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RESEARCH ARTICLE

Delving Into the Interdependencies in the Network of Economic Sustainability Innovations

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ABSTRACT Legislative pressures and public awareness are urging companies to foster sustainability innovations that improve business operations. Limited studies explored the underpinnings of the economic dimension of sustainability innovations; studying economic innovation criteria in the manufacturing sector of emerging economies can inform other industries while recession fears loom the financial prospects. This article develops a decision analysis and evaluation framework for investigating the interdependencies in the network of economic sustainability innovation criteria using fuzzy Total Interpretive Structural Modeling (TISM). It is found that the "*availability of financial resources for promoting innovation*" is the criterion with the most network relations; this is what the managers should focus on to better pursue sustainability innovations in the supply chains and facilitate the shift towards sustainable industrial development. The study is concluded by providing practical insights into the economic dimension of sustainability innovations for industrial managers and academics.

INDEX TERMS Supply chain management, sustainability, economic innovations, interpretive structural modeling (ISM), decision analysis.

I. INTRODUCTION

Concern for the downside of industrial development grows as environmental and social awareness prevail among a larger number of people. Increasingly more regulations and directives are being enforced to materialize sustainable development goals [1]. Given operational and financial limitations, corporations should employ innovative solutions to conform to the requirements more effectively and efficiently. Sustainability innovation refers to novel or improved means of executing business activities with reducing their negative consequences and improving quality of life being the major objectives [2]. Sustainability innovation has emerged as an integral part of establishing organizational competitiveness [3]; it supports the triple bottom-line framework for employing new methods in the supply chain [4]. This type of innovation predominantly seeks to reduce waste and pollution [5] and improve organizational performance [6] by improving strategic, tactical, and operational aspects of the supply chain.

The sustainability innovation literature is in the introduction stage of development; the published works investigated the subject from several viewpoints. Gupta et al. [7] identified the barriers to implementing sustainable supply chain innovation in the manufacturing sector and suggested new strategies to help overcome the barriers. Munten et al. [8] studied the tensions that may exist in coopetition for sustainable innovation using experts' inputs from the automotive sector Petrudi et al. [9] investigated the social innovation performance of suppliers during the COVID-19 pandemic using Group-grey BWM-IGRA methodology. Asadabadi et al. [10] studied the supplier evaluation problem

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considering their environmental sustainability innovation performance using the Stratified-BWM-TOPSIS framework. Few studies explored the underpinnings of sustainability innovations and the current works have focused on environmental, social, or general sustainability innovations.

Considering the negative prospect of the economy in the coming years, understanding the underpinnings of economic innovations facilitates the uninterrupted implementation of industrial sustainable development initiatives. To the best of the authors' knowledge, there are no studies exploring the interdependencies among the economic sustainability innovation criteria; such information provides a basis for prioritizing innovative solutions considering their potential impact. To address this gap, inputs from the manufacturing sector of an emerging economy are used for investigating the following questions: (a) Which criteria are pertinent for evaluating the economic means of sustainability innovations? (b) How do the interdependencies amongst economic innovation criteria impact supply chain sustainability initiatives?

To answer these research questions, this manuscript develops an economic sustainability innovations framework as a basis for general economic innovation decision analysis. The fuzzy Total Interpretive Structural Modeling (TISM) is adopted to explore the interrelationships between the decision criteria. Interpretive Structural Modeling (ISM) analyzes the underpinnings of a system. In contrast to ISM, which considers the direct relationships between the pair of criteria, TISM can investigate both transitive and direct relationships to establish a fully interpretive structural model. TISM uses binary digits to establish the reachability matrix while real-life circumstances can be ambiguous and uncertain with various levels of complexity; real values may be required for situations that cannot be represented using binary values [11]. To address this drawback, fuzzy set theory is employed to account for differences and complexities in the real-world [12]. The main contribution of this work is introducing an evaluation framework for investigating economic sustainability innovation in the manufacturing sector of an emerging economy using fuzzy TISM.

