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Analyzing Factors Affecting Success of E-Supply Chain Management Implementation using Type-2 Fuzzy Group Decision Making (Case Study: The Electronics Industries in Yazd Province)

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KEYWORDS

E-supply chain;
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Type-2 fuzzy;
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ABSTRACT

In this study, type-2 fuzzy AHP and type-2 fuzzy DEMATEL were used to analyze the implementation of the electronic supply chain comprehensively. According to the current theoretical foundations and the comments made by 10 experts (directors of electronic industries in Yazd Province), the factors influencing the implementation of the electronic supply chain were classified as seven dimensions and 31 indicators. Then, AHP and DEMATEL questionnaires were distributed among the experts of electronics industries in Yazd Province to collect data. Type-2 fuzzy AHP and type-2 DEMATEL were employed to determine the weights and causal relations of factors. The research results indicated that influential factors or causes were computer-based technology, infrastructures, inter-organizational relationships, and information. Moreover, the impressible factors or effects were the dimensions of a business environment, demand accountability, and relationships with suppliers.

1. Introduction

In today's competitive market, there is much pressure to make quick decision and find new solutions in the face of frequent environmental changes in order to achieve organizational survival (Englehardt & Simmons, 2002). Traditional supply chains must be replaced by customer-oriented supply chains which have features such as long-term goals, use of technology, and extensive communication throughout the organization (Murphy & Wood, 2003). The important point is that technology is at the heart of the changes that have affected the supply chain, so the most important causes of these changes are the two key factors of computing power and the Internet (Kuglin & Rosenbaum, 2001). Internet's key role in the development of the supply chain has resulted in the formation of a new concept called electronic supply chain management (ESCM) (Pulevska-Ivanovska & Kaleshovska, 2013). Since the year 2000, this concept has become a key issue, such that many contemporary scholars and prestigious journals and scientific databases have considered it a necessity for successful organizations,

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(Giménez & Lourenço, 2008). Unlike traditional supply chains which focused on the product, ESCM focuses on the customers (Holmberg, 2000). Internet and new technologies have created new ways and opportunities to gain competitive advantage for today's organizations. These issues also brought new dimensions to supply chain management, so that the fundamental changes that they have brought to the enterprises' businesses can be called a tsunami. This tsunami has played an effective role in the integration and synchronization of all the data and processes linked to the supply chain management of organizations (Poirier & Bauer, 2000), as it has rapidly reflected the customers' demands and enabled the business partners to integrate their products and services and form effective and long-term relationships with each other (I. L. Wu & Chuang, 2010). Organizations must have the ability to attract suppliers and customer satisfaction, develop the business, and boost product quality and profitability so that they can survive (Iskanius, 2006). Thus, considering the changes that new technologies, especially the Internet, have created in the business scope, the attention of great managers, academics and stakeholders has doubled to electronic supply chain management as an important branch in management with a strong and growing body, the new expectations that have arisen in the participants in supply chains, and the increasing development of the World Wide Web, the importance of electronic supply chain management. Therefore, identification and assessment of factors influencing the implementation of electronic supply chain management is an essential and undeniable matter for planning and creating competitive advantage for enterprises. In this regard, this article seeks to address this issue by using an integrated type-2 fuzzy AHP and type-2 fuzzy DEMATEL approaches.

2. Literature

2-1. Supply chain management

After World War II, supply chains operated as independent trends and processes that connected raw material manufacturers and vendors and warehouse keepers and applicants and customers together (Chou, Tan, & Yen, 2004). Supply chain management history dates back to the late 1950s, when research was carried out regarding the transfer of inventory to the factory and out of it. Since 1970, in the wake of the planning that was done for the needed raw materials, supply chain operations truly began (Schoenherr & Tummala, 2008). In the eighties, in order to gain competitive advantage, organizations focused on total quality management and production and this was despite the fact that all these advantages were imitable by competitors and lacked the necessary stability, because all of them were among organization's internal processes and no attention was paid to the outside of the organization, especially raw material suppliers and customers. Supply chain management concept was born when the organization realized that if they work together to reach a common goal, they would achieve better performances and results (Stavrulaki & Davis, 2010; Schoenherr & Tummala, 2008). Michael Hammer believes that when processes are established within the organization and a relationship is adequately and effectively established between organizations, the power struggle for profit and revenue intensifies and the organization that wins and is successful is the one that finds new ways for their business and implements and manages processes in their organizations longitudinally (Nematbakhsh, 2004). Frazelle considers supply chains one of the new topics that organizations use to create value for shareholders and stakeholders, and it is an interdisciplinary topic that has emerged from fields such as marketing, operations management, purchasing and support (Frazelle, 2002). which aims at managing supply and demand, as well as coordinating activities from purchasing materials to product manufacturing, assembly, warehousing, order entry, management and distribution (Lin, 2013). Therefore, supply chain management is seeking to increase customer satisfaction by facilitating the processes involved in production and reducing its costs, sharing of information between trading partners, reducing costs by coordinating supply and demand, and providing fast and satisfactory services to customers (Chou et al., 2004).

2-2. E-supply chain management

The greater presence of commercial organizations in the competitive markets today than in the past has made a link between supply chain activities of the organizations and new technologies necessary (Patterson, Grimm, & Corsi, 2003). Organizations are turning more and more to the Internet and new communication networks to share information to perform better trades. In the recent century, the rise of information technology has caused radical changes in how consumers are informed about, choose, and purchase products, and it created new business environments and led to the occurrence of fundamental changes in the nature of supply chains and the shaping of a new phenomenon called e-supply chain (Stefan Holmberg & Holmberg, 2000). which through using electronic communications, has caused better and more effective inter-organizational activities and facilitated the interactions between them (Sitkin & Pablo, 1992). Electronic connections lead to supply chain integration, and thus to the effective execution of inter-organizational processes and coordination of organizational operations in the supply chain (Sitkin & Pablo, 1992). The complexities of supply chains on the one hand, and the improvements that have arisen in the field of e-commerce on the other hand, have made organizations use new and online means of communication, such as the Internet. Internet has turned the industrial economy in the commercial method of organizations to network economy in a way that through networking technologies, it has allowed organizations to share and collaborate with their trading partners and reduce costs and increase profits and customer satisfaction (Chou et al., 2004). Using the Internet in the supply chain brings about a competitive advantage for enterprises due to the two following reasons: 1. creating low-cost and effective communications that give even small organizations the ability to use the advantages of e-supply chain management techniques; 2. by creating inter-organizational networks, transactions and integrated businesses are done in real-time (Chou et al., 2004). The Internet also affects SCM in three ways: 1. increasing the use of ERP and planning and optimizing advanced solutions; 2. increasing real-time accessibility of information in order to make timely decisions; 3. information integration and decision-making across all different units of the organization (Bayraktar, Lenny Koh, Gunasekaran, Sari, & Tatoglu, 2008).

2-3. Key factors affecting the success of e-supply chains

There are several key points in business for each organization such that if an organization has a satisfactory performance in those point, its competitive future is guaranteed. These points are the critical success factors which were first introduced by Rockart as information support for top-level managers (Puschmann & Alt, 2005; Rockart, 1978). Managers must always observe the mentioned factors which are critical for the current and future activities of the organization and take actions to identify, modify and correct them (Puschmann & Alt, 2005). The initial studies that were performed on the key factors affecting the success of supply chains offered factors, such as suitable planning, designing appropriate distribution systems, top management commitment, and close relationship with business partners (Korpela & Tuominen, 1996; Neng Chiu, 1995; Tate, 1996). On the other hand, factors such as organization culture and values, understanding business needs, effective communication, mutual commitment, flexibility, and fairness and mutual trust can also be named as key factors (Puschmann & Alt, 2005). Many studies have also been done on the key success factors in electronic supply chain management (Favilla & Fearne, 2005; Gunasekaran & Ngai, 2004; Hwang & Lu, 2013; Soliman, Janz, Puschmann, & Alt, 2005). all of which agree that information technology (IT) is one of the success factors in e-supply chains and consider the necessary infrastructure, including web-based systems, hardware and software, for making the supply chain electronics and forming effective communications between supply chain members as necessary and urgent (Puschmann & Alt, 2005). Although information technology plays an important role in the success of e-supply chain, but if the organization does not receive support, it will not be able to achieve its objectives. Rather, information technology and organization support should move parallel to each other (Favilla & Fearne, 2005; Hwang & Lu, 2013; Puschmann & Alt, 2005). The necessary support includes organizational commitment, positive support of organizational efficiency and productivity, customer satisfaction increase, and better allocation of resources (Puschmann & Alt, 2005) .After reviewing the literature and similar studies, the set of factors affecting the success of implementing e-supply chains can be summarized in the form of Table 1.

3. The Proposed Approach

The aim of the current research is to identify and rank the factors influencing successful implementation of e-supply chains in the electronics industry in Yazd province. To identify the factors, research literature and similar studies and surveys of Experts were used. The experts were 10 experts of electronics industries. Accordingly, a total of 31 indicators in seven factors were determined (Table 1). After determining the factors influencing successful implementation of e-supply chains, their importance was discussed.

The remarkable point in determining the importance of the identified factors is that these factors interact with each other. Therefore, determining the factors' weights regardless of their relationship matrix is not free of errors. Since the aim of this study is to modify the results by considering the weights of factors, to determine their weights, an integrated type-2 fuzzy AHP and type-2 fuzzy DEMATEL approach was used based on the study of Kahraman et al. (2014) and Abdullah and Zulkifli (2015). The proposed approach considers the importance of factors in explaining their effectiveness and impressiveness in order to present results that are more accurate. If the goal is to determine the final weights of factors, the weighted vector of AHP can be multiplied by the matrix of normalized total relationships to determine the final weights of factors. It should be noted that previous studies employed AHP with type-2 fuzzy DEMATEL. However, type-2 fuzzy AHP and type-2 fuzzy DEMATEL were used in this study. Therefore, in the next part of the research, the stages of the research are studied in two phases.

