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Evaluating the Drivers to Information and Communication Technology for Effective Sustainability Initiatives in Supply Chains

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Supply chain (SC) sustainability has become a global issue. To develop sustainability focused SC networks, the role of Information and Communication Technologies (ICTs) is of great significance. An effective information system and management can help not only in improving better customer service and in cost control, but also can assist planning to achieve the three pillars of sustainability (ecological, economic, and societal development), thereby enhancing business efficiency. This paper aims to identify and evaluate the drivers relevant to ICT for sustainability initiatives in SCs. The drivers are finalized through a literature survey and use of the Delphi technique. The finalized drivers are analyzed by a procedure using the fuzzy DEMATEL approach. The research findings suggest that "Government support systems and subsidies", "Knowledge and awareness of ICT tools and techniques," and "Information systems network design" drivers have the most significant influences in the implementation of ICT for incorporating sustainability in SCs. This

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work may help practitioners and researchers in strategic decision-making and in formulating effective plans for the implementation of ICT and for incorporating sustainable concepts in SCs.

Keywords: ICT; fuzzy DEMATEL; supply chain management; sustainability initiatives sustained competitive advantage; performance improvement.

1. Introduction and Background for Work Motivation

Business organizations are using information and communication technologies (ICTs) for communication links with customers, economic budgets and controls, personnel accounting, etc.[1] ICT consists of an extensive variety of hardware, software, communication lines, and information management tools to handle and analyze information.[2] ICT also acts as a supportive tool to individual business action performance. Even, proper use of ICT can increase the competitive advantages of the business organization in the supply chain (SC) scenario by supporting the decision-making processes, enabling the related operations efficiency and improving the quality of customer related services.[3] From an organizational context, ICT can contribute to business sustainability by improving the three pillars of sustainability i.e., economic, environmental, and social gains.[4] Sustainability is a very significant challenge in organizational SC context.[5] Due to dynamic global business environment, there is a great requirement for implementing sustainability initiatives in all aspects of business.[6] Sustainability is defined as "forms of progress that meet the needs of the present without compromising the ability of future generations to meet their needs".[7] The literature suggests that ICT implementation procedures and courses of actions are seen as crucial enablers to achieve sustainable business development.[8,9] Therefore, substantial research is needed regarding traditional business methods and techniques in order to have effective management of energy utilization, environment degradation, and technology-related practices.[10] An organization's need to derive value from its ICT investments is critical,[11] since poor ICT investment decisions can adversely affect profitability.[2] Further, ICT supports sustainable business development, while at the same time, incomplete implementation of ICT may have negative effects on the business.[1] Any inadequacy in integrating ICT to business environment may distort the capability of the system to process and deliver important information regarding ecological impacts to all members in the sustainability focused SC. Thus, the whole SC could be disrupted and the overall performance diminished.[12] Thus, it is important to understand and develop an effective ICT implementation system for improving the business performance and to set up sustainability from the SC context. Research on the drivers for successful ICT implementation in SCs in regard to sustainability is rather scarce and fragmented.

1.1. *Objectives of the research*

In particular, this research paper has the following objectives:

(a) To recognize key drivers to ICT for effective sustainability initiatives in SCs.
(b) To segment the identified key drivers to ICT for effective sustainability initiatives in SCs.

This paper aims to recognize and investigate the key drivers to ICT for effective sustainability initiatives in SCs. This is a multi-criteria decision-type problem. Thus, the present research proposes to utilize a mixed approach based on Delphi and fuzzy DEMATEL techniques for analyzing the key drivers to ICT for effective sustainability initiatives in SCs. The Delphi analysis is very useful for exploring experts' knowledge and consensus-building. The Delphi approach can finalize and validate the key drivers that are identified through the literature.[13] The DEMATEL methodology allows extracting causal interactions along with strength of interactions between considered elements for a system.[14] However, DEMATEL lacks in handling human bias and uncertainty in data during judgment.[15] To deal with the disadvantages of the traditional DEMATEL method, a fuzzy DEMATEL methodology has been utilized for analyzing and segmenting identified key drivers to the successful implementation of ICT under vague surroundings.

This paper is designed as follows. After introductory text, the review of the related literature is covered in Sec. 2. Section 3 discusses and explains the research methods. Section 4 presents the proposed research framework. An example showing the proposed framework applicability is given in Sec. 5. Discussion of the research outcomes and managerial significance of the study are provided in Sec. 6. Then, we present the conclusions along with the scope for future research in Sec. 7.

2. Literature Review

This section discusses the literature on supply chain management (SCM) and sustainability, the role of ICT to incorporate sustainability in SCs and identifies ICT implementation drivers for sustainability initiatives in SCs.

In this work, the Systematic Literature Review (SLR) approach is followed for conducting the literature survey.[16] The literature review was carried out with the help of several key words — "Supply Chain", "Sustainability", "Sustainable Initiatives", "ICT", and "Driving Factors/Drivers/Enablers". Combinations of these keywords were used including (1) Supply Chain and Sustainability and ICT, (2) Supply Chain and Sustainable Initiatives and ICT, (3) Supply Chain and Sustainable Initiatives and ICT and Driving Factors/Drivers/Enablers, and (5) Supply Chain and Sustainability and ICT and Driving Factors/Drivers/Enablers. Google scholar and Google search databases were primarily the basis for searching and gathering the papers published in journals, conference proceedings, and books. We selected the papers written only in English, and all co-authors collaborated on the suitability of the paper selected for the work (a detailed list of papers is given in the reference list).

2.1. *SCM and sustainability initiatives*

SCM includes a set of activities which are responsible for adding value to products and services being delivered to the customers.[17] Growing market dynamics and ecological uncertainty have made difficult for organizations in delivering the right product or service to the customer at the lowest possible cost.[18] From the past few years, customer awareness and regulatory directions have pushed organizations towards SC sustainability.[19] Increased global competition is pushing business organizations to focus on sustainability-related practices in economic, ecological, and social terms.[20] Sustainability has increasingly become important to businesses to reduce usage of natural resources and energy consumption, reduce pollution, better material flow management, improve sharing of information and cooperation among SC members, improve productivity, and triple bottom line performances.[6,21]

Sustainability-oriented SCs also help in reducing waste which may involve with various activities of SCs.[22] The SCM literature has investigated the different metrics related to managing of sustainable SCM. Some of the matrices were quality, air emissions, greenhouse gas emissions, and energy consumption, etc.[23] In other study, Taticchi *et al.*[24] analyzed the previous literature (published between 2000 and 2013) on sustainable SCs and explored the applicability of decision-support techniques in measuring/improving business sustainability. Thus, many business organizations worldwide have choice to adopt sustainability practices, not only in their products and services, but also with their SC partners.[25] Plethora of work has been done so far on SC sustainability. However, little research has analyzed the aspects of ICT for efficient sustainability initiatives in SCs, which are discussed below.