The remainder of this manuscript is structured in four sections with Section II providing a background to sustainability innovations; Section III summarizing the methodology and computational steps; Section IV presenting a case study and discussing the findings and implications, and, finally, Section IV-A concluding this research work.

II. LITERATURE REVIEW

Companies are being held accountable for the adverse economic, social, and environmental impacts of their activities [13]. In this situation, integrating social and environmental considerations in decision-making [14], resource management [15], and other corporate operations [16] forms the basis of Sustainable Supply Chain Management (SSCM). In practice, profitability remains the key goal while non-financial factors, like the use of sustainable materials, green technologies, reducing carbon footprint, and improving human well-being and health are recognized as strong influencers [17].

Sustainability has emerged as a competitive strategy that improves corporates' image [18], brings about supply chain performance improvement and operational effectiveness [19]. The sustainability literature is well supported by a growing number of articles investigating SSCM-related criteria [20], [21]. Incorporating innovation criteria in managerial decisions help in pursuing sustainable development goals [22].

Sustainability innovation is a prerequisite to SSCM with continuous growth being its most important motivational factor [10], [23]. Sustainability innovations refer to the initiatives seeking continuous improvement of products, services, and business processes to alleviate their negative impacts [24]; this often involves different components of an organization and the impacts can be perceived in the financial, market, and environmental performance [25]. Overall, implementing sustainability innovations reduces supply chain costs [26] and improves the corporate image, which also boosts profitability in the long term [27].

To ensure a seamlessly sustainable and innovative organization, economic, social, and environmental considerations should be present [7]. The literature has introduced an array of factors to be considered in developing sustainability innovation evaluation frameworks [28], [29]. In particular, social factors such as poverty, corruption, human rights, health, and safety [30], [31] and environmental factors such as energy saving, pollution prevention, waste reduction and recycling, and environmental protection [32], [33] have been investigated. From the most relevant studies, Kusi-Sarpong et al. [1] developed a general sustainable innovation criteria framework for studying sustainable supply chains in manufacturing companies Badri-Ahmadi et al. [18] developed an evaluation framework for analyzing interdependencies among social innovation criteria using Rough-Z-DEMATEL method during COVID-19 epidemic. These works have focused on environmental, social, or general sustainability innovation (see **Table 1**). The economic aspect has received relatively less attention; a gap that is going to be addressed in the present study. **Table 2** provides an exhaustive list of the identified economic sustainability innovation criteria. These criteria are considered as the basis for developing a decision analysis framework to investigate the interdependencies in the network of economic sustainability innovations.

III. METHODOLOGY

As an extension to explanatory structural modeling, fuzzy TISM helps in comprehending the interrelationships among decision criteria by analyzing the degree of their influence through a structural self-interaction matrix [51]. The fuzzy TISM approach is widely used in analyzing complex decision-making circumstances [52], and inter-partner

TABLE 1. Literature on sustainability innovation.

Decision analysis method	Social Innovation	Environmental Innovation	Economic Innovation	Reference
BWM and Fuzzy TOPSIS		*		[34]
Grey DEMATEL		*		[35]
BWM and Fuzzy TOPSIS	*	*	*	[36]
BWM	*	*	*	[1]
BWM	*	*	*	[7]
BWM-improved PROMETHEE	*	*	*	[37]
Group grey BWM-IGRA	*			[9]
Z-DEMATEL		*		[32]
Rough-Z-DEMATEL	*			[18]
Stratified BWM-TOPSIS		*		[10]

TABLE 2. Economic sustainability innovation criteria supported by the literature.

Criteria	Supporting references
Cost competitive advantage	[37], [38]
Financial availability for innovation	[39], [40]
Financial resumption of products	[40], [1]
Efficiency	[27], [41]
Finance in Research & Development	[42], [37]
Producing sustainable products to decrease material utilization	[43], [44]
Sustainable product cost reduction	[45], [46]
Increased sustainability value to clients	[34], [42]
Turnover per employee	[47], [48]
Value-added per employee	[49], [39]
Productivity	[50], [48]

dynamics-based enablers [53]. This section summarizes the computational elements of the method.