Tab. 1. Factors affecting successful implementation of e-supply chains

Factor	Sub-factor	Reference
Computer-based technology	Internet and web-based e-markets Choosing suitable e-markets Process reengineering Formation of virtual collaborations Using new technologies	(Akyuz & Rehan, 2009; Cullen & Taylor, 2009), (Hwang & Lu, 2013), (Premkumar, 2003; Ratnasingam, 2007; Vaidyanathan & Devaraj, 2003; Wilson, 2000)
Business environment	Externally-imposed and uncontrollable processes Natural incidents Government actions (exchange rate, taxes, ...) Market sensitivity	(Ziegenbein & Nienhaus, 2004; G. a. Zsidisin, Ellram, Carter, & Cavinato, 2004)
Meeting the demand	Ability to respond to today's rapid and severe changes Accepting or refusing the new products Product life Dealing with the sudden cancellation of orders The clarity of the SCM system	(Puschmann & Alt, 2005), (Cullen & Taylor, 2009), (Hwang & Lu, 2013), (Ziegenbein & Nienhaus, 2004), (Johnson, 2001; Svensson, 2002)
Relationship with suppliers	The supply market Nature of the purchased goods or materials Communications and transportation based on technology Building strategic business alliances	(Korpela & Tuominen, 1996), (Wilson, 2000), (G. A. Zsidisin, 2003; G. A. Zsidisin, Ellram, Carter, & Cavinato, 2004)
Infrastructures	Replacing or merging with the old system Fundamental technologies Economical Software preparation Top management commitment	(Cullen & Taylor, 2009),(Korpela & Tuominen, 1996),(Wilson, 2000), (Hwang & Lu, 2013), (Premkumar, 2003; Ratnasingam, 2007; Vaidyanathan & Devaraj, 2003; Wilson, 2000)
Inter-organizational relationships	Relationship integrity Commitment to obligations Trust and confidence of dependent cooperation Resource integration	(Cullen & Taylor, 2009), (Akyuz & Rehan, 2009), (Puschmann & Alt, 2005), (Hwang & Lu, 2013), (Dyer, 2000; Spekman & Davis, 2004)
Information	Quality Safety Ability to document Level of sharing	(Korpela & Tuominen, 1996), (Vaidyanathan & Devaraj, 2003), (Pathak & Baldwin, 2003)

3-1. Phase one: determining the weights of the factors and sub-factors using type-2 fuzzy AHP technique

In 1967, Chang presented a paper in which the hierarchical fuzzy method was discussed. Since uncertainty is one of the most common problems of decision making, fuzzy decision-making methods were developed to address this problem (Ting, 2016). This method allows decision-makers to express their priorities and opinions by fuzzy numbers and include uncertainty in their judgments in these cases. Fuzzy theory is a type of mathematics theory which is designed to understand ambiguous human behaviour, where decision-makers express their opinions generally as optimistic, pessimistic, medium, highly relevant, etc. (Zimmermann, 1996). In this study, to determine the weights of the factors and sub-factors, a hierarchical type-2 fuzzy method is used in which the fuzzy numbers are trapezoidal. The steps of this technique are as follows.

Step 1. Drawing the hierarchical graph

The hierarchical structure consists of two levels: the upper level consists of the factors and the lower level consists of the indicators (sub-factors) affecting the successful implementation of e-supply chains.

Step 2. Creating the matrix of pairwise comparisons using type-2 trapezoidal fuzzy numbers

In this step, experts are asked to express their opinions about the pairwise comparison of the factors affecting the successful implementation of the electronic supply chains based on figure (1), using the linguistic variables in Table 2.

Tab. 2. Type-2 trapezoidal fuzzy number linguistic variables (Kahraman, ßar, ßi, Sarı, & Turanog ˘lu, 2014)

Linguistic variables	Triangular interval type-2 fuzzy scales	Trapezoidal interval type-2 fuzzy scales
Absolutely Strong	(7.5,9,10.5;1)(8.5,9,9.5;0.9)	(7,8,9,9;1,1)(7.2,8.2,8.8,9;0.8,0.8)
Very Strong	(5.5,7,8.5;1)(6.5,7,7.5;0.9)	(5,6,8,9;1,1)(5.2,6.2,7.8,8.8;0.8,0.8)
Fairly Strong	(3.5,5,6.5;1)(4.5,5,5.5;0.9)	(3,4,6,7;1,1)(3.2,4.2,5.8,6.8;0.8,0.8)
Slightly Strong	(1.5,3,4.5;1)(2.5,3,3.5;0.9)	(1,2,4,5;1,1)(1.2,2.2,3.8,4.8;0.8,0.8)
Exactly Equal	(1,1,1;1)(1,1,1;1)	(1,1,1,1;1,1)(1,1,1,1;1,1)

In the mentioned Table, the reverse type-2 trapezoidal fuzzy number is obtained using Eq. (7).

Matrix $\tilde{\tilde{A}}$ is obtained for the factors and indicators using Eq. (7).

$$\tilde{\tilde{A}}=\begin{bmatrix} 1 & \tilde{\tilde{a}}_{12} & \cdots & \tilde{\tilde{a}}_{1n} \\ \tilde{\tilde{a}}_{21} & 1 & \cdots & \tilde{\tilde{a}}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\tilde{a}}_{n1} & \tilde{\tilde{a}}_{n2} & \cdots & 1 \end{bmatrix}=\begin{bmatrix} 1 & \tilde{\tilde{a}}_{12} & \cdots & \tilde{\tilde{a}}_{1n} \\ 1/\tilde{\tilde{a}}_{12} & 1 & \cdots & \tilde{\tilde{a}}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{\tilde{a}}_{1n} & 1/\tilde{\tilde{a}}_{2n} & \cdots & 1 \end{bmatrix} \quad (7)$$

where

$$\frac{1}{\tilde{\tilde{a}}}=\left(\begin{array}{l}\left(\frac{1}{a_{14}^{u}},\frac{1}{a_{13}^{u}},\frac{1}{a_{12}^{u}},\frac{1}{a_{11}^{u}};H_1(a_{12}^{u}),H_2(a_{13}^{u})\right),\\ \left(\frac{1}{a_{24}^{l}},\frac{1}{a_{23}^{l}},\frac{1}{a_{22}^{l}},\frac{1}{a_{21}^{l}};H_1(a_{22}^{l}),H_2(a_{23}^{l})\right)\end{array}\right)$$

Step 3. Checking the compatibility of the pairwise comparison matrix

Suppose that $A=[a_{ij}]$ is a positive interaction matrix and $\tilde{\tilde{A}}=[\tilde{\tilde{a}}_{ij}]$ is the type-2 fuzzy positive interaction matrix. Now, if $A=[a_{ij}]$ is compatible, then $\tilde{\tilde{A}}=[\tilde{\tilde{a}}_{ij}]$ may also be compatible. To calculate the compatibility of the type-2 trapezoidal fuzzy pairwise comparison matrix using Eq. (8), type-2 fuzzy numbers are turned into certain numbers (Kahraman et al., 2014). Then, we calculate the inconsistency rate of the certain matrix of pairwise comparisons.

$$E(U)=DTraT=\frac{1}{2}\left(\begin{array}{l}\frac{(U_u-L_u)+(\beta_u.m_{1u}-L_u)+(\alpha_u.m_{2u}-L_u)}{4}+L_u\\ +\left[\frac{(U_l-L_l)+(\beta_l.m_{1l}-L_l)+(\alpha_l.m_{21}-L_l)}{4}+L_l\right]\end{array}\right) \quad (8)$$

Step 4. Integrating the Experts' matrix of pairwise comparisons: Experts' pairwise comparison matrix is integrated using Eq. (9).

$$\tilde{\tilde{r}}_i=\left[\tilde{\tilde{a}}_{i1}\otimes\ldots\otimes\tilde{\tilde{a}}_{in}\right]^{\frac{1}{n}} \quad (9)$$

where

$$\sqrt[n]{\tilde{\tilde{a}}_{i1}}=\left(\begin{array}{l}\left(\sqrt[n]{\tilde{\tilde{a}}_{ij1}^{u}},\sqrt[n]{\tilde{\tilde{a}}_{ij2}^{u}},\sqrt[n]{\tilde{\tilde{a}}_{ij3}^{u}},\sqrt[n]{\tilde{\tilde{a}}_{ij4}^{u}};H_1^{u}(a_{ij}),H_1^{u}(a_{ij})\right)\\ \left(\sqrt[n]{\tilde{\tilde{a}}_{ij1}^{l}},\sqrt[n]{\tilde{\tilde{a}}_{ij2}^{l}},\sqrt[n]{\tilde{\tilde{a}}_{ij3}^{l}},\sqrt[n]{\tilde{\tilde{a}}_{ij4}^{l}};H_1^{l}(a_{ij}),H_1^{l}(a_{ij})\right)\end{array}\right)$$

Step 5. Calculating the fuzzy weights: the fuzzy weight of each factor and indicator is obtained from Eq. (10).

$$\tilde{\tilde{W}}_j=\tilde{\tilde{r}}_j\otimes\left(\tilde{\tilde{r}}_1\oplus\tilde{\tilde{r}}_2\oplus\ldots\oplus\tilde{\tilde{r}}_n\right)^{-1} \quad (10)$$

where

$$\frac{\approx{a}}{\approx{b}} = \left(\left(\frac{a_1^u}{b_4^u}, \frac{a_2^u}{b_3^u}, \frac{a_3^u}{b_2^u}, \frac{a_4^u}{b_1^u}; \min\left(H_1^u(a), H_1^u(b)\right), \min\left(H_2^u(a), H_2^u(b)\right) \right), \left(\frac{a_1^l}{b_4^l}, \frac{a_2^l}{b_3^l}, \frac{a_3^l}{b_2^l}, \frac{a_4^l}{b_1^l}; \min\left(H_1^l(a), H_1^l(b)\right), \min\left(H_2^l(a), H_2^l(b)\right) \right) \right)$$

Step 6. Calculating the total weights of the indicators: based on Eq. (11), the total weights of the indicators are obtained

$$\tilde{\tilde{U}}_i = \tilde{\tilde{W}}_j \tilde{\tilde{r}}_{ij} \qquad \forall i \tag{11}$$

in which $\tilde{\tilde{W}}_j$ is the j^{th} factor's type-2 fuzzy weight and $\tilde{\tilde{r}}_{ij}$ is the type-2 fuzzy weight of the indicators related to the j^{th} factor.