2.2. *ICT and sustainability initiatives and SCM*

From the past few years, the issues of sustainability have gained important attention among business organizations in their SC contexts.[26] SC sustainability helps to improve firms' brand value and financial gains.[27] To develop a sustainable business culture, it is not only important to incorporate ecological, economic, and societal aspects in SCs, but also to have an effective information system and management for improved customer service and achieved the three pillars of sustainability.[28] In addition, business organizations must build truly smart systems to cope with business surroundings.[20] ICT resources may play critical roles in enabling business organizations to develop capabilities to address sustainability concerns and improve the sustained competitive image.[6] ICT can help managers to manage the products and services lifecycle to reduce ecological impacts in business.[29–31]

In SCM, information systems are very important in managing materials and goods flows and in improving economic advantages and service performances.[32] ICT in SCs involves advanced information technologies that support information complexity, propagation, dispersion, and velocity,[33] and may be leveraged to achieve sustainability in SCs.[34] IT-enabled systems may help managers in sustainability by optimizing the resources and also enabling more improved communications and collaboration among SC activities, thereby reducing resource requirements and waste emissions.[35]

The literature suggests that ICT is an essential factor in effective SCM and business process excellence as well as in social and economic development.[36–38]

From a managerial context, almost every business is influenced by ICT. A digital organization needs to sense its environment and then execute the apparent information to improve its decision-making to become sustainable and to have a competitive edge in the market.[29] To deal with this, it is necessary to know the drivers to ICT for effective sustainability initiatives in SCs, which are discussed below.

2.3. *ICT implementation drivers for sustainability initiatives in SCs*

To identify the ICT implementation drivers for sustainability initiatives in SCs, a literature survey was carried out. Thus, 14 drivers to ICT for effective sustainability initiatives in SCs have been defined from the extensive literature review; with details given below.

2.3.1. *Top management role and support* ($D1$)

For any ICT project to be successful, top management support is imperative.[39–43] Zwikael[43] proposed a list of 17 aspects of top management support in IT projects. Several other empirical studies support such a proposition, resulting in high quality ICT products despite the variations in individual design.[45–47] It has also been observed that the approach of the top management along with persuasion can strengthen the focus and sustain the commitment in larger IT projects.[39]

2.3.2. *Government support systems and subsidies* ($D2$)

Organizations try to incorporate sustainability in their systems with a focus on environmental benefits; and the government should give the support through new systems equipped with ICT tools. This dominantly prehelps smaller organizations to implement the same, for various reasons, and with the long-term perspective of sustaining the business.[12] Elliot[29] argued by taking an example of Australian government policy, explaining how it influences better management in reducing the environmental impacts by using proper ICT tools. Also, Puri and Sahay[48] evaluated the role of ICTs to create participatory development of the economy, with strong support from the government, thus making government policies as one of the enablers for sustainability in operation.

2.3.3. *Information systems network design* ($D3$)

It has been observed that there is a trend of collaborative paradigms in the sustainable SCs in recent times.[49–51] In this, the importance of information-sharing on the network is always an important factor to be focused on.[6,52–54] Further, the Information network has led to centralized information-sharing, reduction in the lead time and handling the SCs at the sub-optimized level. To enable this, the information system should be in various directions that help to sustain the SC. Moreover, some SCs, in order to support sustainability, have better information-sharing in terms of product flows, along with environmental management information on stakeholders in all directions.[31] Thus, it endorses the view that information network design is an important factor for exploration for sustainability studies.

2.3.4. *Socio-environmental impacts of the products* ($D4$)

The concerns related to socio-environmental impacts of products are increasing in business organizations.[55] Understanding of ecological processes and knowledge on the interactions in social environmental systems is growing, yet the capability to improve decisions from the perspective of SC management is still limited.[56] ICT solutions are required for business organizations to prove that materials are acquired in socially responsible way, as well as undertaking Life Cycle Analysis (LCA) of the products.[57]

2.3.5. *Culture related factors* ($D5$)

For any project to be successful, it needs a strong social structure understanding of the various stakeholders involved.[58–60] This aids any ICT project in adapting to the local community needs, so that it can act as an enabler for the sustainability of the SCs. Here, the stakeholder's expectation would be an important factor to be considered. It is interesting to note that projects undergo various changes in alignment with the organizational changes.[49]

2.3.6. *Approach to ICT to adopt sustainability in SCM* ($D6$)

Industry uses different approaches to implement ICT, focusing on the sustainability model, and these are highly diverse in nature.[61–68] These approaches are highly dependent on operations, including the size and nature of products handled in the SC, capital investment in the ICT system, and the service level set by the stakeholders in the SC system. There are some other enablers, such as easy implementation and vertical integration, which accelerate the usage in sustainable SCs. The domain is evolving with different and practical models for implementing ICT in the creation of sustainable SC systems.[69] From the literature, it is observed that there is a good scope for analyzing ICT's role in implementing sustainable SCs.

2.3.7. *ICT infrastructure and financial resources* (*D*7)

For sustainable SC operations, it is vital to have a focused interest on the ICT infrastructure though some early research focused on ICT investment. It is identified as a crucial driver in terms of improving the SC performance.[70] Changing technologies of operations and reporting standards are always linked to the infrastructure and capability measures, and it is mediated by the financial resources in procuring and operationalizing the same.[71] Thus, it is one of the enablers to study in sustainable operations.[33]

2.3.8. *Understanding the nature of sustainability* (*D*8)

Van Breedam[72] advocated on understanding the importance and effect of nature of sustainability in business. It can be due to many factors such as environmental concern, social and political influence, regulatory and compliance requirements, and many more. Organizations would like to know the purpose and priority of incorporating the sustainability measures that would impact on the SCs. Zhang *et al.*[73] analyzed the impact of ICT on SC performance and stated that it could be another dimension of interest in the introduction of sustainability in SCs.

2.3.9. *Brand image and SC competitiveness* (*D*9)

Once ICT tools are implemented effectively, it can boost the image of the firm and increase competitiveness in terms of international norms. Cepolina[74] articulated the contribution of ICT in the competitiveness of an industry through different sustainable initiatives. It can act as the brand differentiator for customers and employees.[76,77] Badurdeen *et al.*[77] endorsed this as an enabler for creating value for the stakeholders and eventually leads to reinforcement of the brand image.