A. FUZZY THEORY

Developed by [54], fuzzy set theory was introduced to handle input data uncertainty. In fuzzy-based decision analysis methods, the feedback obtained from the experts are linguistics and should be converted to fuzzy number for processing the data. In fuzzy theory, every element is related to a class, say C, to a partial extent/degree defined by $\mu_C : Y \rightarrow [0, 1]$, $\mu_C(y) = a \in Y$. In this definition, $\mu_C(y)$ represents the membership function of an element 'y' respective to a concept class C in a proposition, which is modeled in Equation (1) using triangular fuzzy number (TFN), (l, m, h).

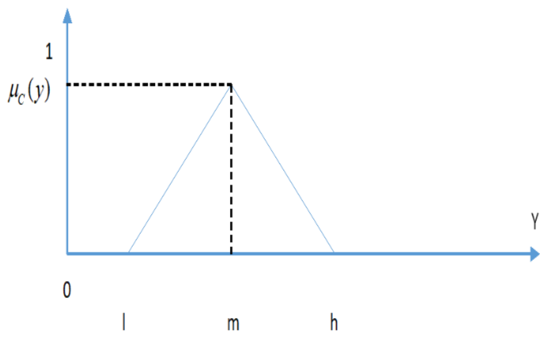

FIGURE 1. Triangular fuzzy numbe $\tilde{C}$.

In this definition, h, m, l are higher, middle, and lower values of $\tilde{C}$ with specifications shown in **Figure 1**, followed by the fundamental fuzzy theorems.

$$\mu_C(Y) = \begin{cases} 0, & y < l \\ \frac{y-l}{m-l} & l \le y \le m \\ \frac{h-y}{h-m} & m \le y \le h \\ 0, & otherwise \end{cases} \quad (1)$$

Theorem 1: With $\tilde{C}_1 = (l, m, h)$ and $\tilde{C}_2 = (a, b, c)$ representing two positive TFNs, the basic addition operations can be performed as shown in Equation (2).

$$\tilde{C}_1 + \tilde{C}_2 = (l, m, h) + (a, b, c) = (l + a, m + b, h + c) \quad (2)$$

Theorem 2: Transforming fuzzy data into crisp scores can be done through defuzzification method [55] to be able to process the data. If $\tilde{C}_p = (l_p, m_p, h_p)$; $p = 1, 2, \ldots, n$ and $\tilde{C}_p^{Crisp}$ represent the positive TFNs and the equivalent crisp value, respectively, the crisp value of the i^{th} criterion can be calculated in a four-steps procedure as follows.

Step 1: Calculate $L = \min l_p$; $H = \min h_p; p = 1, 2, \ldots, n$ and $\Delta = R - H$ for every criterion using Equation (3).

$$y_{lp} = (l_p - L)/\Delta, y_{mp} = (m_p - L)/\Delta, y_{hp} = (h_p - L)/\Delta, \quad (3)$$

Step 2: Determine normalized values of the left (ls) and right scores (rs) using Equation (4).

$$y_p^{ls} = y_{mp}/(1 + y_{mp} - y_{lp}) \, and \, y_p^{rs} = y_{hp}/(1 + y_{hp} - y_{mp}) \quad (4)$$

Step 3: Calculate the total normalized crisp value using Equation (5).

$$y_p^{Crisp} = [y_p^{ls} \times (1 - y_p^{ls}) + y_p^{rs} \times y_p^{rs}]/[1 - y_p^{ls} + y_p^{rs}] \quad (5)$$

Step 4: Obtain the crisp value for $\tilde{C}_p$ using Equation (6).

$$\tilde{C}_p^{Crisp} = L + y_p^{Crisp} \times \Delta \quad (6)$$

B. FUZZY TOTAL INTERPRETIVE STRUCTURAL MODELING

Developed by [56], TISM has been used for structuring new concepts in various supply chain contexts. TISM analyzes elements of a decision system and generates a graph of direct relationships between decision criteria and demonstrates hierarchy levels. As an extension to the basic Interpretive Structural Modeling, TISM shows both direct and transitive relationships to make the structural model fully interpretive. The computational steps of fuzzy TISM are now detailed.

