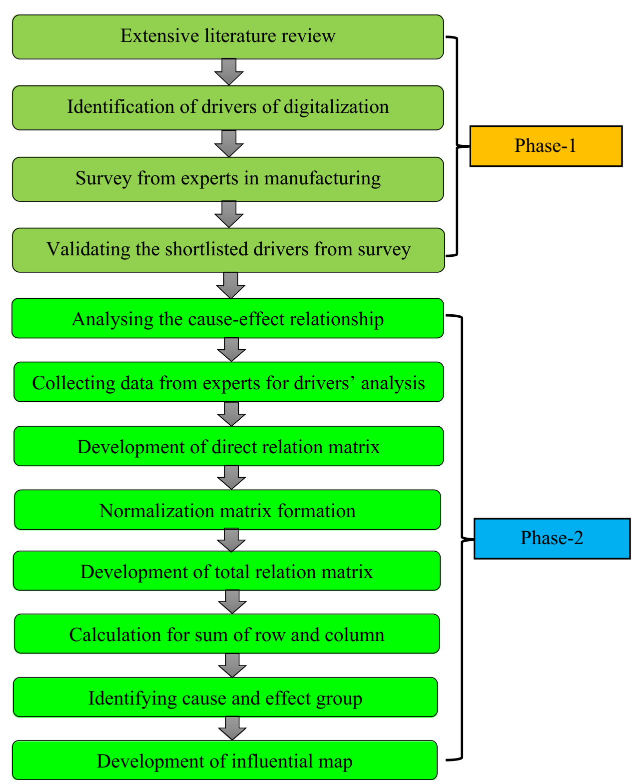

Fig. 1 Research methodology process

Table 2 depicts the list of drivers of digitalization that were identified in the literature to achieve sustainable production. The identified drivers were then circulated for validation through the survey. The responses collected from the survey were then analyzed and the mean and standard deviation of each driver were calculated and presented in Table 4.

The drivers with a mean score higher than 3 were considered for further analysis. So, from the list, out of 20 drivers only 19 drivers were validated using survey data, and one driver, namely, "Enhanced life cycle of equipment," was not included for further study. Also, we asked the respondents to suggest any other drivers of digitalization that were not listed in the survey questionnaire. We got suggestions from respondents to add one more driver, namely, "globalization." So, this study includes 20 drivers, of which 19 were taken from literature and one driver was suggested by experts. Finally, the selected 20 drivers were further evaluated using the Pythagorean DEMATEL approach.

Pythagorean fuzzy set theory

The bias and uncertainty in multi-criteria decision-making (MCDM) approaches can be minimized with the adoption of intuitionistic fuzzy sets (IFS) (Lahane

Table 4 Survey results for drivers of digitalization

Drivers	Mean	SD
Availability of financial resources	3.719	1.231
Support from top management	3.656	1.215
Cost reduction	3.188	0.882
Improve time to market	3.375	0.927
High degree of automation	3.844	1.093
Real-time sensing capability	3.000	1.146
Efficient resource utilization	3.156	1.202
High degree of safety	3.469	1.250
Enhanced resilience of the system	3.219	1.082
Increased customization of product	3.625	1.111
Remote monitoring	3.531	1.118
Decentralization of tactical decision-making	3.688	0.916
High computing power	3.344	0.922
Digital culture	3.875	1.053
High degree of security	3.438	1.273
Enhanced life cycle of equipment	2.156	0.712
Reduced energy consumption	3.375	0.960
High-quality product	3.469	1.250
Enhancing the flexibility in manufacturing process	3.594	1.271
Increased tracking	3.531	0.935

Table 3 Profile of respondents who participated in the survey

Checks	Details	Responses	Percentage
Age group	26–31 years	8	25%
	32–37 years	13	41%
	38–45 years	7	22%
	Above 45	4	13%
Gender	Male	5	16%
	Female	27	84%
Current position	CEO/COO/CIO	1	3%
	Managing director/executive director	1	3%
	SVP/VP/AVP	3	9%
	Manager/consultant	5	16%
	Specialist/analyst/engineer	13	41%
	Supervisor/coordinator	5	16%
	Academia	4	13%
Work experience (in years)	Less than and equal to 5	6	19%
	6–10	11	34%
	11–15	8	25%
	16–20	4	13%
	More than 20	3	9%
Type of organization	Automotive	11	34%
	Manufacturing unit	7	22%
	IT and consulting	4	13%
	Logistics and supply chain	6	19%
	Educational institutions	4	13%