2.3.10. *Security and support services from ICT resources* (*D*10)

It is seen that the necessary information required to manage sustainability and SCs is availably freely in an open access manner. At the same time, the growth of ICT tools introduces flexibility by giving hierarchical access to the same.[78] More solutions are available for the product life cycle to have reduced lead time, giving round-the-clock support to SCs. This enables the information to be available to all the stakeholders at an easy and regular way.[79] This is supported by the multiple initiatives at the international level to access the data through connectivity, network security, etc.[80]

2.3.11. *Human expertise* (*D*11)

ICT capability runs through the constant up-grading and skill sets from the professionals involved. These are the resources, together with capability, that determine the overall effectiveness in an organization.[81] For technology and innovation frameworks, human interaction is considered an important factor to be considered.[82–84]

Dubey and Gunasekaran[85] classified the skill sets required to manage the sustainability into hard and soft skills. However, they leave scope for discussing the role of ICT in the sustainable SCs, though they prominently position technology in the category of hard skills.[85]

2.3.12. *Technological factors* ($D12$)

Traditionally, interest has been laid out for issues of innovation and implementation in real time. As a result, over time, factors such as Growth of Internet, Industry, and external pressure increase the efficiency through cost reduction initiatives, to have economic savings, increase in the energy costs, and lower server utilization rates. Green information technology concepts are becoming core components in running the business efficiently. Gallagher[87] elucidated the various technological factors that help to implement sustainable ICTs for business applications.[86] Thus, it is appropriate to take them as strong enablers for the microlevel behavioral changes at the business level.[9]

2.3.13. *Knowledge and awareness of ICT tools and techniques* ($D13$)

It is always a challenge to align the environmental performance and awareness for a better efficiency in operation.[87] Sustainability cannot be passed or induced on the practitioners, unless they are completely aware of the usage, impact, and recent developments. Using ICT to create awareness in sustainability through web portals, company-based access research reports available in various e-platforms, blogs, and wikis and also through interactive sessions would also help SCs to improve their efficiency.[88,89]

2.3.14. *Information-sharing across hierarchy* ($D14$)

Increasingly, coordination in SCs is becoming a key concept and is also important for sustainability-induced SC operations, or to sustain the SC to operate for the long term.[88,90,91] Further, it has been argued that ICT plays an imperative role by sharing the information across the SCs through a dyadic web pattern, which results in the reengineering of the SCs, leading to cost savings in operations.[92] Though these developments were practised through various concepts such as Collaborative Planning, Forecasting and Replenishment (CPFR) techniques at the upstream level in the last two decades, now industry has started adopting the Computer Supported Collaborative Learning (CSCL) community for the downstream partners as well, which has a huge role in the sustainable operations of the business for future generations as well.[89]

3. Research Methods

The Delphi and fuzzy DEMATEL approaches have been utilized as research methods. The Delphi method is a methodical technique that relies on a group of independent professionals.[27] It helps to finalize the drivers in the implementation of ICT to incorporate sustainability. While interactions between ICT implementation drivers were devised using fuzzy DEMATEL. The combined Delphi — fuzzy DEMATEL approach is a systematic decision support, which provides scientific means not only to select the ICT based drivers for efficient sustainability initiatives in SCs, but also allows to investigate the causal interactions among drivers.[93] Details of the proposed research methods are explained below.

3.1. *Delphi technique*

Delphi was introduced by the RAND Corporation in 1950s.[94] This method is among the most effective tools when there is lack of theory building, and professionals have related appropriate information on the topic being researched.[95] Delphi combines the informed judgments from a group of professionals and improves decision-making by enabling experts, anonymously to restrict bias in their responses, control feedback and iteration to allow interchange in their responses and formal group aggregation to extract a well-defined group response.[95–97] Delphi flexibly allows reaching a consensus, in which judgments are reviewed and sent back to the group for further analysis in refining a problem. From the last two or three decades, the Delphi method has been one of the well-used methods in decision-making in various fields, like forecasting, location decision, supplier selection, project management, SCM, etc.[41,96–100] In Delphi, there are certain important criteria to accurately resolve any problematic situations, like the basis of selecting the experts, number of experts, etc. Generally, Delphi analysis uses a minimum of 15–20 experts. Next, it is suggested to select candidates from consulting organization, academia and industry to reduce the human bias.

The various computational steps involved in understanding the Delphi method[99,100] are described as follows:

(a) To identify the problem and frame the relevant questionnaires to work on understanding the problem and generating solutions.
(b) To identify and contact the experts in the problem area. The experts are used in relation to the problem and related aspects by questionnaire. It is to be noted that appropriate care is taken of maintaining anonymity for the participants and structuring of information gathered from the questionnaire.
(c) The experts are asked to resolve the problem and possibly generate new ideas and solutions.
(d) The responses are collected from the experts and analyzed using controlled feedback.
(e) The responses are collected again, and the process further iterated for obtaining consensus.
(f) Once consensus is reached, a final report is prepared.

3.2. *Fuzzy DEMATEL*

The DEMATEL method can envisage the structure of complex causal relationships,[101] and helps to determine direct and indirect influences among criteria. It also helps in computing the relationships and strengths among various factors. DEMATEL does not need a huge amount of data and is capable of uncovering relationships among factors influencing other factors.[102] DEMATEL is superior to other MCDM systems such as BWM/AHP/ANP/ISM due to its capability of revealing causal interactions among the considered variables for any system.[103–107]

In this work, we used fuzzy-based DEMATEL methodology that deals with problems of vagueness, uncertainties, inexactness of data, and the subjectivity/bias associated with human judgment.[15] In the literature, fuzzy DEMATEL has been used successfully to analyze various decision problems, for instance, in global managers' competencies,[108] in evaluating green suppliers,[109] in city logistics concept selection[110] and in information security management and improvement strategies.[111]

Zadeh[112] introduced the fuzzy set theory and suggested its relevance to deal with linguistic information. Fuzzy numbers can be used to decode linguistic variables and generally, triangular and trapezoidal fuzzy numbers (TrFNs) are being used in the literature. The TrFNs for a fuzzy number $A = (a, b, c, d)$, where $a \leq b \leq c \leq d$. If $A_1 = (a, b, c, d)$ and $A_2 = (p, q, r, s)$ are two TrFNs, then it can be equal if and only if $a = p,\ b = q,\ c = r,\ d = s$.

Fuzzy DEMATEL has the following steps:

Step 1. The identified drivers to ICT for sustainability initiatives in SCs are finalized as evaluation criteria using expert's inputs.

Step 2. To develop pairwise comparisons between the identified drivers using a fuzzy linguistic scale (0 = no influence and 4 = very high influence). Keeping this scale in mind, experts are asked for their judgment on developing a direct assessment/relation matrix of identified drivers. These linguistic judgments were transformed into the fuzzy assessments (see Table 1).