Step 1: Define the study goal.

This step initiates the decision analysis process by defining its goal.

Step 2: Structure the problem.

Given a set of decision criteria, there often exist interrelationships between every pairs. To deal with uncertainty in analyzing these interrelationships, a fuzzy linguistic scale is adopted for group decision-making. The influence degree will be obtained using the following linguistic terms: Very High (VH), High (H), Low (L), Very Low (VL), and No influence (N).

Step 3: Data collection.

A panel of experienced managers, hereafter called our industry experts, is considered for data collection. The feedback is collected using the linguistic terms defined in Step 2 and four directional functions: V, A, X, and O. On this basis, the following alternatives are available to the respondents.

i. Function V denotes criterion *i* leads *j*. The feedback V could be V(VH), V(H) etc. For example, V(VH) means that *i* has a "very high" influence on *j*.
ii. Function A represents that the variable *j* leads *i*. For example, if expert gives feedback of A(H), he/she means that variable *j* has a 'high' impact on *i*.
iii. Function X specifies a 'mutual' link between variables *i* and *j*; meaning that *i* and *j* both can influence each other. For example, X(VL) shows that criteria *i* and *j* have a 'very low' influence on each other.
iv. Function O denotes that criteria *i* and *j* are not related or cannot influence each other.

Step 4: Establish the Structural Self Interaction and Fuzzy Reachability Matrices.

This step consists of aggregating the preferences of the experts considering the 'mode' operator, i.e., the feedbacks with the highest frequency. A fuzzy reachability matrix should then be developed from the Structural Self Interaction matrix (SSIM); this contains fuzzy triangular values instead of linguistic terms. The following conditions may raise in the development procedure.

1. If the entry associated with (*i, j*) is V(VH):$(i, j) = (0.75, 1.0, 1.0)$ and $(j, i) = (0, 0, 0.25)$.
2. If the entry associated with (*i, j*) is V(H): $(i, j) = (0.5, 0.75, 1.0)$ and $(j, i) = (0, 0, 0.25)$.
3. If the entry associated with (*i, j*) is V(L): $(i, j) = (0.25, 0.5, 0.75)$ and $(j, i) = (0, 0, 0.25)$.

4. If the entry associated with (i, j) is V(VL): $(i, j) = (0, 0.25, 0.5)$ and $(j, i) = (0, 0, 0.25)$.
5. If the entry associated with (i, j) is A(VH): $(j, i) = (0, 0, 0.25)$ and $(i, j) = (0.75, 1.0, 1.0)$.
6. If the entry associated with (i, j) is A(H): $(j, i) = (0, 0, 0.25)$ and $(i, j) = (0.5, 0.75, 1.0)$.
7. If the entry associated with (i, j) is A(L): $(j, i) = (0, 0, 0.25)$ and $(i, j) = (0.25, 0.5, 0.75)$.
8. If the entry associated with (i, j) is A(VL): $(j, i) = (0, 0, 0.25)$ and $(i, j) = (0, 0.25, 0.5)$.
9. If the entry associated with (i, j) is X(VH): $(j, i) = (i, j) = (0.75, 1.0, 1.0)$.
10. If the entry associated with (i, j) is X(H): $(j, i) = (i, j) = (0.5, 0.75, 1.0)$.
11. If the entry associated with (i, j) is X(L): $(j, i) = (i, j) = (0.25, 0.5, 0.75)$.
12. If the entry associated with (i, j) is X(VL): $(j, i) = (i, j) = (0, 0.25, 0.5)$.
13. If the entry associated with (i, j) is X (VH, H), then $(i, j) = (0.75, 1.0, 1.0)$ and $(j, i) = (0.5, 0.75, 1.0)$. Similar circumstances, including X (VH, L), X (VH, VL), X (H, VH), X (H, L), X (H, VL), X (L, VH), X (L, H), X (L, VL), X (VL, VL), X (VL, H), X (VL, H), X (VL, H), X (VL, H), X (VL,L), will be handled similarly.
    a) Finally, if the entry associated with (i, j) is $0\{\text{No}\}$, then $(j, i) = (i, j) = (0, 0, 0.25)$.