Step 7. Defuzzifying and normalizing the fuzzy weights: Using Eq. (12), the defuzzified weights of factors and indicators are obtained (Kahraman et al., 2014).

$$E(U) = DTraT = \frac{1}{2}\left(\frac{(U_u - L_u) + (\beta_u . m_{1u} - L_u) + (\alpha_u . m_{2u} - L_u)}{4} + L_u + \left[\frac{(U_l - L_l) + (\beta_l . m_{1l} - L_l) + (\alpha_l . m_{2l} - L_l)}{4} + L_l \right] \right) \tag{12}$$

3-2. Phase two. The relationship between indicators using type-2 fuzzy DEMATEL technique

Two researchers named Fontela and Gabus in 1976 first presented DEMATEL method. This technique is one of the decision making methods based on pairwise comparisons (Gabus & Fontela, 1972) .The most important characteristic of the DEMATEL method is that it is a multi-criteria decision making method with the ability to build relationships and structures between factors. In addition to turning causal relationships into a visual-structural model, this technique can identify internal dependencies between elements and make them understandable (W.-W. Wu, 2008). In general, estimating the expert opinions in exact numerical values, especially in conditions of uncertainty, is very difficult, because the results of their decisions heavily depend on inaccurate and ambiguous subjective judgment. This is why fuzzy logic is required in the DEMATEL method. As a result, in the fuzzy DEMATEL technique, type-2 fuzzy linguistic variables are used and this facilitates decision-making in environmental uncertainty conditions (Abdullah & Zulkifli, 2015). The steps of this technique are mentioned below.

Step 8. Creating the initial direct relationship matrix (A): Questionnaires are prepared and distributed among Experts about the level of influence of each indicator on other indicators, and after gathering expert opinions and using Table 3, linguistic data are converted into type-2 trapezoidal fuzzy numbers and the initial direct relationship matrix is determined using Eq. (13).

$$A_{ij} = \frac{1}{H} \sum_{k=1}^{H} x_{ij}^{k} \tag{13}$$

Step 9. Normalizing the initial direct relationship matrix (D): the initial direct relationship matrix is obtained using Eqs. (14) and (15).

$$D = \frac{A}{S} \tag{14}$$

$$S = \max\left(\max_{1 \le i \le n} \sum_{j=1}^{n} A_{ij} , \max_{1 \le i \le n} \sum_{i=1}^{n} A_{ij} \right) \tag{15}$$

Step 10. Creating matrix $Z = Z_x$: using Eq. (16), matrix $Z = Z_x$ is built.

$$Z_x = \begin{bmatrix} 0 & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & 0 \end{bmatrix} \tag{16}$$

where

$x = (UMF, LMF) = ((a,b,c,d),(g,h,i,j))$, of which eight $n \times n$ matrixes are derived with unfuzzy numbers as elements. The reason for writing matrix D as eight matrixes is the ease of calculations in the next step. It should be noted that the number of rows in matrix $Z = [Z_x]$ is equal to the number of columns of matrix D.

Step 11. Presenting the total relationship matrix (T_x): We obtain the indicators' total relationship matrix using Eq. (17) where I is the identity matrix.

$$T_x = Z_x (I - Z_x)^{-1} \tag{17}$$

Step 12. Analyzing the causal relationships: The sum of rows and columns is obtained to analyse causal relationships, and to determine the values of $\left(\tilde{\tilde{D}}_i + \tilde{\tilde{R}}_i\right)$ and $\left(\tilde{\tilde{D}}_i - \tilde{\tilde{R}}_i\right)$, Eqs. (18-20) are used.

$$T_x = \left[t_{ij} \right]_{n \times n} \qquad i, j = 1, 2, ..., n \tag{18}$$

$$r_x = \left[\sum_{j=1}^{n} t_{ij} \right]_{n \times 1 = [t_i] n \times 1} \tag{19}$$

$$c_x = \left[\sum_{j=1}^{n} t_{ij} \right]_{1 \times n = [t_i] 1 \times n} \tag{20}$$

Step 13. Calculating the certain values $E(W)$: For the obtained $\left(\tilde{\tilde{D}}_i + \tilde{\tilde{R}}_i\right)$ and $\left(\tilde{\tilde{D}}_i - \tilde{\tilde{R}}_i\right)$ values in the previous step, we calculate the certain values using Eq. (21).

$$E(W) = \frac{1}{2}\left(\frac{1}{4}\sum_{i=1}^{4}\left(w_i^l + w_i^u\right)\right) \times \frac{1}{4}\left(\sum_{i=1}^{2}\left(w_i\left(A^l\right) + w_i\left(A^u\right)\right)\right) \qquad (21)$$

in which

$$w_i = \left(w_i^u + w_i^l\right) = \begin{pmatrix} \left(w_1^U, w_2^U, w_3^U, w_4^U; H_1\left(w_i^U\right), H_2\left(w_i^U\right)\right), \\ \left(w_1^L, w_2^L, w_3^L, w_4^L; H_1\left(w_i^L\right), H_2\left(w_i^L\right)\right) \end{pmatrix}$$

Step 14. Combining the fuzzy weights and $E(W)$: We combine the fuzzy weights obtained from step 7 of the first phase with the values of $E(W)$ associated with each indicator and factor to obtain new values. In order to do this, we use Eq. (22).

$$E(W)new = E(U_i) \otimes E(W) \qquad (22)$$

Step 15. Designing the causal diagram: We draw the causal diagram of the factors and all the indicators.

Results of the research

In the current section, the results of the data collection of research are presented.

Phase 1. Determining the fuzzy weights using type-2 fuzzy AHP technique:

Step 1. Drawing a hierarchical tree: As noted above, in order to determine the factors influencing successful implementation of e-supply chains, first, by reviewing the literature and similar studies, a set of factors was identified. Then, through interviews with Experts, the final effective factors were determined in seven factors and 31 indicators. Based on the identified factors, the hierarchical tree of the research was obtained, as shown in Fig. 1.

Step 2. Creating the pairwise comparison matrix using type-2 fuzzy numbers: Based on the hierarchical tree of the research, the pairwise comparison questionnaire was designed and distributed among the electronics industry Experts in Yazd province. After collecting linguistic data, linguistic variables are turned into type-2 fuzzy numbers using Table 2. For example, the matrix of pairwise comparisons of the factors is presented in Table 3.

Step 3. Checking the compatibility of the pairwise comparison matrix: In order to check the compatibility of the pairwise comparison matrix, first, the defuzzified values of the pairwise comparison matrixes of factors and indicators were determined using Eq. (8). Then, the incompatibility rate of each of the matrixes was investigated. The results showed that the incompatibility rate of all eight pairwise comparison matrixes was less than 0.1.

Step 4. Integrating the Experts' pairwise comparison matrix: Experts' pairwise comparison matrixes were integrated using Eq. (9). In Table 4, the pairwise comparison matrix of the factors is given as an example.