Step 3. These fuzzy numbers are then converted into crisp number using defuzzification process. Bisection of the area method is used for this purpose as given in Eq. (3.1). These crisp numbers form the fuzzy initial direct-relation matrix (F).

Table 1. Fuzzy Linguistic Scale.[113]

Judgment score	Linguistic variable	Equivalent TrFN
0	No influence (No)	(0, 0, 0.1, 0.2)
1	Very low influence (VL)	(0.1, 0.2, 0.3, 0.4)
2	Low influence (L)	(0.3, 0.4, 0.5, 0.6)
3	High influence (H)	(0.5, 0.6, 0.7, 0.8)
4	Very high influence (VH)	(0.7, 0.8, 0.9, 1)

Next, we obtained the fuzzy average matrix (A):

$$I_T = 1/4(a + b + c + d). \tag{3.1}$$

Step 4: The normalized initial direct-relation matrix (D) of the evaluation drivers is formed by using the following equations:

$$m = \min\left[\frac{1}{\max\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max\sum_{i=1}^{n}|a_{ij}|}\right], \tag{3.2}$$

$$D = m \times A. \tag{3.3}$$

Step 5. The total-relation matrix of evaluation drivers is formed using the following equation:

$$T = (I - D)^{-1}, \tag{3.4}$$

where I: Identity matrix; T: Total-relation matrix.
Step 6. The sum of rows (R) and the sum of columns (C) is calculated by using the following equations:

$$R = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1}, \tag{3.5}$$

$$C = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n}, \tag{3.6}$$

where R gives the overall influences of one driver, say (i) on the other driver (j) and C represents the overall influences experienced by driver (j) due to driver (i).
Step 7: A cause and effect graph of the evaluation is drawn by using the values of ($R + C$; $R - C$)

The dataset ($R + C$), i.e., "Prominence" is the degree of significance for the identified drivers. While, ($R - C$), i.e., "Relation or influence" is the degree of whole effect of identified drivers to the implementation of ICT. The cause and effect group drivers are determined through the values of ($R - C$).

4. Projected Research Framework

The projected framework for analyzing the drivers to ICT for effective sustainability initiatives in SCs, based on Delphi and fuzzy DEMATEL techniques, is shown in Fig. 1.

The projected research framework is based on the study of Platts,[114] which includes — all the processes of this framework are based on the purpose of this work — drivers selection, selection of research techniques, etc. Next, each process of this framework has a substantial background in terms of the literature support and the expert's agreement.

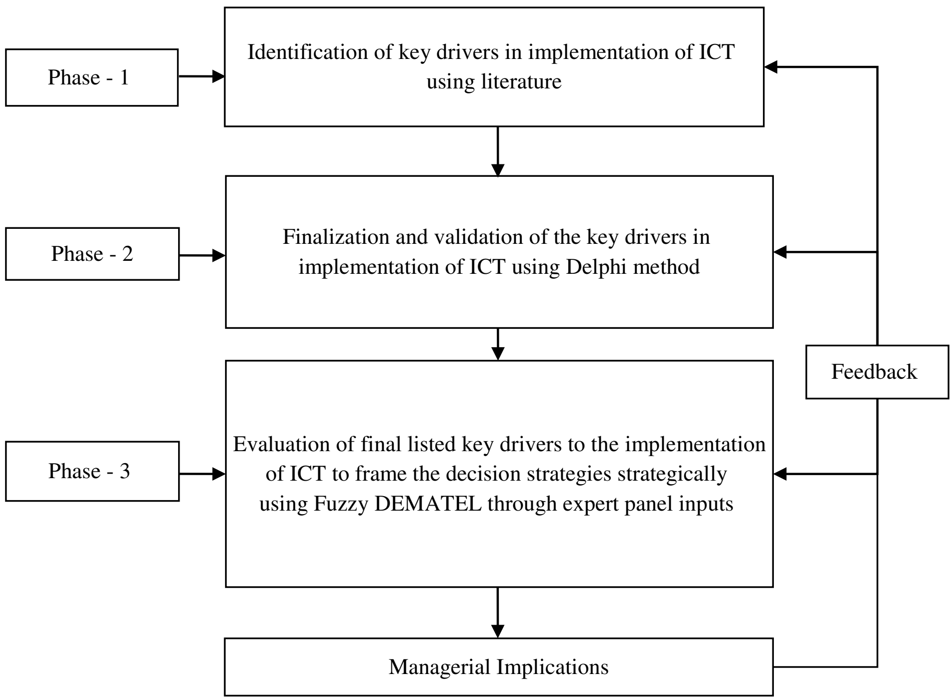

Fig. 1. Projected research framework.

This work uses combined Delphi–fuzzy DEMATEL approach, Next to this, research outcome is useful to the managers and practitioners. The proposed framework can assist practicing managers not only to select the ICT-based drivers for efficient sustainability initiatives in SCs, but also allows analyzing the causal interactions among drivers.

4.1. *Stage* 1: *Identification of the key drivers to ICT for effective sustainability initiatives in SCs*

In this stage, the literature survey was used to identify key drivers to the successful implementation of ICT.

4.2. *Stage* 2: *Finalization and validation of the key drivers to ICT for effective sustainability initiatives in SCs using Delphi method*

In this stage, the literature-based identified drivers were validated using the Delphi method. Initially, a panel of experts from industry and academia was formed. Based on Delphi analysis, the inputs received from the experts will be useful in finalizing the drivers in implementation of ICT.

4.3. *Stage 3: Evaluation of final listed key drivers to ICT for effective sustainability initiatives to frame the decision strategies strategically using Fuzzy DEMATEL through expert panel inputs*

The final listed key drivers were analyzed to segment into cause and group drivers using fuzzy DEMATEL through expert panel inputs. This classification will enable managers to frame the decision strategies to achieve sustainability in the long run.

5. An Example: Application of the Proposed Framework

To test the proposed framework, we considered an example of an arbitrary organizational sustainability focused SC and the problem is to drive the ICT applications to help managers to establish the SC with a sustainability orientation. For this, initially different drivers related to implementation of ICT for sustainability initiatives in SCs are explored; however, the application of the projected framework is described through the three stages mentioned in Sec. 4, and with respect to the arbitrary example discussed in this study as follows:

5.1. *Stage 1: Identification of the key drivers to ICT for effective sustainability initiatives in SCs*

In this stage, 14 drivers to ICT for effective sustainability in SCs are identified through the literature review. The details of the drivers have been given in Sec. 2.3.

5.2. *Stage 2: Finalization and validation of the key drivers to ICT for effective sustainability initiatives in SCs using Delphi method*

Initially, 14 key drivers were identified using the literature. Later, Delphi analysis was used to finalize and validate the key drivers in the implementation of ICT for sustainability initiatives in SCs.