and Kant 2021a). There are three ways to represent IFS, namely, hesitancy, membership, and non-membership function (Lahane and Kant 2021b). However, in certain instances, IFS could not manage imprecision when the degree of the membership function is greater than one. So, to avoid these issues, IFS has been integrated with three separate extensions, namely, the Pythagorean set, the neutrosophic set, and the orthopedic set (Abdullah and Goh 2019; Yazdi et al. 2020). In the present study, the Pythagorean fuzzy set was used to handle issues related to bias, uncertainty, and imprecision. All data points in the IFS, i.e., (x,y), will lie under the line $X + Y \leq 1$, but in the case of the Pythagorean fuzzy set, all data points lie under the area $X^2 + Y^2 \leq 1$. Hence, the range for the Pythagorean fuzzy set is larger than IFS. Therefore, the Pythagorean fuzzy set gives more flexibility to the decision-makers for the problem related to vagueness in decision-making. A comparison of space for the Pythagorean fuzzy set and the IFS is represented in Fig. 2. The Pythagorean fuzzy set used in this study for data collection is presented in Table 5.

Pythagorean DEMATEL

Many MCDM methods exist in the literature for solving decision-making problems. One such MCDM method is DEMATEL, which is widely used for analyzing the drivers/factors/barriers and making a causal model (Abdullah and Goh 2019; Li and Yazdi 2022a). It is considered a highly informative approach that provides useful information for cause-and-effect group factors. There are certain advantages of DEMATEL over other MCDM methods (Yazdi et al. 2020) such as:

Table 5 Pythagorean fuzzy number and linguistic terms were used in the study (Shafiee et al. 2022)

Linguistic terms	Pythagorean fuzzy number
Very low impact (VLI)	(.15, .85)
Low impact (LI)	(.25, .75)
Moderate low impact (MLI)	(.35, .65)
Medium impact (MI)	(.50, .45)
Moderate high impact (MHI)	(.65, .35)
High impact (HI)	(.75, .25)
Very high impact (VHI)	(.85, .15)

- It develops a digraph that helps in visualizing the structural model of factors in a decision-making problem.
- It develops a cause-and-effect model that categorizes factors into two groups, namely, the cause group and the effect group.
- It identifies the strength of the interrelationship between factors, which makes it more advantageous over other structural modeling approaches (Li and Yazdi 2022b) such as interpretive structural modeling (ISM) and total interpretive structural modeling (TISM).

But the problem with classical DEMATEL is that it cannot handle vagueness in human decision-making (Lahane and Kant 2021b). In this regard, IFS DEMATEL and Pythagorean fuzzy set DEMATEL came into the picture to deal with vagueness in decision-making. This study uses Pythagorean fuzzy DEMATEL, which has an added advantage in dealing with imprecision over IFS DEMATEL.

Thus, in this study, the Pythagorean fuzzy set was used along with the DEMATEL approach to analyze the drivers

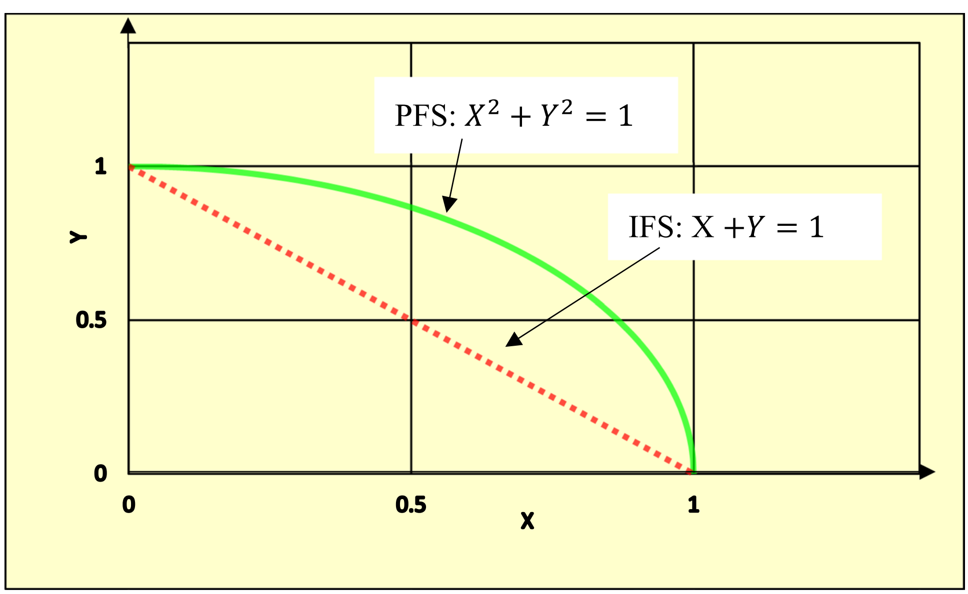

Fig. 2 Comparison of space in IFS and PFS

of digital technologies to achieve sustainable production and consumption in a net-zero economy. Recently, many researchers have used Pythagorean fuzzy DEMATEL, as mentioned in Table 6.