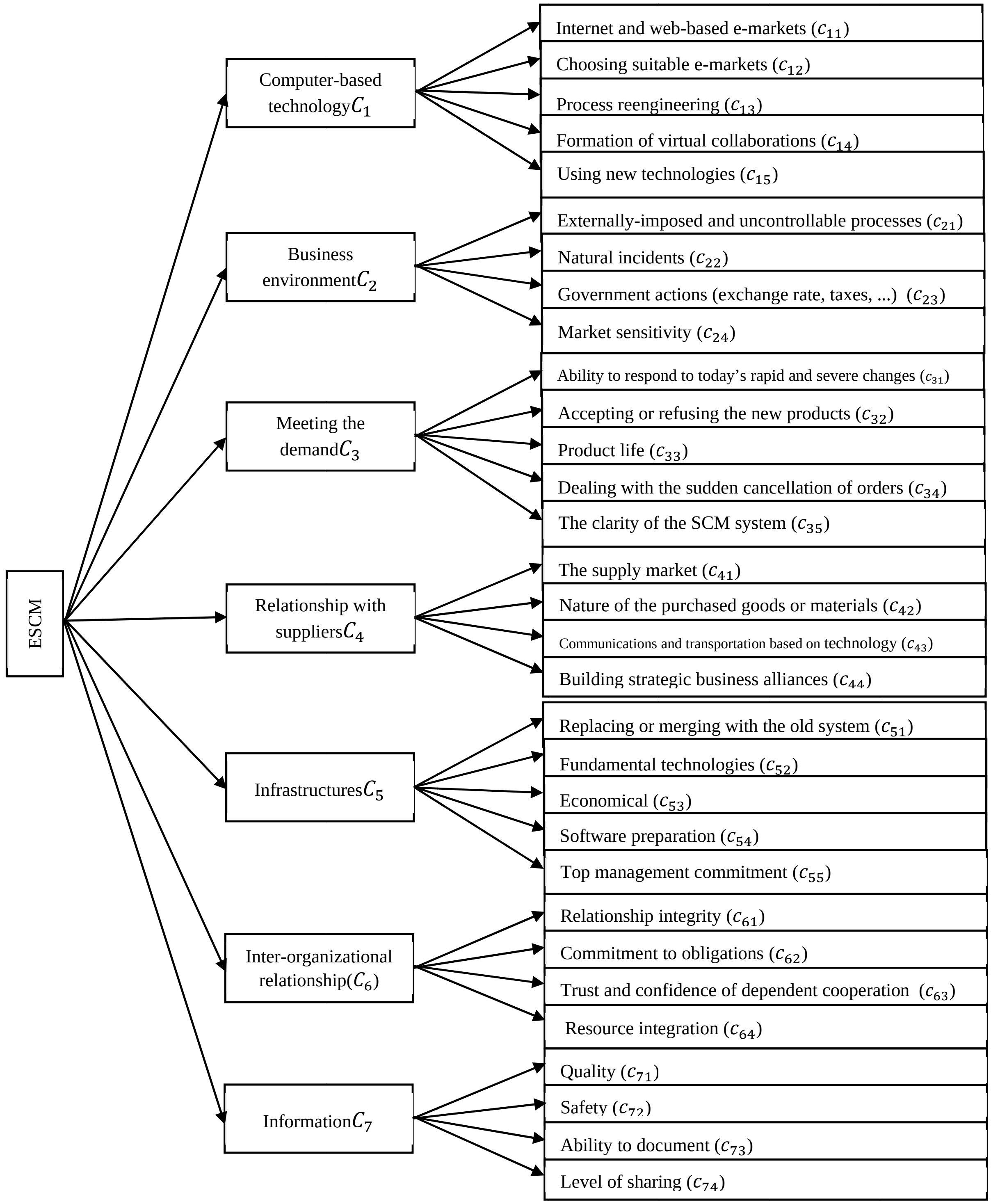

Fig. 1. The hierarchical tree of factors affecting the success of implementing e-supply chains

Tab. 3. Pairwise comparison matrix of factors affecting the success of e-supply chains

Dimension	C_1	C_7	C_3	C_4	C_5	C_6	C_7
C_1	((1,1,1,1;1,1),(1,1,1,1;0.8,0.8))	((1,2,4,5;1,1),(1.2,2.2,3.8,4.8;0.8,0.8))	((1.732,2.828,4.899,5.916;1,1),(1.96,3.04,4.695,5.713;0.8,0.8))	((1,2,4,5;1,1),(1.2,2.2,3.8,4.8;0.8,0.8))	((1,1,1,1;1,1),(1,1,1,1;0.8,0.8))	((3,4,6,7;1,1),(3.2,4.2,5.8,6.8;0.8,0.8))	((1,2,4,5;1,1),(1.2,2.2,3.8,4.8;0.8,0.8))

c_2	((0.2,0.25,0.5,1;1,1),(0.21,0.26,0.45,0.83;0.8,0.8))	((1,1,1,1;1,1),(1,1,1,1;0.8,0.8))	((1.732,2.828,4.899,5.916;1,1),(1.96,3.04,4.695,5.713;0.8,0.8))	((0.11,0.13,0.17,0.2;1,1),(0.11,0.13,0.16,0.19;0.8,0.8))	((1,1.414,2,2.236;1,1),(1.095,1.483,1.949,2.191;0.8,0.8))	((3.873,4.899,6.928,7.937;1,1),(4.079,5.103,6.726,7.736;0.8,0.8))	((0.2,0.25,0.5,1;1,1),(0.21,0.26,0.45,0.83;0.8,0.8))
c_3	((0.167,0.206,0.354,0.574;1,1),(0.177,0.21,0.329,0.507;0.8,0.8))	((0.167,0.206,0.354,0.574;1,1),(0.177,0.21,0.329,0.507;0.8,0.8))	((1,1,1,1;1,1),(1,1,1,1;0.8,0.8))	((1,2,4,5;1,1),(1.2,2.2,3.8,4.8;0.8,0.8))	((3.873,4.899,6.928,7.937;1,1),(4.079,5.103,6.726,7.736;0.8,0.8))	((3,4,6,7;1,1),(3.2,4.2,5.8,6.8;0.8,0.8))	((1,2,4,5;1,1),(1.2,2.2,3.8,4.8;0.8,0.8))
c_4	((0.2,0.25,0.5,1;1,1),(0.21,0.26,0.45,0.83;0.8,0.8))	((5,6,8,9;1,1),(5.2,6.2,7.8,8.8;0.8,0.8))	((0.2,0.25,0.5,1;1,1),(0.21,0.26,0.45,0.83;0.8,0.8))	((1,1,1,1;1,1),(1,1,1,1;0.8,0.8))	((1,2,4,5;1,1),(1.2,2.2,3.8,4.8;0.8,0.8))	((0.447,0.5,0.707,1;1,1),(0.458,0.51,0.671,0.911;0.8,0.8))	((0.2,0.25,0.5,1;1,1),(0.21,0.26,0.45,0.83;0.8,0.8))
c_5	((1,1,1,1;1,1),(1,1,1,1;0.8,0.8))	((0.447,0.5,0.707,1;1,1),(0.458,0.51,0.671,0.911;0.8,0.8))	((0.124,0.149,0.206,0.257;1,1),(0.128,0.149,0.196,0.243;0.8,0.8))	((0.148,0.18,0.292,0.447;1,1),(0.152,0.184,0.268,0.397;0.8,0.8))	((1,1,1,1;1,1),(1,1,1,1;0.8,0.8))	((0.2,0.25,0.5,1;1,1),(0.21,0.26,0.45,0.83;0.8,0.8))	((0.124,0.149,0.206,0.257;1,1),(0.128,0.149,0.196,0.243;0.8,0.8))
c_6	((0.14,0.17,0.25,0.33;1,1),(0.15,0.17,0.24,0.31;0.8,0.8))	((0.124,0.149,0.206,0.257;1,1),(0.128,0.149,0.196,0.243;0.8,0.8))	((0.14,0.17,0.25,0.33;1,1),(0.15,0.17,0.24,0.31;0.8,0.8))	((0.374,0.583,1,1.285;1,1),(0.424,0.612,0.955,1.22;0.8,0.8))	((1,2,4,5;1,1),(1.2,2.2,3.8,4.8;0.8,0.8))	((1,1,1,1;1,1),(1,1,1,1;0.8,0.8))	((0.124,0.149,0.206,0.257;1,1),(0.128,0.149,0.196,0.243;0.8,0.8))
c_7	((0.2,0.25,0.5,1;1,1),(0.21,0.26,0.45,0.83;0.8,0.8))	((1,2,4,5;1,1),(1.2,2.2,3.8,4.8;0.8,0.8))	((0.2,0.25,0.5,1;1,1),(0.21,0.26,0.45,0.83;0.8,0.8))	((0.447,0.707,1.414,2.236;1,1),(0.502,0.756,1.308,1.996;0.8,0.8))	((3.873,4.899,6.928,7.937;1,1),(4.079,5.103,6.726,7.736;0.8,0.8))	((3.873,4.899,6.928,7.937;1,1),(4.079,5.103,6.726,7.736;0.8,0.8))	((1,1,1,1;1,1),(1,1,1,1;0.8,0.8))

Tab. 4. The integrated pairwise comparison matrix of the Experts related to the factors affecting the successful implementation of e-supply chains

ESCM	$\tilde{\tilde{r}}_{ij}$
c_1	((1.265,1.903,2.936,3.393;1,1),(1.406,2.017,2.841,3.304;0.8,0.8))
c_2	((0.605,0.769,1.163,1.545;1,1),(0.637,0.796,1.104,1.437;0.8,0.8))
c_3	((0.852,1.188,1.88,2.4;1,1),(0.928,1.243,1.798,2.271;0.8,0.8))
c_4	((0.563,0.713,1.16,1.723;1,1),(0.595,0.741,1.089,1.555;0.8,0.8))
c_5	((0.297,0.337,0.46,0.605;1,1),(0.304,0.341,0.438,0.562;0.8,0.8))
c_6	((0.273,0.357,0.522,0.644;1,1),(0.294,0.365,0.502,0.615;0.8,0.8))
c_7	((0.829,1.113,1.827,2.552;1,1),(0.89,1.166,1.725,2.349;0.8,0.8))

Step 5. Calculating the type-2 fuzzy weights: Using Eq. (10), the fuzzy weights of the factors and indicators were determined. The calculated values of the factors are depicted in Table 5.

Step 6. Calculating the total weight of indicators: Based on Eq. (11), the total weight of the effective indicators was determined as shown in Table 6.

Step 7. Defuzzifying and normalizing the type-2 fuzzy weights: Using Eq. (12), the defuzzified weights of the indicators that affect the success of the implementation of e-supply chains are shown in the last column of Table 6.