According to the procedural steps of Delphi, initially, the problem is defined to identify and analyze the key drivers. Next, a panel of 16 experts (eight from an academic background and eight from an industrial background) was formed to analyze the above-mentioned problem. The concerned experts are highly skilled in decision-making. Then, a feedback survey was mailed to experts for their inputs to determine the importance of each driver. The factors with low importance ratings were agreed to be deleted with provided expert's agreement. The responses were recorded. In addition, we also asked experts to add any other important key driver. Thus, one more driver was added to the initial list containing 14 drivers. The one added driver is given as "Organizational related factors ($D15$)". Again, the recorded responses were sent to the experts for further feedback and to have their consensus on the additional key driver. Finally, consensus was obtained in the experts' responses

Table 2. Fuzzy initial direct-relation matrix of the drivers to ICT for effective sustainability initiatives in SCs.

	$D1$	$D2$	$D3$	$D4$	$D5$	$D6$	$D7$	$D8$	$D9$	$D10$	$D11$	$D12$	$D13$	$D14$	$D15$
$D1$	0.08	0.65	0.75	0.65	0.65	0.55	0.75	0.60	0.65	0.70	0.55	0.60	0.65	0.60	0.50
$D2$	0.50	0.08	0.80	0.70	0.45	0.75	0.60	0.70	0.65	0.60	0.45	0.75	0.55	0.65	0.65
$D3$	0.55	0.70	0.09	0.75	0.65	0.65	0.85	0.80	0.70	0.60	0.65	0.45	0.40	0.60	0.50
$D4$	0.85	0.65	0.50	0.08	0.55	0.35	0.40	0.55	0.55	0.65	0.50	0.75	0.45	0.60	0.50
$D5$	0.70	0.70	0.70	0.55	0.08	0.65	0.65	0.80	0.45	0.55	0.45	0.70	0.35	0.50	0.40
$D6$	0.40	0.55	0.65	0.45	0.55	0.08	0.75	0.65	0.60	0.80	0.60	0.70	0.60	0.60	0.55
$D7$	0.60	0.50	0.60	0.70	0.55	0.45	0.08	0.55	0.65	0.50	0.60	0.70	0.65	0.60	0.60
$D8$	0.55	0.40	0.55	0.50	0.35	0.60	0.65	0.08	0.55	0.70	0.70	0.65	0.55	0.70	0.75
$D9$	0.60	0.50	0.65	0.55	0.45	0.55	0.55	0.60	0.08	0.50	0.65	0.60	0.80	0.55	0.65
$D10$	0.50	0.55	0.45	0.60	0.65	0.65	0.65	0.70	0.55	0.08	0.55	0.50	0.55	0.50	0.55
$D11$	0.70	0.45	0.60	0.65	0.40	0.50	0.70	0.55	0.55	0.40	0.08	0.40	0.55	0.30	0.50
$D12$	0.65	0.70	0.65	0.85	0.55	0.55	0.60	0.55	0.70	0.50	0.30	0.08	0.55	0.60	0.65
$D13$	0.55	0.55	0.50	0.55	0.70	0.70	0.60	0.60	0.65	0.45	0.80	0.50	0.08	0.55	0.75
$D14$	0.70	0.50	0.40	0.55	0.70	0.65	0.70	0.45	0.60	0.55	0.60	0.60	0.65	0.08	0.55
$D15$	0.55	0.55	0.50	0.55	0.75	0.65	0.45	0.60	0.65	0.65	0.65	0.40	0.55	0.75	0.08

and hence a total of 15 key drivers related to the implementation of ICT for sustainability initiatives are selected.

5.3. *Stage 3: Evaluation of final listed key drivers to ICT for effective sustainability initiatives in SCs to frame the decision strategies strategically using Fuzzy DEMATEL through expert panel inputs*

Around 15 key drivers were selected as mentioned in the step and were analyzed using fuzzy DEMATEL. The pairwise comparison of drivers as made by experts is provided in Table 1. The linguistic statements were changed to fuzzy numbers and

Table 3. Fuzzy normalized initial direct-relation matrix of the drivers to ICT for effective sustainability initiatives in SCs.

	$D1$	$D2$	$D3$	$D4$	$D5$	$D6$	$D7$	$D8$	$D9$	$D10$	$D11$	$D12$	$D13$	$D14$	$D15$
$D1$	0.01	0.07	0.08	0.07	0.07	0.06	0.08	0.07	0.07	0.08	0.06	0.07	0.07	0.07	0.06
$D2$	0.06	0.01	0.09	0.08	0.05	0.08	0.07	0.08	0.07	0.07	0.05	0.08	0.06	0.07	0.07
$D3$	0.06	0.08	0.01	0.08	0.07	0.07	0.09	0.09	0.08	0.07	0.07	0.05	0.04	0.07	0.06
$D4$	0.09	0.07	0.06	0.01	0.06	0.04	0.04	0.06	0.06	0.07	0.06	0.08	0.05	0.07	0.06
$D5$	0.08	0.08	0.08	0.06	0.01	0.07	0.07	0.09	0.05	0.06	0.05	0.08	0.04	0.06	0.04
$D6$	0.04	0.06	0.07	0.05	0.06	0.01	0.08	0.07	0.07	0.09	0.07	0.08	0.07	0.07	0.06
$D7$	0.07	0.06	0.07	0.08	0.06	0.05	0.01	0.06	0.07	0.06	0.07	0.08	0.07	0.07	0.07
$D8$	0.06	0.04	0.06	0.06	0.04	0.07	0.07	0.01	0.06	0.08	0.08	0.07	0.06	0.08	0.08
$D9$	0.07	0.06	0.07	0.06	0.05	0.06	0.06	0.07	0.01	0.06	0.07	0.07	0.09	0.06	0.07
$D10$	0.06	0.06	0.05	0.07	0.07	0.07	0.07	0.08	0.06	0.01	0.06	0.06	0.06	0.06	0.06
$D11$	0.08	0.05	0.07	0.07	0.04	0.06	0.08	0.06	0.06	0.04	0.01	0.04	0.06	0.03	0.06
$D12$	0.07	0.08	0.07	0.09	0.06	0.06	0.07	0.06	0.08	0.06	0.03	0.01	0.06	0.07	0.07
$D13$	0.06	0.06	0.06	0.06	0.08	0.08	0.07	0.07	0.07	0.05	0.09	0.06	0.01	0.06	0.08
$D14$	0.08	0.06	0.04	0.06	0.08	0.07	0.08	0.05	0.07	0.06	0.07	0.07	0.07	0.01	0.06
$D15$	0.06	0.06	0.06	0.06	0.08	0.07	0.05	0.07	0.07	0.07	0.07	0.04	0.06	0.08	0.01

consequently, these fuzzy numbers are transformed into crisp numbers to initial direct-relation matrix or average matrix. Fuzzy initial direct-relation matrix of the drivers is shown in Table 2.