The steps involved in the PF-DEMATEL approach are as follows:

Step 1: Developing a direct relation matrix

It is the first step in the PF-DEMATEL approach, where data is collected from experts and the raw data is presented in the form of a relationship matrix. The raw data collected from the experts was then converted into a Pythagorean fuzzy set (μ_{ij}, v_{ij}). The input relation matrix in the form of a Pythagorean fuzzy set is presented in Eq. 1 (Shafiee et al. 2022).

$$D = \begin{bmatrix} (0,0) & (\mu_{12}, v_{12}) & \cdots & (\mu_{1n}, v_{1n}) \\ (\mu_{21}, v_{21}) & (\mu_{22}, v_{22}) & \cdots & (\mu_{2n}, v_{2n}) \\ \cdots & \cdots & \cdots & \cdots \\ (\mu_{n1}, v_{n1}) & (\mu_{n2}, v_{n2}) & \cdots & (0,0) \end{bmatrix} \tag{1}$$

Further, the relationship matrix received from each expert was then aggregated together to make a single direct relationship matrix. A direct relationship matrix was formed by using Eq. 2 (Shafiee et al. 2022).

$$[a_{ij}] = \left[\left(\sqrt{1 - \prod_{k=1}^{m}\left(1 - (\mu_{ij})^2\right)^{\frac{1}{m}}}, \prod_{k=1}^{m}(v_{ij})^{\frac{1}{m}}\right)\right] \tag{2}$$

where a_{ij} indicated the elements of aggregated direct relationship matrix, m represents the number of experts considered in the study, and μ_{ij}, v_{ij} is the rating in the form of a Pythagorean fuzzy set that indicates the influence of driver i on j by expert k.

Step 2: Conversion of the Pythagorean fuzzy average matrix into crisp number average direct relation matrix

Conversion of Pythagorean fuzzy set into crisp numbers was done using Eq. 3 and the average direct matrix in crisp numbers is presented in Eq. 4 (Lahane and Kant 2021b).

$$a_{ij} = \mu_{ij}^2 - v_{ij}^2 \tag{3}$$

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \tag{4}$$

Step 3: Development of normalized relation matrix

Once we prepare the average crisp direct relation matrix, the next step is to develop a normalized relation matrix. The normalized relation matrix is formulated using Eq. 5 and is presented in Eq. 6 (Majumdar et al. 2022).

$$m = min\left[\frac{1}{max\sum_{j=1}^{n} a_{ij}}, \frac{1}{max\sum_{i=1}^{n} a_{ij}}\right] \tag{5}$$

$$N = A \times m \tag{6}$$

Step 4: Formulate the total relationship matrix (T)

The total relationship matrix is calculated by using Eq. 7.

$$T = N(I - N)^{-1} \tag{7}$$

where I is a unit matrix.

Step 5: Categorization of drivers into the cause-and-effect group

Table 6 Recent studies on Pythagorean fuzzy DEMATEL

Study	Contribution
Abdullah and Goh (2019)	PF-DEMATEL was used to analyze the evaluation criteria of solid waste management. Ten evaluation criteria were considered for solid waste management, and using the approach, it was found that four criteria belong to the cause group and six criteria belong to the effect group
Xie et al. (2021)	Aimed toward identifying and analyzing the innovative investment strategies for the renewable energy sector using the PF-DEMATEL approach
Lahane and Kant (2021b)	Used PF-DEMATEL to analyze the barriers to the adoption of circular practices in the supply chain for their successful adoption to minimize waste generation and enhance environmental conditions
Giri et al. (2022)	Used PF-DEMATEL for supplier selection for sustainable supply chain management
Yüksel and Dinçer (2022)	Aimed to analyze the investment strategies for the nuclear energy sector in Turkey. The authors use the PF-DEMATEL approach to analyze the factors affecting investment strategies for nuclear energy in Turkey
Sivri et al. (2022)	This study analyzes the attributes of polar clothing. Clothing is one of the most important problems facing scientists in the Antarctica region for reasons of safety and comfort. To analyze different polar clothing, various alternatives were assessed using certain attributes such as material, layer number, and waterproofing capability. These attributes were analyzed using the PF-DEMATEL approach
Shafiee et al. (2022)	The authors used PF-DEMATEL to analyze the risk associated with the supply chain of perishable products during COVID-19

To categorize drivers into the cause-and-effect group, a total relation matrix was used. Each row and column of the total relation matrix are summed up and are represented by using the letters "R" and "C." Further, (R + C) and (R – C) were calculated and are presented in Table 7. (R + C) shows the prominent score of a driver, i.e., the importance of a driver based on its dependence on others. (R – C) score shows the driver's influence on the system. The positive value of (R – C) is categorized as cause group drivers whereas the negative value of (R – C) is categorized as effect group drivers.