Tab. 5. The fuzzy and certain weights of the factors affecting the successful implementation of e-supply chains

ESCM	$\tilde{\tilde{r}}_{ij}$	$\tilde{\tilde{W}}_j$	$E\left(U_D\right)$
c_1	((1.265,1.903,2.936,3.393;1,1),(1.406,2.017,2.841,3.304;0.8,0.8))	((0.098,0.191,0.46,0.724;1,1),(0.116,0.212,0.426,0.654;0.8,0.8))	0.34

c_2	((0.605,0.769,1.163,1.545;1,1),(0.637,0.796,1.104,1.437;0.8,0.8))	((0.047,0.077,0.182,0.33;1,1),(0.053,0.084,0.165,0.284;0.8,0.8))	0.15
c_3	((0.852,1.188,1.88,2.4;1,1),(0.928,1.243,1.798,2.271;0.8,0.8))	((0.066,0.119,0.295,0.512;1,1),(0.077,0.131,0.27,0.449;0.8,0.8))	0.23
c_4	((0.563,0.713,1.16,1.723;1,1),(0.595,0.741,1.089,1.555;0.8,0.8))	((0.044,0.072,0.182,0.368;1,1),(0.049,0.078,0.163,0.308;0.8,0.8))	0.15
c_5	((0.297,0.337,0.46,0.605;1,1),(0.304,0.341,0.438,0.562;0.8,0.8))	((0.023,0.034,0.072,0.129;1,1),(0.025,0.036,0.066,0.111;0.8,0.8))	0.06
c_6	((0.273,0.357,0.522,0.644;1,1),(0.294,0.365,0.502,0.615;0.8,0.8))	((0.021,0.036,0.082,0.138;1,1),(0.024,0.038,0.075,0.122;0.8,0.8))	0.06
c_7	((0.829,1.113,1.827,2.552;1,1),(0.89,1.166,1.725,2.349;0.8,0.8))	((0.064,0.112,0.286,0.545;1,1),(0.074,0.123,0.259,0.465;0.8,0.8))	0.23
$\tilde{a}_1 \oplus \tilde{a}_2 \oplus ... \oplus \tilde{a}_n$	((4.684,6.38,9.948,12.862;1,1),(5.054,6.669,9.497,12.093;0.8,0.8))		
$\left(\tilde{a}_1 \oplus \tilde{a}_2 \oplus ... \oplus \tilde{a}_n\right)^{-1}$	((0.078,0.101,0.157,0.213;1,1),(0.083,0.105,0.15,0.198;0.8,0.8))		

Tab. 6. The fuzzy and certain weights of the indicators affecting the successful implementation of e-supply chains

ESCM	index	$\tilde{\tilde{r}}_{ij}$	$\tilde{\tilde{U}}_j$	$E(U_C)$
C_1	C_{11}	((0.39,0.46,0.63,0.8;1,1),(0.41,0.47,0.61,0.76;0.8,0.8))	((0.041,0.061,0.124,0.206;1,1),(0.045,0.064,0.116,0.182;0.8,0.8))	0.10
	C_{12}	((1.25,1.64,2.49,3.16;1,1),(1.33,1.72,2.39,2.99;0.8,0.8))	((0.129,0.214,0.486,0.813;1,1),(0.146,0.233,0.452,0.719;0.8,0.8))	0.38
	C_{13}	((0.7,1.03,1.62,2;1,1),(0.78,1.09,1.56,1.91;0.8,0.8))	((0.072,0.134,0.317,0.515;1,1),(0.085,0.148,0.296,0.46;0.8,0.8))	0.24
	C_{14}	((0.26,0.29,0.4,0.53;1,1),(0.27,0.23,0.38,0.5;0.8,0.8))	((0.027,0.038,0.079,0.137;1,1),(0.029,0.032,0.073,0.119;0.8,0.8))	0.06
	C_{15}	((1.29,1.69,2.52,3.16;1,1),(1.38,1.77,2.42,3;0.8,0.8))	((0.133,0.22,0.492,0.813;1,1),(0.15,0.24,0.458,0.72;0.8,0.8))	0.39
C_2	C_{21}	((0.65,0.74,0.92,1.04;1,1),(0.67,0.75,0.9,1.01;0.8,0.8))	((0.101,0.124,0.181,0.228;1,1),(0.106,0.127,0.174,0.217;0.8,0.8))	0.15
	C_{22}	((0.2,0.23,0.29,0.34;1,1),(0.21,0.23,0.28,0.33;0.8,0.8))	((0.032,0.039,0.058,0.074;1,1),(0.033,0.039,0.054,0.07;0.8,0.8))	0.05
	C_{23}	((1.61,1.77,2.03,2.14;1,1),(1.64,1.8,2.01,2.12;0.8,0.8))	((0.25,0.296,0.4,0.469;1,1),(0.26,0.306,0.39,0.454;0.8,0.8))	0.34
	C_{24}	((2.1,2.33,2.73,2.91;1,1),(2.15,2.37,2.69,2.87;0.8,0.8))	((0.326,0.39,0.538,0.637;1,1),(0.339,0.404,0.523,0.615;0.8,0.8))	0.45
C_3	C_{31}	((0.9,1.2,1.89,2.54;1,1),(0.97,1.25,1.79,2.36;0.8,0.8))	((0.087,0.148,0.369,0.699;1,1),(0.099,0.161,0.334,0.596;0.8,0.8))	0.30
	C_{32}	((0.57,0.86,1.41,1.79;1,1),(0.64,0.91,1.35,1.7;0.8,0.8))	((0.056,0.107,0.277,0.493;1,1),(0.066,0.117,0.252,0.43;0.8,0.8))	0.22
	C_{33}	((1.55,2.3,3.57,4.15;1,1),(1.71,2.43,3.45,4.03;0.8,0.8))	((0.15,0.284,0.697,1.142;1,1),(0.176,0.314,0.641,1.019;0.8,0.8))	0.53
	C_{34}	((0.37,0.48,0.81,1.23;1,1),(0.39,0.5,0.76,1.11;0.8,0.8))	((0.036,0.059,0.159,0.34;1,1),(0.04,0.065,0.141,0.28;0.8,0.8))	0.13
	C_{35}	((0.23,0.28,0.42,0.61;1,1),(0.24,0.28,0.39,0.55;0.8,0.8))	((0.023,0.034,0.082,0.168;1,1),(0.025,0.036,0.073,0.14;0.8,0.8))	0.07
C_4	C_{41}	((0.9,1.14,1.57,1.81;1,1),(0.95,1.17,1.52,1.75;0.8,0.8))	((0.112,0.161,0.291,0.403;1,1),(0.121,0.17,0.275,0.375;0.8,0.8))	0.23

	C_{42}	((0.24,0.28,0.4,0.54;1,1),(0.25,0.28,0.38,0.5;0.8,0.8))	((0.03,0.04,0.074,0.12;1,1),(0.032,0.041,0.069,0.107;0.8,0.8))	0.06
	C_{43}	((0.4,0.5,0.68,0.79;1,1),(0.42,0.51,0.65,0.76;0.8,0.8))	((0.05,0.071,0.125,0.176;1,1),(0.054,0.074,0.118,0.163;0.8,0.8))	0.10
	C_{44}	((2.94,3.46,4.43,4.88;1,1),(3.05,3.56,4.33,4.79;0.8,0.8))	((0.367,0.49,0.822,1.088;1,1),(0.391,0.518,0.783,1.025;0.8,0.8))	0.65
C_5	C_{51}	((0.21,0.23,0.32,0.41;1,1),(0.21,0.15,0.3,0.39;0.8,0.8))	((0.025,0.031,0.054,0.083;1,1),(0.026,0.02,0.051,0.075;0.8,0.8))	0.04
	C_{52}	((0.85,1.08,1.48,1.73;1,1),(0.9,1.11,1.43,1.67;0.84,0.84))	((0.101,0.143,0.25,0.351;1,1),(0.109,0.152,0.239,0.324;0.8,0.8))	0.20
	C_{53}	((1.54,2.02,2.75,3.06;1,1),(1.65,2.11,2.68,3;0.8,0.8))	((0.183,0.269,0.466,0.618;1,1),(0.201,0.288,0.45,0.581;0.8,0.8))	0.36
	C_{54}	((0.41,0.49,0.68,0.88;1,1),(0.43,0.49,0.65,0.82;0.8,0.8))	((0.049,0.065,0.116,0.178;1,1),(0.052,0.067,0.109,0.16;0.8,0.8))	0.09
	C_{55}	((1.93,2.08,2.29,2.35;1,1),(1.97,2.11,2.26,2.34;0.84,0.84))	((0.23,0.277,0.387,0.475;1,1),(0.239,0.288,0.379,0.453;0.8,0.8))	0.32
C_6	C_{61}	((0.81,0.91,1.11,1.23;1,1),(0.83,0.92,1.09,1.2;0.85,0.85))	((0.135,0.17,0.255,0.327;1,1),(0.143,0.175,0.245,0.308;0.8,0.8))	0.21
	C_{62}	((1.08,1.19,1.44,1.63;1,1),(1.1,1.21,1.4,1.58;0.82,0.82))	((0.181,0.222,0.33,0.431;1,1),(0.189,0.23,0.317,0.404;0.8,0.8))	0.27
	C_{63}	((1.61,1.93,2.41,2.62;1,1),(1.68,1.98,2.37,2.58;0.8,0.8))	((0.271,0.36,0.555,0.694;1,1),(0.289,0.378,0.535,0.66;0.8,0.8))	0.44
	C_{64}	((0.28,0.32,0.4,0.47;1,1),(0.29,0.32,0.39,0.45;0.82,0.82))	((0.048,0.06,0.092,0.124;1,1),(0.051,0.061,0.088,0.116;0.8,0.8))	0.08
C_7	C_{71}	((1.15,1.19,1.25,1.28;1,1),(1.16,1.2,1.25,1.27;0.89,0.89))	((0.208,0.238,0.304,0.357;1,1),(0.214,0.244,0.297,0.344;0.8,0.8))	0.26
	C_{72}	((0.43,0.48,0.65,0.87;1,1),(0.44,0.48,0.62,0.81;0.85,0.85))	((0.077,0.095,0.158,0.244;1,1),(0.081,0.099,0.148,0.218;0.8,0.8))	0.13
	C_{73}	((1.4,1.77,2.29,2.51;1,1),(1.49,1.83,2.25,2.47;0.8,0.8))	((0.254,0.354,0.558,0.703;1,1),(0.276,0.374,0.536,0.668;0.8,0.8))	0.44
	C_{74}	((0.59,0.68,0.8,0.87;1,1),(0.61,0.69,0.79,0.85;0.8,0.8))	((0.107,0.136,0.195,0.244;1,1),(0.113,0.14,0.187,0.231;0.8,0.8))	0.16