Given these transformations, the fuzzy reachability matrix, RM, can be structured as shown in Equation (7), where $\tilde{x}_{ij} = (l_{ij}, m_{ij}, h_{ij})$.

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & ,\ldots, & \tilde{x}_{1p} \\ \tilde{x}_{21} & \tilde{x}_{22} & ,\ldots, & \tilde{x}_{2p} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \tilde{x}_{n1} & \tilde{x}_{n2} & ,\ldots, & \tilde{x}_{np} \end{bmatrix} \quad (7)$$

Step 5: Perform MICMAC Analysis.

Given the fuzzy reachability matrix (RM), the driving force, and dependence can be determined by adding the rows and columns of $\tilde{X}$ using Equation (2). Equation (6) should then be used to defuzzify the results and perform MICMAC analysis.

Step 6: Level partitioning of the results.

In this step, the transitivity of the reachability matrix should first be tested to ensure that no transitive relationships exist. RM is then segmented using relational and level partitioning methods.

Step 7: Create the TISM digraphs.

After defuzzification of the reachability matrix acquired in Step 4, the TISM digraph can be structured using directed arrows between the pair of criteria. For this purpose, the symbols presented in **Figure 2** are used to establish the right linkage between the criteria. To avoid information overload, the fuzzy reachability matrix is defuzzied by treating the linguistics terms H and VH as 1 while the rest are considered as 0. **Table 3** presents fuzzy linguistic variables for criteria assessment.

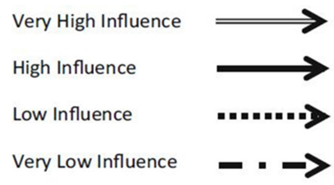

FIGURE 2. Symbols for representing fuzzy interrelationships between the criteria.

TABLE 3. Fuzzy linguistic variables for criteria assessment.

Linguistic term	Fuzzy value
Very High Influence (VH)	(0.75, 1.0, 1.0)
High Influence (H)	(0.5, 0.75, 1.0)
Low Influence (L)	(0.25, 0.5, 0.75)
Very Low Influence (VL)	(0, 0.25, 0.5)
No Influence (N)	(0, 0, 0.25)

IV. CASE STUDY

A. CASE DESCRIPTION

Sustainability innovation practices are in the early development stages; social and environmental aspects are relatively well studied but further investigation is required to understand the economic aspect of the problem. Considering that recession fears loom the prospect of the economy, the developing nations may be even more constrained in applying sustainable industrial development initiatives. A case study from a developing country in the middle east is considered to study the economic aspect of sustainability innovation.

This study targets senior level management professionals in the manufacturing industry. An initial pool of experts was first contacted to communicate the research targets. Those who expressed their interest in evaluating economic sustainability innovation criteria in their supply chains were chosen as participants. Considering that a small sample of experts can be sufficient for expert-based studies [57], a sample of six managers from six different manufacturing corporations is eventually considered as our industry experts. These experts have a minimum of 13 years of working experience and are intentionally selected from different backgrounds to ensure homogeneity and generalizable results to inform other industry situations. **Table 4** summarizes the experts' profiles.