Analysis and discussion

The above-described methodology was adopted to analyze the drivers of digitalization to achieve sustainable production and a net-zero economy. Data were collected from ten industrial experts (one—general manager, two—Sr. managers, three—managers, three—shift in charge, and one—industrial engineer) in the form of linguistic terms as specified in Table 5. Further, the collected data was then converted to Pythagorean fuzzy numbers. The data from all experts were then aggregated and converted into a crisp number, which is presented in Appendix Table 9. In Appendix Table 10, a normalized relation matrix is developed and is presented. Further, the total relation matrix is calculated and is presented in Appendix Table 11. Then finally, the drivers are categorized into the cause-and-effect group and are presented in Table 7.

Cause group drivers

The main objective of this study is to identify the major drivers of digitalization to achieve a net-zero economy in a supply-chain loop. The research findings are illustrated in the sections below to answer the research questions proposed for our study. To answer the research questions, the identified cause drivers are in a sequence based on the influential score of R + C. The influential map of drivers of digitalization was created and is presented in Fig. 3. Out of 11 causal drivers, three major and three minor drivers are identified from the analysis. The major three causal drivers, in ascending order, are high degree of automation, enhancing flexibility in the manufacturing process, and real-time sensing capability. From the bottom, the lowest three causal drivers are a high degree of security, decentralization of tactical decision-making, and high-quality product. In a similar way, the (R – C) value is also calculated for the cause-effect drivers. High computing power, availability of financial resources, and remote monitoring are the major causal factors. According to the (R–C) evaluation, the minimal cause drivers are decentralization of tactical decision-making, a high degree of security, and enhancing the flexibility in the manufacturing process.

Table 7 Categorization of drivers into the cause-and-effect group

Drivers	R	C	R + C	R – C	Cause/effect
Availability of financial resources	0.796	– 0.095	0.701	0.891	Cause
Supports from top management	– 0.642	0.6	– 0.042	– 1.241	Effect
Cost reduction	– 1.059	0.04	– 1.018	– 1.099	Effect
Improve time to market	– 0.403	0.491	0.088	– 0.895	Effect
High degree of automation	1.371	0.87	2.241	0.501	Cause
Real-time sensing capability	1.105	0.37	1.475	0.735	Cause
Efficient resource utilization	– 0.151	0.712	0.561	– 0.863	Effect
High degree of safety	– 0.288	0.597	0.309	– 0.885	Effect
Enhanced resilience of the system	0.452	1.28	1.732	– 0.828	Effect
Increased customization of product	0.878	0.292	1.17	0.586	Cause
Remote monitoring	1.024	0.28	1.304	0.744	Cause
Decentralization of tactical decision-making	0.111	– 0.022	0.089	0.133	Cause
High computing power	1.016	– 0.329	0.686	1.345	Cause
Digital culture	0.479	0.847	1.325	– 0.368	Effect
High degree of security	– 0.109	– 0.367	– 0.475	0.258	Cause
Reduced energy consumption	– 0.121	0.12	– 0.001	– 0.241	Effect
High-quality product	0.429	– 0.066	0.363	0.495	Cause
Enhancing the flexibility in manufacturing process	1.086	0.665	1.751	0.421	Cause
Increased tracking	0.535	– 0.021	0.514	0.556	Cause
Globalization	0.879	1.124	2.003	– 0.245	Effect