Phase 2. The relationship between the indicators using type-2 fuzzy DEMATEL technique

Step 8. Creating the initial direct relationship matrix (A): After the certain weights of the indicators are determined, the questionnaire about the level of influence of each indicator on other indicators was prepared and distributed among Experts, and after gathering the Experts' opinions and using Table 2, the linguistic data were turned into type-2 trapezoidal fuzzy numbers. Then, the initial direct relationships matrix was determined using Eq. (13). As an example, the initial direct-relation matrix of the factors affecting the successful implementation of e-supply chains is shown in Table 7.

Step 9. Normalizing the initial direct-relation matrix (D): Using Eqs. (14) and (15), the normalized matrix is determined. The normalized matrix of the factors is shown in Table 8.

Tab. 7. Initial direct-relation matrix of the effective factors

	c_1	c_7	c_3	c_4	c_5	c_6	c_7
c_1	((0,0.1,0.1,0.1;1,1),(0,0.1,0.1,0.05;0.8,0.8))	((0.4,0.5,0.5,0.6;1,1),(0.45,0.5,0.5,0.55;0.8,0.8))	((0.2,0.3,0.3,0.4;1,1),(0.25,0.3,0.3,0.35;0.8,0.8))	((0.6,0.7,0.7,0.8;1,1),(0.65,0.7,0.7,0.75;0.8,0.8))	((0.8,0.9,0.9,1;1,1),(0.85,0.9,0.9,0.95;0.8,0.8))	((0.4,0.5,0.5,0.6;1,1),(0.45,0.5,0.5,0.55;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))
c_2	((0.6,0.7,0.7,0.8;1,1),(0.65,0.7,0.7,0.75;0.8,0.8))	((0,0.1,0.1,0.1;1,1),(0,0.1,0.1,0.05;0.8,0.8))	((0.2,0.3,0.3,0.4;1,1),(0.25,0.3,0.3,0.35;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))	((0.6,0.7,0.7,0.8;1,1),(0.65,0.7,0.7,0.75;0.8,0.8))	((0.2,0.3,0.3,0.4;1,1),(0.25,0.3,0.3,0.35;0.8,0.8))
c_3	((0.6,0.7,0.7,0.8;1,1),(0.65,0.7,0.7,0.75;0.8,0.8))	((0.6,0.7,0.7,0.8;1,1),(0.65,0.7,0.7,0.75;0.8,0.8))	((0,0.1,0.1,0.1;1,1),(0,0.1,0.1,0.05;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))	((0.2,0.3,0.3,0.4;1,1),(0.25,0.3,0.3,0.35;0.8,0.8))	((0.2,0.3,0.3,0.4;1,1),(0.25,0.3,0.3,0.35;0.8,0.8))	((0.2,0.3,0.3,0.4;1,1),(0.25,0.3,0.3,0.35;0.8,0.8))
c_4	((0,0.1,0.1,0.1;1,1),(0,0.1,0.1,0.05;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))	((0.2,0.3,0.3,0.4;1,1),(0.25,0.3,0.3,0.35;0.8,0.8))	((0,0.1,0.1,0.1;1,1),(0,0.1,0.1,0.05;0.8,0.8))	((0.6,0.7,0.7,0.8;1,1),(0.65,0.7,0.7,0.75;0.8,0.8))	((0.8,0.9,0.9,1;1,1),(0.85,0.9,0.9,0.95;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))

c_5	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))	((0.6,0.7,0.7,0.8;1,1),(0.65,0.7,0.7,0.75;0.8,0.8))	((0.8,0.9,0.9,1;1,1),(0.85,0.9,0.9,0.95;0.8,0.8))	((0,0.1,0.1,0.1;1,1),(0,0.1,0.1,0.05;0.8,0.8))	((0.8,0.9,0.9,1;1,1),(0.85,0.9,0.9,0.95;0.8,0.8))	((0.6,0.7,0.7,0.8;1,1),(0.65,0.7,0.7,0.75;0.8,0.8))
c_6	((0.4,0.5,0.5,0.6;1,1),(0.45,0.5,0.5,0.55;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))	((0.8,0.9,0.9,1;1,1),(0.85,0.9,0.9,0.95;0.8,0.8))	((0.6,0.7,0.7,0.8;1,1),(0.65,0.7,0.7,0.75;0.8,0.8))	((0.4,0.5,0.5,0.6;1,1),(0.45,0.5,0.5,0.55;0.8,0.8))	((0,0.1,0.1,0.1;1,1),(0,0.1,0.1,0.05;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))
c_7	((0.4,0.5,0.5,0.6;1,1),(0.45,0.5,0.5,0.55;0.8,0.8))	((0.8,0.9,0.9,1;1,1),(0.85,0.9,0.9,0.95;0.8,0.8))	((0.5,0.6,0.6,0.7;1,1),(0.55,0.6,0.6,0.65;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))	((0.5,0.6,0.6,0.7;1,1),(0.55,0.6,0.6,0.65;0.8,0.8))	((0.3,0.4,0.4,0.5;1,1),(0.35,0.4,0.4,0.45;0.8,0.8))	((0,0.1,0.1,0.1;1,1),(0,0.1,0.1,0.05;0.8,0.8))

Tab. 8. Matrix D of the factors

	c_1	c_7	c_3	c_4	c_5	c_6	c_7
c_1	((0,0.021,0.021,0.021;1,1),(0,0.021,0.021,0.011;0.8,0.8))	((0.085,0.106,0.106,0.128;1,1),(0.096,0.106,0.106,0.117;0.8,0.8))	((0.043,0.064,0.064,0.085;1,1),(0.053,0.064,0.064,0.074;0.8,0.8))	((0.128,0.149,0.149,0.17;1,1),(0.138,0.149,0.149,0.16;0.8,0.8))	((0.17,0.191,0.191,0.213;1,1),(0.181,0.191,0.191,0.202;0.8,0.8))	((0.085,0.106,0.106,0.128;1,1),(0.096,0.106,0.106,0.117;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))
c_2	((0.128,0.149,0.149,0.17;1,1),(0.138,0.149,0.149,0.16;0.8,0.8))	((0,0.021,0.021,0.021;1,1),(0,0.021,0.021,0.011;0.8,0.8))	((0.043,0.064,0.064,0.085;1,1),(0.053,0.064,0.064,0.074;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))	((0.128,0.149,0.149,0.17;1,1),(0.138,0.149,0.149,0.16;0.8,0.8))	((0.043,0.064,0.064,0.085;1,1),(0.053,0.064,0.064,0.074;0.8,0.8))
c_3	((0.128,0.149,0.149,0.17;1,1),(0.138,0.149,0.149,0.16;0.8,0.8))	((0.128,0.149,0.149,0.17;1,1),(0.138,0.149,0.149,0.16;0.8,0.8))	((0,0.021,0.021,0.021;1,1),(0,0.021,0.021,0.011;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))	((0.043,0.064,0.064,0.085;1,1),(0.053,0.064,0.064,0.074;0.8,0.8))	((0.043,0.064,0.064,0.085;1,1),(0.053,0.064,0.064,0.074;0.8,0.8))	((0.043,0.064,0.064,0.085;1,1),(0.053,0.064,0.064,0.074;0.8,0.8))
c_4	((0,0.021,0.021,0.021;1,1),(0,0.021,0.021,0.011;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))	((0.043,0.064,0.064,0.085;1,1),(0.053,0.064,0.064,0.074;0.8,0.8))	((0,0.021,0.021,0.021;1,1),(0,0.021,0.021,0.011;0.8,0.8))	((0.128,0.149,0.149,0.17;1,1),(0.138,0.149,0.149,0.16;0.8,0.8))	((0.17,0.191,0.191,0.213;1,1),(0.181,0.191,0.191,0.202;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))
c_5	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))	((0.128,0.149,0.149,0.17;1,1),(0.138,0.149,0.149,0.16;0.8,0.8))	((0.17,0.191,0.191,0.213;1,1),(0.181,0.191,0.191,0.202;0.8,0.8))	((0,0.021,0.021,0.021;1,1),(0,0.021,0.021,0.011;0.8,0.8))	((0.17,0.191,0.191,0.213;1,1),(0.181,0.191,0.191,0.202;0.8,0.8))	((0.128,0.149,0.149,0.17;1,1),(0.138,0.149,0.149,0.16;0.8,0.8))
c_6	((0.085,0.106,0.106,0.128;1,1),(0.096,0.106,0.106,0.117;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))	((0.17,0.191,0.191,0.213;1,1),(0.181,0.191,0.191,0.202;0.8,0.8))	((0.128,0.149,0.149,0.17;1,1),(0.138,0.149,0.149,0.16;0.8,0.8))	((0.085,0.106,0.106,0.128;1,1),(0.096,0.106,0.106,0.117;0.8,0.8))	((0,0.021,0.021,0.021;1,1),(0,0.021,0.021,0.011;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))
c_7	((0.085,0.106,0.106,0.128;1,1),(0.096,0.106,0.106,0.117;0.8,0.8))	((0.17,0.191,0.191,0.213;1,1),(0.181,0.191,0.191,0.202;0.8,0.8))	((0.106,0.128,0.128,0.149;1,1),(0.117,0.128,0.128,0.138;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))	((0.106,0.128,0.128,0.149;1,1),(0.117,0.128,0.128,0.138;0.8,0.8))	((0.064,0.085,0.085,0.106;1,1),(0.074,0.085,0.085,0.096;0.8,0.8))	((0,0.021,0.021,0.021;1,1),(0,0.021,0.021,0.011;0.8,0.8))