Next, we developed the fuzzy normalized direct-relation matrix of identified drivers as shown in Table 3.

Further, the total direct-relation matrix of the drivers was obtained and presented in Table 4.

Table 4. Fuzzy total direct-relation matrix of the drivers to ICT for effective sustainability initiatives in SCs.

	$D1$	$D2$	$D3$	$D4$	$D5$	$D6$	$D7$	$D8$	$D9$	$D10$	$D11$	$D12$	$D13$	$D14$	$D15$
$D1$	0.91	0.92	0.97	0.99	0.92	0.94	1.03	0.99	0.98	0.95	0.92	0.95	0.91	0.93	0.92
$D2$	0.95	0.86	0.97	0.99	0.90	0.95	1.01	1.00	0.97	0.93	0.91	0.97	0.90	0.94	0.93
$D3$	0.96	0.92	0.90	1.00	0.92	0.95	1.04	1.01	0.98	0.94	0.93	0.94	0.89	0.93	0.92
$D4$	0.89	0.83	0.85	0.83	0.82	0.83	0.89	0.89	0.87	0.85	0.82	0.88	0.80	0.84	0.83
$D5$	0.91	0.87	0.90	0.91	0.80	0.89	0.95	0.94	0.89	0.87	0.85	0.90	0.82	0.86	0.85
$D6$	0.90	0.87	0.92	0.93	0.87	0.85	0.98	0.95	0.93	0.92	0.89	0.92	0.87	0.89	0.89
$D7$	0.90	0.85	0.90	0.93	0.85	0.87	0.89	0.92	0.92	0.87	0.87	0.91	0.86	0.88	0.88
$D8$	0.89	0.83	0.88	0.91	0.83	0.88	0.95	0.87	0.90	0.88	0.87	0.89	0.84	0.88	0.88
$D9$	0.90	0.85	0.90	0.91	0.84	0.88	0.94	0.93	0.85	0.87	0.87	0.89	0.87	0.87	0.88
$D10$	0.86	0.83	0.85	0.89	0.84	0.86	0.92	0.91	0.88	0.80	0.84	0.86	0.82	0.84	0.84
$D11$	0.82	0.76	0.80	0.83	0.75	0.78	0.86	0.83	0.81	0.77	0.72	0.78	0.76	0.75	0.77
$D12$	0.93	0.89	0.92	0.97	0.87	0.90	0.97	0.94	0.94	0.89	0.86	0.86	0.87	0.90	0.90
$D13$	0.92	0.87	0.90	0.93	0.89	0.91	0.97	0.95	0.93	0.88	0.91	0.90	0.81	0.89	0.91
$D14$	0.91	0.85	0.87	0.91	0.87	0.89	0.95	0.91	0.91	0.87	0.87	0.89	0.85	0.82	0.87
$D15$	0.90	0.85	0.88	0.91	0.87	0.89	0.93	0.93	0.92	0.88	0.87	0.87	0.85	0.89	0.82

Table 5. Values of $(R + C)$ and $(R - C)$ of the drivers to ICT for effective sustainability initiatives in SCs.

Drivers	R	C	$R + C$	Rank	$R - C$	Cause/Effect
$D1$	14.23	13.55	27.78	1	0.68	Cause
$D2$	14.17	12.84	27.01	5	**1.33**	Cause
$D3$	14.22	13.41	27.63	2	0.81	Cause
$D4$	12.73	13.85	26.58	9	−1.11	Effect
$D5$	13.21	12.83	26.04	13	0.39	Cause
$D6$	13.59	13.26	26.85	8	0.33	Cause
$D7$	13.30	14.28	27.58	3	−0.98	Effect
$D8$	13.19	13.97	27.16	4	−0.78	Effect
$D9$	13.24	13.69	26.93	7	−0.46	Effect
$D10$	12.83	13.17	26.01	14	−0.34	Effect
$D11$	11.80	13.01	24.81	15	−1.21	Effect
$D12$	13.59	13.41	27.00	6	0.18	Cause
$D13$	13.57	12.72	26.29	12	0.84	Cause
$D14$	13.22	13.10	26.33	11	0.12	Cause
D 15	13.27	13.09	26.37	10	0.18	Cause

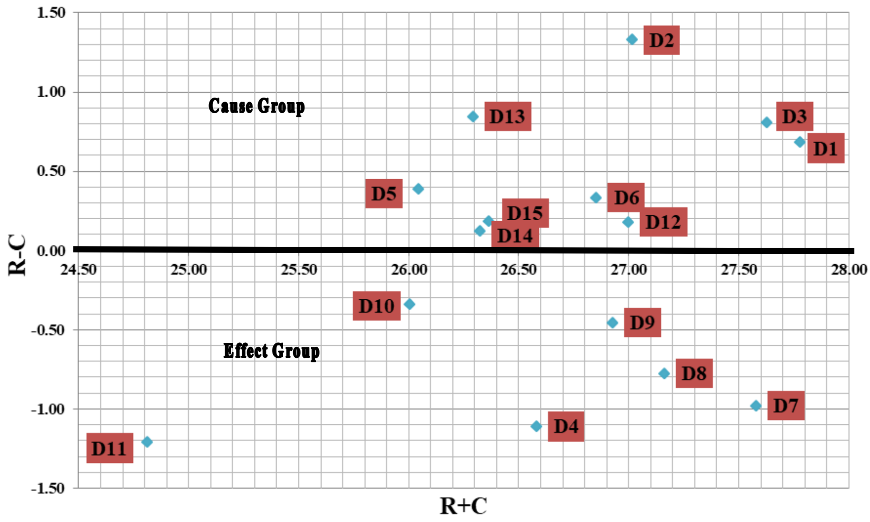

Fig. 2. The cause and effect diagram of the drivers to ICT for effective sustainability initiatives in SCs