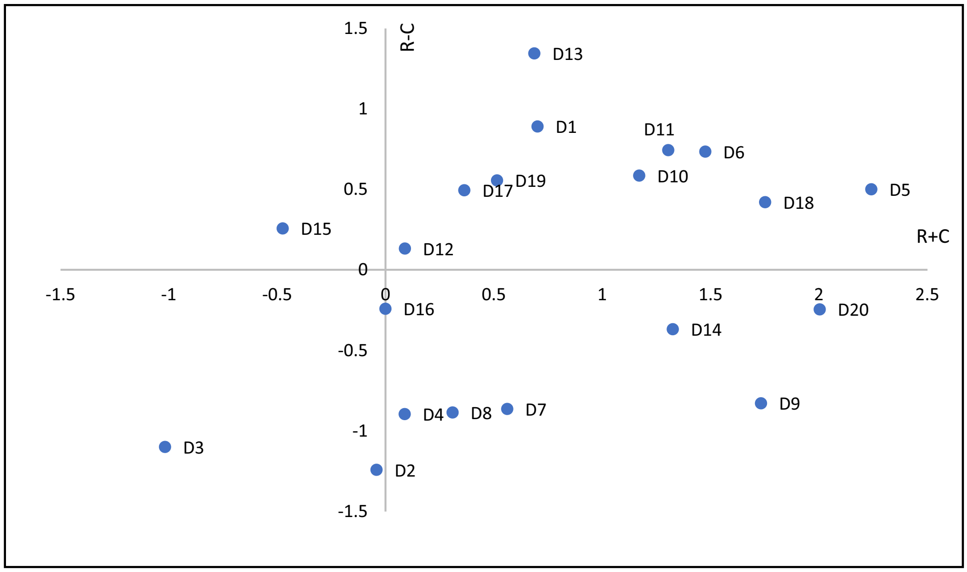

Fig. 3 Influence map of drivers of digitalization

Effect group drivers

Three major and minor drivers have been identified out of nine effect drivers. Globalization, enhanced resilience of the system, and digital culture are the three major effect drivers. Cost reduction supports from top management and reduced energy consumption are the minimal effect drivers. It is always required to attract stakeholders by adopting the net-zero economy in the supply chain. Similarly, all effect drivers for (R – C) show minimal values. All these cause-effect drivers need specific attention from scientists, policymakers, and researchers to be handled perfectly. The role of industry is very crucial in this regard. Scientists work continuously toward this success. Recycling industry products is the major focus of net-zero CE. Industry and academic collaboration is required on a long-term basis for the development to receive governmental funding. New-age technologies like cloud-IoT, AI-ML, and augmented reality are required to achieve multidisciplinary research work. Subscription-based technologies should be explored before being purchased from the same academic institutions.

A comparative study of current study with other published article on drivers of NZE is presented in Table 8.

Implications

Theoretical implications

Nowadays, industries are growing up to a net-zero economy in supply chain management. Twenty drivers were taken for the study. Out of twenty drivers, nineteen were filtered to finally answer the research questions that were identified from the literature and the research gaps. Based on the opinion of the domain experts, the questionnaire was circulated to the respective industries. Twenty drivers were tested using the help of the PF-DEMATEL approach. There are a greater number of cause groups than effect groups. Customer awareness can be achieved through

Table 8 Comparison of the current study and previous published studies

Study	Contributions
Pan and Pan (2021)	The barriers, drivers, and strategies for zero carbon building development in high-density cities were discussed. The study found the economic driver to be most significant. Further, a multi-level framework was developed by integrating measures, initiatives, and visions to achieve zero carbon buildings
Walk and Stognief (2022)	Aimed to examine the driving factors behind the UK's climate policy, from its decision to phase out coal to its commitment to achieving net-zero emissions by 2050, by considering the opinion of 22 experts
Singh et al. (2022)	Presents an exploratory framework that examines the drivers, barriers, and practices associated with the transition to a net-zero economy, from a supply chain and multi-stakeholder perspective
Present study	The important drivers of net-zero economy, primarily in manufacturing sectors, were identified, and the Pythagorean DEMATEL method was used to analyze the contextual relationship of one driver over another, followed by the development of a cause and effect plot of the drivers of net-zero economy

collaborative work with academia and industry. The study has some unique contributions in terms of drivers. It exclusively analyzes the drivers and identifies the cause-effect relationships among the drivers. The cause-effect digraph only represents the strong effect. This strategy's implementation will surely help organizations tackle new challenges. In the past few years, some researchers have started using the concept of the net-zero economy. The study explains the evolution of CE by using previous data from various geographical locations and industries. Many industries are not prepared for the net-zero economy and there is enough scope for future research agendas. The study will give future research directions in the field of the net-zero economy.