Step 10. Creating matrix $Z_a, Z_b, Z_c, Z_d, Z_e, Z_f, Z_g$ *and* Z_h: using Eq. (16), eight $n \times n$ matrixes are derived from matrix D as $Z_a, Z_b, Z_c, Z_d, Z_e, Z_f, Z_g$ *and* Z_h , so the next step can be calculated easily. Matrix Z_a is shown as an example in Table 9.

Tab. 9. Matrix Z_a

Dimension	c_1	c_7	c_3	c_4	c_5	c_6	c_7
c_1	0.000	0.085	0.043	0.128	0.170	0.085	0.064
c_2	0.128	0.000	0.043	0.064	0.064	0.128	0.043
c_3	0.128	0.128	0.000	0.064	0.043	0.043	0.043
c_4	0.000	0.064	0.043	0.000	0.128	0.170	0.064
c_5	0.064	0.064	0.128	0.170	0.000	0.170	0.128

c_6	0.085	0.064	0.170	0.128	0.085	0.000	0.064
c_7	0.085	0.170	0.106	0.064	0.106	0.064	0.000

Step 11. Obtaining the total relation matrix (T_X): The total relation matrix was obtained using Eq. (17). The total relation matrix of the factors of successful implementation of the electronic supply chain management is shown in Table 10. Based on the mentioned equation, the total relation matrix of the indicators was determined as a 31 × 31 matrix.

Tab. 10. The total relation matrix of the factors

	c_1	c_7	c_3	c_4	c_5	c_6	c_7
c_1	((0.091,0.246,0.246,0.551;1,1),(0.132,0.246,0.246,0.317;0.8,0.8))	((0.184,0.35,0.35,0.713;1,1),(0.24,0.35,0.35,0.456;0.8,0.8))	((0.152,0.315,0.315,0.673;1,1),(0.208,0.315,0.315,0.42;0.8,0.8))	((0.244,0.42,0.42,0.801;1,1),(0.302,0.42,0.42,0.529;0.8,0.8))	((0.27,0.44,0.44,0.809;1,1),(0.325,0.44,0.44,0.545;0.8,0.8))	((0.22,0.403,0.403,0.8;1,1),(0.281,0.403,0.403,0.517;0.8,0.8))	((0.148,0.29,0.29,0.604;1,1),(0.197,0.29,0.29,0.382;0.8,0.8))
c_2	((0.194,0.332,0.332,0.623;1,1),(0.238,0.332,0.332,0.412;0.8,0.8))	((0.087,0.235,0.235,0.545;1,1),(0.128,0.235,0.235,0.314;0.8,0.8))	((0.132,0.277,0.277,0.601;1,1),(0.182,0.277,0.277,0.373;0.8,0.8))	((0.165,0.323,0.323,0.669;1,1),(0.219,0.323,0.323,0.424;0.8,0.8))	((0.16,0.313,0.313,0.648;1,1),(0.212,0.313,0.313,0.411;0.8,0.8))	((0.223,0.387,0.387,0.745;1,1),(0.278,0.387,0.387,0.49;0.8,0.8))	((0.109,0.237,0.237,0.521;1,1),(0.154,0.237,0.237,0.322;0.8,0.8))
c_3	((0.192,0.325,0.325,0.607;1,1),(0.235,0.325,0.325,0.403;0.8,0.8))	((0.199,0.342,0.342,0.657;1,1),(0.247,0.342,0.342,0.433;0.8,0.8))	((0.075,0.216,0.216,0.51;1,1),(0.115,0.216,0.216,0.291;0.8,0.8))	((0.153,0.305,0.305,0.641;1,1),(0.205,0.305,0.305,0.404;0.8,0.8))	((0.134,0.281,0.281,0.607;1,1),(0.184,0.281,0.281,0.377;0.8,0.8))	((0.143,0.301,0.301,0.65;1,1),(0.197,0.301,0.301,0.404;0.8,0.8))	((0.102,0.225,0.225,0.5;1,1),(0.145,0.225,0.225,0.308;0.8,0.8))
c_4	((0.084,0.223,0.223,0.49;1,1),(0.12,0.223,0.223,0.283;0.8,0.8))	((0.149,0.298,0.298,0.614;1,1),(0.197,0.298,0.298,0.387;0.8,0.8))	((0.143,0.29,0.29,0.601;1,1),(0.191,0.29,0.29,0.377;0.8,0.8))	((0.107,0.266,0.266,0.58;1,1),(0.148,0.266,0.266,0.339;0.8,0.8))	((0.208,0.362,0.362,0.682;1,1),(0.256,0.362,0.362,0.448;0.8,0.8))	((0.264,0.43,0.43,0.773;1,1),(0.316,0.43,0.43,0.522;0.8,0.8))	((0.132,0.26,0.26,0.533;1,1),(0.174,0.26,0.26,0.337;0.8,0.8))
c_5	((0.174,0.346,0.346,0.705;1,1),(0.229,0.346,0.346,0.444;0.8,0.8))	((0.194,0.379,0.379,0.783;1,1),(0.257,0.379,0.379,0.496;0.8,0.8))	((0.249,0.431,0.431,0.826;1,1),(0.309,0.431,0.431,0.544;0.8,0.8))	((0.298,0.494,0.494,0.916;1,1),(0.361,0.494,0.494,0.613;0.8,0.8))	((0.14,0.33,0.33,0.725;1,1),(0.194,0.33,0.33,0.431;0.8,0.8))	((0.309,0.513,0.513,0.952;1,1),(0.375,0.513,0.513,0.637;0.8,0.8))	((0.214,0.373,0.373,0.72;1,1),(0.267,0.373,0.373,0.473;0.8,0.8))
c_6	((0.175,0.329,0.329,0.651;1,1),(0.224,0.329,0.329,0.417;0.8,0.8))	((0.171,0.336,0.336,0.699;1,1),(0.227,0.336,0.336,0.442;0.8,0.8))	((0.257,0.419,0.419,0.772;1,1),(0.31,0.419,0.419,0.52;0.8,0.8))	((0.236,0.411,0.411,0.792;1,1),(0.294,0.411,0.411,0.52;0.8,0.8))	((0.193,0.363,0.363,0.734;1,1),(0.25,0.363,0.363,0.47;0.8,0.8))	((0.13,0.312,0.312,0.692;1,1),(0.182,0.312,0.312,0.409;0.8,0.8))	((0.141,0.283,0.283,0.596;1,1),(0.19,0.283,0.283,0.375;0.8,0.8))
c_7	((0.181,0.336,0.336,0.662;1,1),(0.231,0.336,0.336,0.426;0.8,0.8))	((0.263,0.429,0.429,0.791;1,1),(0.318,0.429,0.429,0.532;0.8,0.8))	((0.202,0.365,0.365,0.723;1,1),(0.257,0.365,0.365,0.469;0.8,0.8))	((0.183,0.359,0.359,0.745;1,1),(0.242,0.359,0.359,0.471;0.8,0.8))	((0.211,0.382,0.382,0.755;1,1),(0.268,0.382,0.382,0.49;0.8,0.8))	((0.194,0.377,0.377,0.778;1,1),(0.256,0.377,0.377,0.494;0.8,0.8))	((0.082,0.225,0.225,0.522;1,1),(0.122,0.225,0.225,0.3;0.8,0.8))

Step 12. Analyzing the causal relationships: The sum of the elements of the rows and columns was calculated in order to obtain the analysis of the causal relationships. Eqs. (18-20) were used to determine the values of $\left(\tilde{\tilde{D}}_i + \tilde{\tilde{R}}_i\right)$ and $\left(\tilde{\tilde{D}}_i - \tilde{\tilde{R}}_i\right)$. The results for the factors and indicators are shown in Tables 11 and 12, respectively.

Step 13. Calculating the certain values of $\left(\tilde{\tilde{D}}_i + \tilde{\tilde{R}}_i\right)$ and $\left(\tilde{\tilde{D}}_i - \tilde{\tilde{R}}_i\right)$ for the factors and indicators $E(W)$: Using Eq. (21), the certain values were obtained for the factors and indicators of the implementation of e-supply chain management. The results are shown in Tables 11 and 12.

Step 14. Combining the fuzzy weights of $E(U)$ and $E(W)$: Using Eq. (22), the fuzzy weights obtained in step 7 are combined with the certain values obtained in step 13. The values are shown in Tables 11 and 12.