B. EVALUATION FRAMEWORK AND RESULTS

A survey considering the criteria listed in **Table 2** was first sent to the experts for review; they were asked to evaluate the criteria as either relevant *(Yes)* or irrelevant *(No)*. They were also asked to suggest different or additional economic innovation criteria. The list was modified in three review rounds to identify the decisive criteria in the supply chain of the case companies. It was agreed that the criteria confirmed

TABLE 4. **Profile of the involved industry experts.**

Expert	Position	Industry	Managerial role	Working Experience (Years)
1	Supply Chain Manager	Automotive	Sourcing contract	18
2	Purchasing Manager	Electronics	Purchasing program implementation	13
3	Financial Manager	Tile	Financial budgetary of the corporation	14
4	General Manager	Plastic	The daily business operations of the corporation	16
5	Marketing Manager	Motorcycle	The daily marketing activities	15
6	Production Manager	Leather	The production processes	19

by at least four of the panel members in the screening process will be considered for further analysis. The data collection protocol is provided in Appendix A. **Table 5** presents the screening outcomes.

Data collected from our experts, which assesses the interrelationships amongst the economic innovation criteria, are presented in **Tables** B1-B6 of Appendix B. Using this data as input, the computational procedure of the fuzzy TISM method begins with preparing the aggregated SSIM and the fuzzy RM, as shown in **Tables** C1 and C2 of Appendix C, respectively.

The next step consists of cross-impact matrix multiplication applied to classification (MICMAC) analysis of the criteria for classifying them considering the driving and dependence powers; results are shown in **Table 6**. For every economic innovation criterion, the driving force indicates the number of criteria that it facilitates their implementation, and the dependence power refers to the innovations which help a certain criterion's successful implementation. This analysis is followed by transforming the initial reachability matrix into the final reachability matrix by incorporating transitivity, which are provided in **Tables** D1-D2 of Appendix D. Given these inputs, the level identification process was completed in seven iterations; results are shown in **Table 7**.

As a final step to implementing the fuzzy TISM method, a digraph is used to visualize the relations in the network of economic sustainability innovation criteria. Given defuzzified values in the reachability matrix, the linguistic terms H and VH are treated as 1 and the rest are filtered out to draw the digraph in **Figure 3**. In this hierarchy, C3 and C6 are characterized with the same reachability and intersection sets, hence, form the first level of the digraph. The intermediate level consists of three criteria and the last level in the hierarchy contains only one economic innovation criterion.

C. DISCUSSION AND MANAGERIAL MPLICATIONS

The reachability analysis of the criteria shows that decreasing the production cost of sustainable products and finance in research and development mutually support the achievement of each other. The antecedent analysis reveals that reducing wastes and input sources requires the support of four other criteria for effective implementation. The transitive relation between C1 and C2/C6 is another notable observation, which implies direct and indirect impact between the related innovations.

Financial resumption of the products (C3) showed to have the weakest driving power followed by reducing wastes and input sources (C6); these criteria are characterized by the strongest dependence power, therefore, are called our dependence variables. Given the position of C3 and C6 in the top level of the hierarchy, it becomes obvious that they do not exert significant influence on the rest of the network criteria while they get influenced by the intermediate level criteria (i.e., C1, C4, and C5).

Expectedly, the availability of financial resources for promoting innovation (C2) has the strongest drive power followed by finance in R&D (C5). Given the meaningfully small dependence power of C2, this criterion can be considered

TABLE 5. List of decisive economic innovation criteria after screening.

Criteria	Description
Decreasing the cost of producing sustainable products (C_1)	Reducing overheads through various cost-reduction strategies
Availability of financial resources for promoting innovation (C_2)	Gaining leadership supports for promoting sustainability innovations and assigning resources
Financial resumption of the products (C_3)	Possibilities of reusing, repurposing, recovering, and recycling for improving circularity.
Enhanced sustainability value to customers (C_4)	Creating tangible benefits for customers by reducing the price, enhancing the product's functionality, service level, and creating awareness about the expected outcomes.
Finance in Research & Development (C_5)	Availability of resources for supporting research and development activities along the value chain.
Reducing wastes and input sources (C_6)	Minimizing non-value-adding activities, material usage, and energy consumption along the value chain.