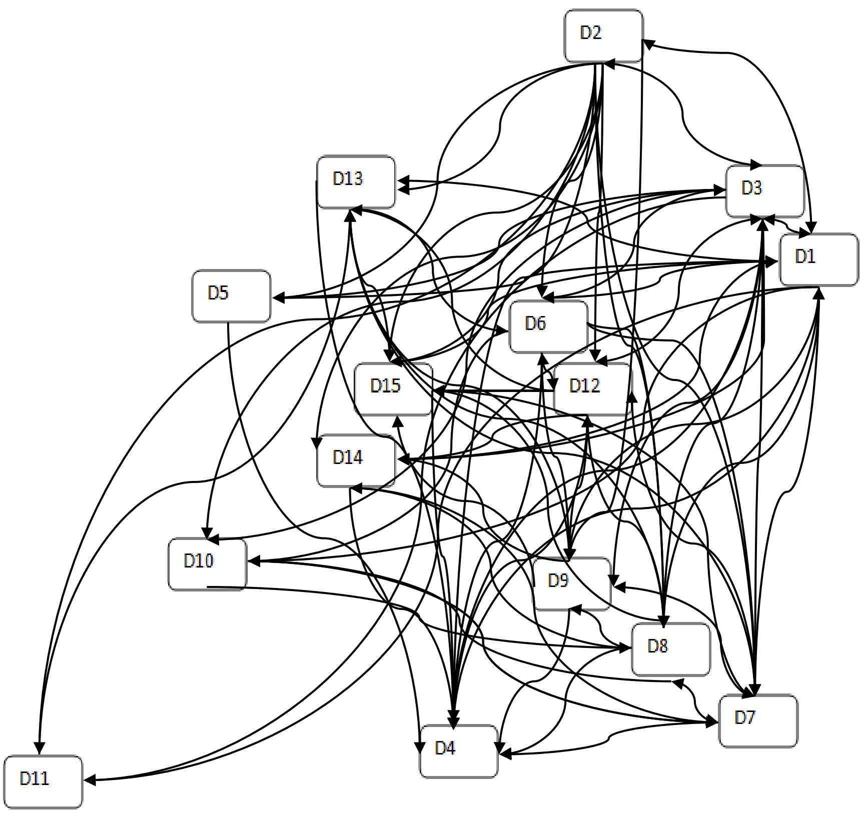

Fig. 3. Relationship diagram of the drivers to ICT for effective sustainability initiatives in SCs.

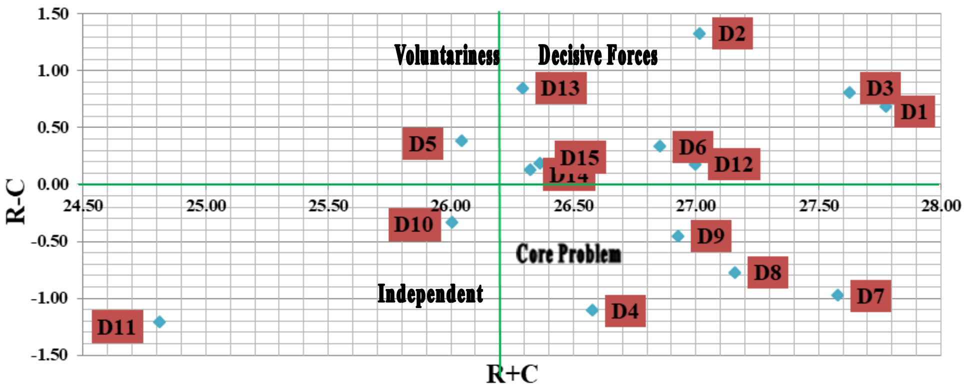

Fig. 4. Segmentation of the identified drivers to ICT for effective sustainability initiatives in SCs.

The values of R and C of the drivers were calculated and further $(R + C)$ and $(R - C)$ values are calculated and shown in Table 5.

Prominence $(R + C)$ provides the importance of the drivers. Likewise, Relation $(R - C)$ provides the sorting of the drivers into the cause and effect groups. Further, ranking of the drivers was achieved through $(R + C)$ dataset (see Table 5). Based on $(R + C)$ and $(R - C)$ values, we formed the cause and effect diagram of the drivers (see Fig. 2).

Further, we computed the threshold value by considering the average of all the elements in the total direct-relation matrix of the drivers, which comes out to be 0.89. The values in Table 4 higher than the threshold value are are considered to draw the relationship diagram as shown in Fig. 3.

Next, for better understanding, the identified drivers have been segmented into four groups (Decisive forces, Voluntariness, Independent, and Core problems) and has been shown in Fig. 4.

6. Discussions of Findings

The important order of the identified drivers based upon the $R + C$ dataset (in Table 5) is given as "Top management role and support ($D1$)", "Information systems network design ($D3$)", "ICT infrastructure and financial resources ($D7$)", "Understanding on the nature of sustainability ($D8$)", "Government support systems and subsidies ($D2$)", "Technological factors ($D12$)", "Brand image and SC competitiveness ($D9$)", "Approach to ICT to adopt sustainability in SCM ($D6$)", "Socio-environmental impacts of the products ($D4$)", "Organizational-related factors ($D15$)", "Information-sharing across hierarchy ($D14$)", "Knowledge and awareness of ICT tools and techniques ($D13$)", "Cultural-related factors ($D5$)", "Security and support services from ICT resources ($D10$)", and"Human expertise ($D11$)".

6.1. *Analysis of cause group drivers*

"Government support systems and subsidies ($D2$)" have the highest ($R - C$) score of 1.33, meaning that $D2$ has the highest influence. However, its ($R + C$) score (equal to 27.01) is reasonably low, meaning that Government support systems and subsidies influence other drivers significantly. The significant positive relationships between government support systems and ICT adoption can be found Refs. 115–117 The next driver in ($R - C$) column is the "Knowledge and awareness of ICT tools and techniques ($D13$)", with a score of 0.84. Proper knowledge and awareness related to the use of ICT tools/techniques will help business organizations to proactively transform value chain operations to gain economically, environmentally, and socially.[118,119] Next, driver is "Information systems network design ($D3$)", with ($R - C$) score of 0.81 is important in enhancing the ICT applications for sustainability in SC. According to the recent research, Brindley and Oxborrow[120] suggested that the information exchange network should be designed to meet changes or disruptions in the SCs and must be aligned to market needs. Next driver is given as "Top management role and support ($D1$)", having ($R - C$) score of 0.68. Top management must support activities towards implementation of ICT to achieve best practices for sustainability initiatives in SCs.[121] "Culture-related factors ($D5$)" (with ($R - C$) score of 0.39) are crucial in understanding and responding to local cultural variations and in developing the right ICT skills.[122] Next, "Approach to ICT to adopt sustainability in SCM ($D6$)" (having ($R - C$) score of 0.33) is very important in supporting the implementation of sustainability.[123] The drivers "Technological factors ($D12$)" and "Organizational-related factors ($D15$)" are equally important with ($R - C$) score of 0.18. Finally, in the cause group, the driver "Information-sharing across hierarchy ($D14$)" having ($R - C$) score of 0.12 is crucial in sharing the information in the day-to-day operations, making information-sharing/collaboration and triggering the co-creation along with the other stakeholders for sustainability initiatives in SCs.[124]