Practical implications

The present study has the following implications:

- The study suggests that emerging technologies like artificial intelligence (AI), blockchain, and the internet of things (IoT) can contribute significantly to achieving sustainable practices in a net-zero economy. Therefore, individuals and organizations should adopt these technologies to enhance their sustainability practices.
- Collaboration between different stakeholders, like businesses, governments, and civil society, is essential in promoting sustainable practices. The study highlights the importance of collaboration in the development and deployment of emerging technologies. Thus, policymakers and organizations should increase collaboration to leverage the potential of these technologies.
- The study emphasizes the need to create awareness among individuals and organizations about the potential of emerging technologies in promoting sustainability. Therefore, organizations should create awareness campaigns and training programs to educate their employees and stakeholders about the benefits of such technologies.
- The study suggests that innovation is critical to driving sustainable practices. Therefore, policymakers should encourage innovation through research grants and tax incentives to promote the development of sustainable technologies.
- The study suggests that setting targets is essential to achieving sustainable practices. Therefore, policymakers should set targets for reducing greenhouse gas emissions and promoting sustainable practices in different sectors, such as transportation, agriculture, and energy.

Conclusion

Now the current trend in the supply chain is the NZE. Based on this trend, the drivers are also changing from a linear economy to CE and now NZE. Hence, from the literature review, twenty drivers were identified. Then it is filtered into 19 drivers based on their relevance to the specific industry. The DEMATEL analysis identifies important causal factors as a high degree of automation, enhancing the flexibility in the manufacturing process, and real-time sensing. The major contributions of the study are two-fold. It analyzes the drivers for implementation in various industries. The study draws a cause-effect digraph among the drivers to identify the major causes and the effects there after. This study will undoubtedly aid industries in maintaining a net-zero economy.

Our study has enough future scope for further research. The analysis technique can be a common method for academicians and industry people to maintain a net-zero economy. Researchers can use survey methods to determine the exact situation, which will be useful for future research on this topic. Even if so, many studies are available in this area, but still net-zero economy in supply chain management is still a contemporary research agenda with a lot on offer for exploration in future. Novel frameworks can be developed out of this study.

Again, the study has certain limitations. The outcome of the study will be useful for developing countries like India, where NZE is a very important factor. That is why the results should not be based on developed countries, where the values may vary. The analysis of the drivers is mostly dependent on the experts from academia and industry during the data collection stage. The finalized drivers can be utilized for CE and other technological methods such as neural networks. These drivers can be tested in other geographical locations with various industries in the future.

Future research can focus on evaluating the impact of emerging technologies on sustainable practices in different industries, such as energy, transportation, and agriculture. Such studies can explore the role of technologies such as blockchain, artificial intelligence, and the internet of things in facilitating sustainable practices and achieving NZE. Future research can focus on the potential of emerging technologies to reduce carbon footprints in different sectors. Another area of research can examine the role of policy and regulatory frameworks in promoting the adoption of emerging technologies in the context of sustainable practices and NZE. Such studies can explore the impact of government policies and incentives on the adoption of sustainable technologies and practices, and identify gaps that need to be addressed.

Appendix 1

Table 9 Average direct relation matrix in crisp number

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20
D1	0	.057	−.5	.141	.376	.606	−.428	.442	.31	.532	.606	−.428	.645	−.317	.606	−.428	.047	.376	.5	−.163
D2	.057	0	−.562	−.043	−.562	−.3	−.163	−.562	.3	−.3	−.5	.442	−.562	.442	−.5	−.049	−.3	.047	.047	−.629
D3	.31	.442	0	.31	−.5	−.562	.141	−.7	−.7	−.486	−.629	−.3	−.428	.141	−.7	.58	−.5	−.629	−.7	.141
D4	−.7	−.317	.141	0	−.562	−.629	.141	−.5	.58	−.428	−.3	.047	−.428	.3	−.5	.3	.047	.5	−.3	.7
D5	.151	.047	.7	.5	0	.58	.5	.3	.5	.645	.7	.047	.5	.5	.376	.442	.5	.3	.7	.5
D6	.141	−.215	−.362	.141	.7	0	.484	.606	.442	−.317	.645	−.362	.7	.58	.141	.225	−.163	.58	.645	.58
D7	.442	.532	.606	−.163	.3	−.362	0	.047	.645	−.3	−.562	.047	−.428	−.5	−.5	.5	−.362	.225	−.215	.31
D8	−.3	.5	−.5	−.5	.047	−.428	−.163	0	−.049	−.163	−.5	−.3	.58	.225	.7	−.5	−.562	.057	−.486	.31
D9	.225	.442	−.3	.5	.606	.236	.606	.484	0	.141	.3	−.629	−.5	.141	−.362	.047	−.049	.225	−.215	.532
D10	−.428	.047	−.428	.3	.532	.376	−.629	.533	.5	0	.225	.3	.376	.5	.141	−.3	.645	.645	−.163	.645
D11	.33	.225	−.5	.606	.7	.645	.5	.151	.7	−.043	0	−.163	.58	.5	.645	−.629	−.5	.057	.645	.532
D12	−.428	.151	.225	.3	.442	−.163	.3	.225	.606	.376	−.3	0	−.428	.047	−.428	.047	−.049	.442	−.486	.225
D13	−.163	.141	.225	.225	.5	.532	.606	.5	.532	.047	.7	−.163	0	.141	.3	.3	.442	.442	.225	.442
D14	−.5	.047	.376	.3	.645	.3	.5	.442	.645	.58	.5	−.428	−.5	0	−.163	.047	.047	.165	−.362	.31
D15	−.5	.31	−.7	−.7	.3	.047	−.3	.5	.384	−.27	−.5	.047	.5	.3	0	−.3	−.5	−.049	−.362	.225
D16	.225	.5	.7	−.3	.047	.047	.7	.047	.384	−.5	−.5	.3	−.5	.3	−.3	0	.047	−.362	−.562	.645
D17	−.3	.3	−.362	−.5	.424	.165	−.27	.7	.047	.7	.3	−.3	−.5	.3	−.5	−.5	0	.645	.225	.442
D18	.047	.225	.3	.484	.5	.424	.5	.047	.7	.7	.3	.5	−.3	.5	−.5	.3	.5	0	.5	.7
D19	−.3	−.5	−.5	.384	.3	.645	−.3	.047	.478	−.5	.7	.3	.047	.5	.5	.047	−.5	.047	0	.5
D20	.33	.442	.58	.236	.5	.3	.606	.5	.645	.606	.3	.7	−.5	.5	−.5	.047	.3	.3	.047	0