TABLE 6. Driving and dependence power analysis.

No.	C1	C2	C3	C4	C5	C6	Dr^F	Dr^C
C1	(1.0,1.0,1.0)	(0.0,0.0,0.25)	(0.25,0.5,0.75)	(0.0,0.25,0.5)	(0.5,0.75,1.0)	(0.0,0.0,0.25)	(1.75,2.5,3.75)	2.624
C2	(0.25,0.5,0.75)	(1.0,1.0,1.0)	(0.75,1.0,1.0)	(0.0,0.0,0.25)	(0.5,0.75,1.0)	(0.75,1.0,1.0)	(3.25,4.25,5)	4.143
C3	(0.0,0.0,0.25)	(0.0,0.0,0.25)	(1.0,1.0,1.0)	(0.0,0.0,0.25)	(0.0,0.25,0.5)	(0.0,0.0,0.25)	(1,1.25,2.5)	1.447
C4	(0.0,0.0,0.25)	(0.0,0.0,0.25)	(0.5,0.75,1.0)	(1.0,1.0,1.0)	(0.0,0.0,0.25)	(0.0, 0.0, 0.25)	(1.5,1.75,3)	1.965
C5	(0.5,0.75,1.0)	(0.0,0.0,0.25)	(0.0,0.0,0.25)	(0.0,0.25,0.5)	(1.0,1.0,1.0)	(0.75,1.0,1.0)	(2.25,3,4)	3.048
C6	(0.0,0.0,0.25)	(0.0,0.0,0.25)	(0.25,0.5,0.75)	(0.0,0.25,0.5)	(0.0,0.0, 0.25)	(1.0,1.0,1.0)	(1.25,1.75,3)	1.936
De^F	(1.75,2.25,3.5)	(1,1,2.25)	(2.75,3.75,4.75)	(1,1.75,3)	(2,2.75,4)	(2.5,3,3.75)		
De^C	2.423	1.188	3.686	1.909	2.850	3.047		

De: Dependence power, Dr: driving power, F: fuzzy value, C: crisp value.

the driving variable in the strongest sense; its position in the bottom level of the digraph confirms this argument. No autonomous criteria were found, confirming that all the criteria are closely involved in the network. Finally, decreasing the cost of producing sustainable products (C1) can be considered as a linkage variable considering its relatively strong drive and dependence power values; this can be seen in the digraph considering four incoming and outgoing arrows.

With the possibility of a recession on the horizon, companies should proactively search for initiatives that support the economic innovation criteria identified in this study. The purchasing (sourcing) element of the supply chain significantly influences the environmental performance of the company [1], [58]; seeking 3D party-produced goods and services with low negative impacts is beyond selecting a good supplier and includes initiatives like supplier development

TABLE 7. Level partitioning.

Iteration	Criteria	Reachability Set	Antecedent Set	Intersection Set	Level
1	C1	1, 5, 6	1, 2, 5	1, 5	-
	C2	1, 2, 3, 5, 6	2	2	-
	C3	3	2, 3, 4	3	I
	C4	3, 4	4	4	-
	C5	1, 5, 6	1, 2, 5	1, 5	-
	C6	6	1, 2, 5, 6	6	I
	Criteria	Reachability Set	Antecedent Set	Intersection Set	Level
2-7	C1	1, 5	1, 2, 5	1, 5	II
	C2	2	2	2	III
	C3	3	2, 3, 4	3	I
	C4	4	4	4	II
	C5	1, 5	1, 2, 5	1, 5	II
	C6	6	1, 2, 5, 6	6	I