6.2. *Analysis of effect group drivers*

Drivers in the effect group make a significant contribution on the system. In all, the effect group driver, "Human expertise ($D11$)" receives the highest influence represented by its highest ($R - C$) score of -1.21. Regular upgrading of knowledge to adapt to the newer ICT technologies, coupled with the right attitude of the human resources involved in the SCs, will enhance sustainability initiatives.[125] Among the effect group drivers, "Socio-environmental impacts of the products ($D4$)", "ICT infrastructure and financial resources ($D7$)" "Understanding on the nature of sustainability ($D8$)", "Brand image and SC competitiveness ($D9$)", and "Security and support services from ICT resources ($D10$)" are having ($R - C$) a score of -1.11, -0.98, -0.78, -0.46 -0.34, respectively. ICT supports the sustainability initiatives through the application of increased efficiencies in energy use, production, and distribution.[126] But, ICT requires a lot of additional infrastructure and financial resources to make the ICT work for sustainability initiatives in SCs.[1] The driver "ICT infrastructure and financial resources ($D7$)" is among the top drivers based on its $(R + C)$ score of 27.58. This means that ICT infrastructure and financial resources are crucial in the successful implementation of ICT for sustainability initiatives in SCs. Most business organizations need to trade-off between the investment and value in decisions on SC sustainability. At the moment, a sustainability "Knowledge-to-Action" gap is observed in the SC members' behavior.[127] By reducing this gap, ICT will help to achieve a better brand image and improved competitiveness of their products/services in the SC by effective utilization of resources.

The cause and effect diagram provides valuable insights analyzing the drivers in successful implementation of ICT for sustainability initiatives in SCs. By virtue of this work, managers can differentiate the driver which greatly affects the initiatives of implementing ICT to incorporate sustainability in the chains, and thus, improvements can be made accordingly.

6.3. *Implications of the research*

The present contribution explores both the sustainability aspects in SCs and key drivers. Delphi and fuzzy DEMATEL-based modeling provide not only an opportunity to examine the different drivers, but also to understand their causal relationships. The identified drivers have been mapped into four quadrants (decisive forces, voluntariness, independent and core problems) and present a visual structure to manager. With regard to these four quadrants (see Fig. 4), this study offers several implications for operations management and management science professionals as follows:

- Quadrant I drivers obtain the highest prominence and relation, referring to the utmost interaction influence on other drivers. In respect to this point, eight drivers ("Top management role and support ($D1$)", "Government support systems and subsidies ($D2$)", "Information systems network design ($D3$)", "Approach to ICT to adopt sustainability in SCM ($D6$)", "Technological factors ($D12$)", "Knowledge and awareness of ICT tools and techniques ($D13$)", "Information-sharing across hierarchy ($D14$)", "Organizational-related factors ($D15$)") fall into the decisive forces area. It means that these eight drivers may play decisive role in effectively implementing ICT to incorporate sustainability in SCs. Our result suggests that, in order to implement sustainability initiatives, the one of the decisive factors is Top management role and support. Management role and support is imperative in sustainability of SC as concerned management is fully responsible in allocating adequate financial, technological and HRs for implementing ICT concepts, while adding sustainable initiatives in SCs.[128,129] Government support systems and subsidies are next significant decisive factor in achieving SC sustainability through ICT applicability. The government support and directive systems may vary from country to country, that's why developing economies have less advanced to sustainability initiatives in SCs as compared to the developed economies.[117] In this sense, a collaborative and cooperation culture is needed to develop between government agencies in a country context. Next, a robust and resilient information systems network should be designed and applied to deal with probable disruption and maximizing the overall performance of sustainable SCs. In line with this, the approach to ICT to adopt sustainability in SC management is crucial to deliver better customer service, better planning, good organization supplier relationships, and other process improvements aligned to the market needs. Management role is decisive here and therefore, managers are suggested to follow proactive approach for accomplishing sustainable and competitive gains in the market. In deciding the managerial approach to ICT applicability, the provision of technological advancement and upgradation are significant. Thus, it is suggested to develop a contemporary culture of satisfying the technological requirements in sustainable business development. In order to have efficient technological advancements, the knowledge and awareness of ICT tools and techniques are significant, and thus, management should focus on developing the IT skills and expertise in all members (horizontal and vertical) of SCs for sustainable development. Some regular training and education programs may be initiated for this purpose. Information-sharing across hierarchy is also important for SC sustainability. Managers should share real information and exact data with other stakeholders for the improved customer satisfaction and performances. Organizations have understood the importance of information-sharing with the other partners in achieving benefits in the SCs, and that's why organizational-related factors are also crucial decisive ICT-based factor in SC sustainability. Thus, managers should focus on developing the organizational internal environment and capabilities to adopting/managing ICT-driven sustainable SC networks successfully.

- Quadrant II has lower prominence but high relation, and is known as voluntariness. After focusing on decisive group drivers, it is needed to work out on this group driver. Driver ($D5$) is located in this quadrant.
- Quadrant III (independent) indicates low prominence and relation; and less interaction within the system. Only two drivers ($D10$ and $D11$) fall into the independent area.
- Quadrant IV represents the core problems (high prominence and low relation) that are required to be solved. These drivers are actually core problems, as they may not directly improve the system, but should be improved by other driver, e.g., the decisive group and follow-up drivers.

7. Conclusions

This work puts into practice effective sustainable business aspects by evaluating the key drivers to ICT for effective sustainability initiatives in SCs. The current work uses Delphi and fuzzy DEMATEL-based techniques to explore the key drivers and to analyze the influenced and influential relations among the drivers. Delphi analysis is used to finalize the key-related drivers which are identified through the literature initially. Fuzzy DEMATEL is used to evaluate the causal interactions among the ICT-driven sustainability focused drivers under uncertain surroundings.

This study lists 15 drivers to ICT for effective sustainability developments initiatives in SCs through the literature and Delphi analysis. Based on fuzzy DEMATEL technique, drivers namely $D1$, $D2$, $D3$, $D5$, $D6$, $D12$, $D13$, $D14$, and $D15$ come under cause group driver and needs to be improved for the desired outcome. Drivers namely $D4$, $D7$, $D8$, $D9$, $D10$, and $D11$ come under effect group. Further, these identified drivers have been categorized into four quadrants, namely, Decisive factors, Voluntariness, Independent, and Core problems. This study promises significant contributions to implementation of ICT for sustainability development decisions in SCs from the industrial viewpoint.

This work has certain limitations. Some disadvantages of Delphi are the time and expense of designing questionnaire, potentially high attrition rate, difficulties in conducting surveys and questionnaires, compiling responses, and following up the respondents for multiple iterations. This work is based on expert's feedback. Future research may be carried out to understand the interrelations among the drivers using some other MCDM techniques, such as ANP and TOPSIS. A real life application of the suggested framework may be tested in the future studies.

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