Table 10 Normalized relation matrix

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20
D1	0	.007	−.059	.017	.044	.071	−.05	.052	.037	.063	.071	−.05	.076	−.037	.071	−.05	.006	.044	.059	−.019
D2	.007	0	−.066	−.005	−.066	−.035	−.019	−.066	.035	−.035	−.059	.052	−.066	.052	−.059	−.006	−.035	.006	.006	−.074
D3	.037	.052	0	.037	−.059	−.066	.017	−.082	−.082	−.057	−.074	−.035	−.05	.017	−.082	.068	−.059	−.074	−.082	.017
D4	−.082	−.037	.017	0	−.066	−.074	.017	−.059	.068	−.05	−.035	.006	−.05	.035	−.059	.035	.006	.059	−.035	.082
D5	.018	.006	.082	.059	0	.068	.059	.035	.059	.076	.082	.006	.059	.059	.044	.052	.059	.035	.082	.059
D6	.017	−.025	−.043	.017	.082	0	.057	.071	.052	−.037	.076	−.043	.082	.068	.017	.027	−.019	.068	.076	.068
D7	.052	.063	.071	−.019	.035	−.043	0	.006	.076	−.035	−.066	.006	−.05	−.059	−.059	.059	−.043	.027	−.025	.037
D8	−.035	.059	−.059	−.059	.006	−.05	−.019	0	−.006	−.019	−.059	−.035	.068	.027	.082	−.059	−.066	.007	−.057	.037
D9	.027	.052	−.035	.059	.071	.028	.071	.057	0	.017	.035	−.074	−.059	.017	−.043	.006	−.006	.027	−.025	.063
D10	−.05	.006	−.05	.035	.063	.044	−.074	.063	.059	0	.027	.035	.044	.059	.017	−.035	.076	.076	−.019	.076
D11	.039	.027	−.059	.071	.082	.076	.059	.018	.082	−.005	0	−.019	.068	.059	.076	−.074	−.059	.007	.076	.063
D12	−.05	.018	.027	.035	.052	−.019	.035	.027	.071	.044	−.035	0	−.05	.006	−.05	.006	−.006	.052	−.057	.027
D13	−.019	.017	.027	.027	.059	.063	.071	.059	.063	.006	.082	−.019	0	.017	.035	.035	.052	.052	.027	.052
D14	−.059	.006	.044	.035	.076	.035	.059	.052	.076	.068	.059	−.05	−.059	0	−.019	.006	.006	.019	−.043	.037
D15	−.059	.037	−.082	−.082	.035	.006	−.035	.059	.045	−.032	−.059	.006	.059	.035	0	−.035	−.059	−.006	−.043	.027
D16	.027	.059	.082	−.035	.006	.006	.082	.006	.045	−.059	−.059	.035	−.059	.035	−.035	0	.006	−.043	−.066	.076
D17	−.035	.035	−.043	−.059	.05	.019	−.032	.082	.006	.082	.035	−.035	−.059	.035	−.059	−.059	0	.076	.027	.052
D18	.006	.027	.035	.057	.059	.05	.059	.006	.082	.082	.035	.059	−.035	.059	−.059	.035	.059	0	.059	.082
D19	−.035	−.059	−.059	.045	.035	.076	−.035	.006	.056	−.059	.082	.035	.006	.059	.059	.006	−.059	.006	0	.059
D20	.039	.052	.068	.028	.059	.035	.071	.059	.076	.071	.035	.082	−.059	.059	−.059	.006	.035	.035	.006	0