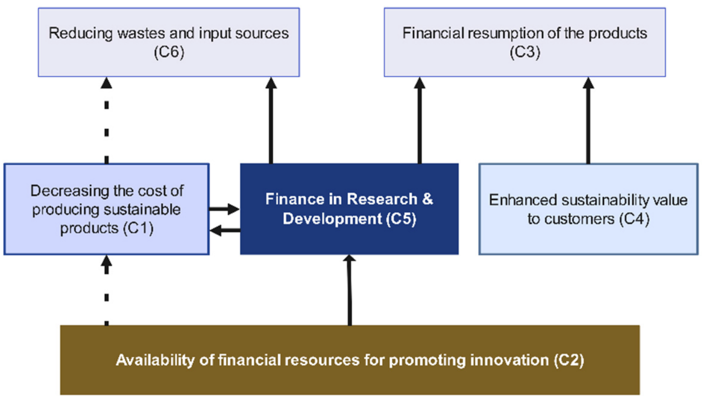

FIGURE 3. Digraph of the economic sustainability innovations.

programs and audits. The availability of financial resources is especially crucial for implementing such initiatives.

The "process optimization" related sustainability initiatives relate to reducing waste in both production and transportation operations. Initiatives like the introduction of new managerial roles, e.g. energy manager, use of cogeneration plants, energy efficiency improvement [59] and cutting off non-value-adding activities are prime examples of reducing input sources. Design for sustainability as a major initiative for product design and usage is mainly concerned with reducing the product's energy consumption and hazardous contents [30]. Our analysis shows that finance for research & development has a significant driving impact on the continuity of such initiatives.

Developing reporting systems for assessing the environmental and social impact of supply chain activities is one of the initiatives that inform the customers and improve their awareness of the generated impact [59]. Such initiatives are expected to enhance the financial resumption of the products, for example, by encouraging the consumers to contribute to closing the supply chain loop. Overall, enhancing sustainability value to the customers can be considered as an opportunity for attracting new customers and even exploring new means of creating value by benefiting from the changing consumer behavior in the downturn financial periods.

Investigating the economic innovation criteria amid the financial downturn after the COVID-19 pandemic and international conflicts was the major contribution of this research. Understanding the underpinnings of economic sustainability innovation support SSCM decisions; the industry requires more academic investigations on economic sustainability innovations, for example, through adopting different theoretical lenses and incorporating such considerations into the strategic and tactical decisions. Economic innovation will always be a prerequisite for the prosperity of sustainability initiatives.

V. CONCLUDING REMARKS

Innovative practices boost organizational sustainability when the traditional practices are not creating the desired impact. This article is the first attempt to study the underpinnings of the economic sustainability innovation; a list of economic innovation criteria was identified through literature review and a decision analysis framework was developed for investigating the independencies among the decisive criteria. Inputs from the manufacturing sector of a developing economy was used in the assessment process. The ''availability of financial resources for promoting innovation (C2)'' is introduced as the most critical economic innovation criterion. The practical insights help the industrial experts to focus on the most effective means of economic innovation to pursue SSCM amid financial crises.

This study has certain limitations, which can be considered as opportunities for deeper works on this research topic. First limitation of this article is that experts from one emerging economy and one sector participated in the study. Possible future works could focus on comparative analysis by building on our findings. Besides, future studies may explore interdependencies among economic innovation factors before, during, and after the COVID-19 pandemic considering varying financial situations. Second limitation is that the introduced criteria are rather broad and general. We suggest that future research extends the list by introducing sub-criteria particular to the need of the company and industry. Exploring political/law and technological criteria pertinent to sustainability innovation is another interesting research direction to pursue. Finally, from a methodological aspect, future works may consider applying stratified version of DEMATEL or ISM for analyzing the interrelationship under uncertain situations to account for the events that may impact the financial and political prospect in the future.

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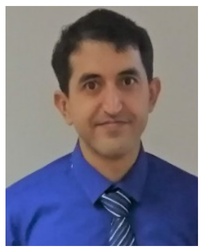

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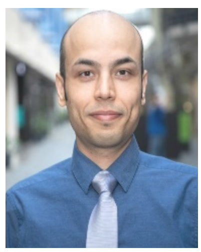

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