Table 11 Total relation matrix

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20
D1	−.014	.009	−.089	.035	.092	.111	−.032	.093	.088	.071	.114	−.054	.113	.008	.104	−.062	.007	.079	.091	.03
D2	.002	−.02	−.063	−.008	−.083	−.046	−.034	−.083	.011	−.036	−.064	.049	−.08	.025	−.065	−.006	−.031	−.007	−.003	−.099
D3	.049	.034	.024	.011	−.122	−.105	−.01	−.132	−.136	−.077	−.113	−.026	−.076	−.033	−.102	.075	−.055	−.111	−.104	−.048
D4	−.067	−.03	.05	.001	−.085	−.095	.026	−.081	.044	−.044	−.058	.016	−.101	.016	−.104	.049	.013	.038	−.059	.066
D5	.015	.035	.082	.086	.049	.088	.097	.066	.121	.081	.099	.002	.042	.103	.026	.059	.051	.066	.079	.123
D6	.022	0	−.028	.045	.132	.035	.104	.105	.117	−.02	.107	−.044	.082	.103	.025	.034	−.022	.092	.091	.123
D7	.072	.07	.084	−.018	.005	−.06	−.002	−.021	.05	−.039	−.087	.011	−.074	−.072	−.081	.07	−.041	.006	−.038	.013
D8	−.039	.058	−.06	−.07	−.001	−.05	−.025	.002	−.013	−.013	−.061	−.028	.073	.018	.087	−.059	−.058	0	−.058	.011
D9	.035	.062	−.027	.068	.079	.031	.083	.06	.028	.025	.04	−.068	−.061	.032	−.046	.008	−.004	.041	−.013	.079
D10	−.063	.023	−.047	.057	.107	.067	−.035	.1	.109	.038	.058	.034	.035	.103	.007	−.038	.09	.113	−.004	.124
D11	.032	.036	−.06	.098	.127	.103	.093	.053	.147	.005	.038	−.024	.076	.092	.083	−.061	−.06	.044	.093	.109
D12	−.043	.03	.047	.044	.042	−.036	.044	.015	.069	.053	−.05	.006	−.078	.008	−.081	.019	.006	.053	−.07	.033
D13	−.011	.044	.031	.044	.094	.076	.106	.082	.11	.014	.091	−.02	−.009	.052	.023	.041	.043	.073	.033	.099
D14	−.047	.025	.053	.049	.085	.031	.077	.055	.092	.071	.053	−.05	−.067	.019	−.035	.013	.006	.028	−.044	.063
D15	−.058	.04	−.078	−.084	.042	.01	−.025	.07	.045	−.021	−.05	.004	.065	.035	.011	−.034	−.051	−.004	−.04	.016
D16	.046	.072	.1	−.042	−.017	−.023	.08	−.014	.021	−.058	−.086	.032	−.089	.013	−.067	.013	−.003	−.057	−.086	.045
D17	−.038	.039	−.052	−.036	.08	.044	−.024	.103	.035	.107	.063	−.027	−.046	.067	−.045	−.069	.01	.096	.047	.075
D18	.007	.048	.05	.091	.094	.062	.091	.028	.134	.1	.052	.06	−.066	.094	−.088	.045	.063	.034	.055	.132
D19	−.036	−.049	−.049	.065	.07	.092	.008	.031	.098	−.051	.1	.029	.012	.082	.063	.01	−.063	.021	.008	.094
D20	.04	.073	.073	.055	.08	.035	.09	.067	.11	.087	.036	.076	−.08	.08	−.082	.013	.034	.058	−.001	.034

Author contribution Rohit Agrawal: conceptualization, data curation, methodology, and writing—original draft. Pragati Priyadarshinee: methodology, data curation, and visualization. Anil Kumar: visualization, supervision, and editing. Sunil Luthra: writing—review and editing. Jose Arturo Garza-Reyes: review and editing. Sneha Kadyan: drafting the paper and editing.

Data availability All the data has been specified in the manuscript.

Declarations

Ethics approval and consent to participate All authors have followed the ethics in the research and gave consent to participate in the research.

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