Tab. 11. $\left(\tilde{\tilde{D}}_i + \tilde{\tilde{R}}_i\right)$ and $\left(\tilde{\tilde{D}}_i - \tilde{\tilde{R}}_i\right)$ of the factors of the implementation of ESCM

ESCM	$\left(\tilde{\tilde{D}}_i + \tilde{\tilde{R}}_i\right)$	$\left(\tilde{\tilde{D}}_i - \tilde{\tilde{R}}_i\right)$	$E(W)$		New $E(W)$	
			D+R	D-R	New D+R	New D-R
c_1	((2.402,4.602,4.602,9.241;1,1),(3.094,4.602,4.602,5.868;0.8,0.8))	((0.218,0.327,0.327,0.661;1,1),(0.276,0.327,0.327,0.463;0.8,0.8))	4.65	0.35	1.581	0.119
c_2	((2.317,4.474,4.474,9.153;1,1),(3.025,4.474,4.474,5.807;0.8,0.8))	((-0.177,-0.265,-0.265,-0.449;1,1),(-0.204,-0.265,-0.265,-0.314;0.8,0.8))	4.55	-0.26	0.6825	-0.039
c_3	((2.208,4.31,4.31,8.879;1,1),(2.9,4.31,4.31,5.615;0.8,0.8))	((-0.211,-0.316,-0.316,-0.534;1,1),(-0.243,-0.316,-0.316,-0.374;0.8,0.8))	4.39	-0.31	1.0097	-0.0713
c_4	((2.471,4.706,4.706,9.418;1,1),(3.174,4.706,4.706,5.992;0.8,0.8))	((-0.3,-0.449,-0.449,-0.868;1,1),(-0.37,-0.449,-0.449,-0.608;0.8,0.8))	4.75	-0.47	0.7125	-0.0705
c_5	((2.892,5.336,5.336,10.587;1,1),(3.682,5.336,5.336,6.811;0.8,0.8))	((0.263,0.394,0.394,0.666;1,1),(0.303,0.394,0.394,0.466;0.8,0.8))	5.40	0.39	0.324	0.0234
c_6	((2.784,5.175,5.175,10.326;1,1),(3.561,5.175,5.175,6.628;0.8,0.8))	((0.042,0.885,0.007,3.623;1,1),(0.318,0.885,0.656,2.311;0.8,0.8))	5.24	1.05	0.3144	0.063
c_7	((2.624,3.936,5.081,5.637;1,1),(3.052,3.936,4.224,3.609;0.8,0.8))	((0.386,0.58,0.58,0.979;1,1),(0.445,0.58,0.58,0.685;0.8,0.8))	3.81	0.57	0.8763	0.1311

Tab. 12. $\left(\tilde{\tilde{D}}_i + \tilde{\tilde{R}}_i\right)$ and $\left(\tilde{\tilde{D}}_i - \tilde{\tilde{R}}_i\right)$ of the indicators of the implementation of ESCM

ESCM	index	$\left(\tilde{\tilde{D}}_i + \tilde{\tilde{R}}_i\right)$	$\left(\tilde{\tilde{D}}_i - \tilde{\tilde{R}}_i\right)$	$E(W)$		New $E(W)$	
				D+R	D-R	New D+R	New D-R
C_1	C_{11}	((2.451,5.08,5.08,10.642;1,1),(3.152,5.08,5.08,6.252;0.8,0.8))	((0.385,0.613,0.613,1.27;1,1),(0.482,0.613,0.613,0.829;0.8,0.8))	5.10	0.65	0.51	0.065
	C_{12}	((2.338,4.9,4.9,10.52;1,1),(3.062,4.9,4.9,6.172;0.8,0.8))	((0.136,0.216,0.216,0.38;1,1),(0.156,0.216,0.216,0.248;0.8,0.8))	4.97	0.21	1.8886	0.0798
	C_{13}	((2.361,4.937,4.937,10.609;1,1),(3.093,4.937,4.937,6.23;0.8,0.8))	((0.087,0.139,0.139,0.244;1,1),(0.1,0.139,0.139,0.159;0.8,0.8))	5.01	0.14	1.2024	0.0336
	C_{14}	((2.208,4.694,4.694,9.958;1,1),(2.872,4.694,4.694,5.805;0.8,0.8))	((-0.626,-0.996,-0.996,-1.948;1,1),(-0.76,-0.996,-0.996,-1.272;0.8,0.8))	4.72	-1.02	0.2832	-0.0612
	C_{15}	((2.919,5.825,5.825,12.114;1,1),(3.723,5.825,5.825,7.213;0.8,0.8))	((0.018,0.029,0.029,0.055;1,1),(0.022,0.029,0.029,0.036;0.8,0.8))	5.87	0.03	2.2893	0.0117
C_2	C_{21}	((2.899,6.854,6.854,19.034;1,1),(3.828,6.854,6.854,8.723;0.8,0.8))	((0.116,0.21,0.21,0.696;1,1),(0.166,0.21,0.21,0.355;0.8,0.8))	7.39	0.26	1.1085	0.039
	C_{22}	((3.289,7.558,7.558,20.832;1,1),(4.309,7.558,7.558,9.64;0.8,0.8))	((0.172,0.312,0.312,0.708;1,1),(0.201,0.312,0.312,0.361;0.8,0.8))	8.16	0.32	0.408	0.016
	C_{23}	((3.479,7.902,7.902,21.634;1,1),(4.533,7.902,7.902,10.048;0.8,0.8))	((-0.004,-0.007,-0.007,-0.007;1,1),(-0.003,-0.007,-0.007,-0.004;0.8,0.8))	8.52	-0.01	2.8968	-0.0034
	C_{24}	((2.88,6.82,6.82,18.965;1,1),(3.807,6.82,6.82,8.688;0.8,0.8))	((-0.285,-0.515,-0.515,-1.397;1,1),(-0.363,-0.515,-0.515,-0.712;0.8,0.8))	7.36	-0.58	3.312	-0.261
C_3	C_{31}	((2.91,6.656,6.656,19.31;1,1),(3.899,6.656,6.656,8.975;0.8,0.8))	((-0.086,-0.152,-0.152,-0.533;1,1),(-0.126,-0.152,-0.152,-0.275;0.8,0.8))	7.38	-0.20	2.214	-0.06
	C_{32}	((3.216,7.195,7.195,20.617;1,1),(4.263,7.195,7.195,9.648;0.8,0.8))	((0.091,0.161,0.161,0.546;1,1),(0.131,0.161,0.161,0.281;0.8,0.8))	7.96	0.20	1.7512	0.044
	C_{33}	((3.412,7.54,7.54,21.589;1,1),(4.515,7.54,7.54,10.149;0.8,0.8))	((-0.016,-0.028,-0.028,-0.069;1,1),(-0.019,-0.028,-0.028,-0.036;0.8,0.8))	8.35	-0.03	4.4255	-0.0159

	C_{34}	((2.988,6.793,6.793,19.808;1,1),(4.014,6.793,6.793,9.231;0.8,0.8))	((-0.146,-0.257,-0.257,-0.604;1,1),(-0.171,-0.257,-0.257,-0.311;0.8,0.8))	7.56	-0.27	0.9828	-0.0351
	C_{35}	((3.437,7.584,7.584,21.686;1,1),(4.543,7.584,7.584,10.198;0.8,0.8))	((0.156,0.275,0.275,0.661;1,1),(0.185,0.275,0.275,0.34;0.8,0.8))	8.40	0.29	0.588	0.0203
C_4	C_{41}	((1.913,3.332,3.332,5.179;1,1),(2.317,3.332,3.332,3.765;0.8,0.8))	((-0.163,-0.222,-0.222,-0.342;1,1),(-0.193,-0.222,-0.222,-0.275;0.8,0.8))	3.15	-0.22	0.7245	-0.0506
	C_{42}	((1.621,2.934,2.934,4.652;1,1),(1.998,2.934,2.934,3.342;0.8,0.8))	((0.232,0.316,0.316,0.468;1,1),(0.269,0.316,0.316,0.376;0.8,0.8))	2.77	0.31	0.1662	0.0186
	C_{43}	((1.813,3.196,3.196,5.054;1,1),(2.225,3.196,3.196,3.665;0.8,0.8))	((0.163,0.223,0.223,0.291;1,1),(0.177,0.223,0.223,0.233;0.8,0.8))	3.03	0.21	0.303	0.021
	C_{44}	((2.091,3.575,3.575,5.551;1,1),(2.528,3.575,3.575,4.064;0.8,0.8))	((-0.232,-0.316,-0.316,-0.416;1,1),(-0.253,-0.316,-0.316,-0.334;0.8,0.8))	3.39	-0.30	2.2035	-0.195
C_5	C_{51}	((1.555,3.388,3.388,7.012;1,1),(2.099,3.388,3.388,4.297;0.8,0.8))	((0.015,0.023,0.023,-0.041;1,1),(-0.001,0.023,0.023,-0.029;0.8,0.8))	3.39	0.00	0.1356	0
	C_{52}	((2.864,5.371,5.371,10.32;1,1),(3.606,5.371,5.371,6.608;0.8,0.8))	((0.067,0.102,0.102,0.175;1,1),(0.079,0.102,0.102,0.123;0.8,0.8))	5.34	0.10	1.068	0.02
	C_{53}	((2.216,4.389,4.389,8.723;1,1),(2.869,4.389,4.389,5.492;0.8,0.8))	((0.146,0.221,0.221,0.36;1,1),(0.166,0.221,0.221,0.252;0.8,0.8))	4.39	0.21	1.5804	0.0756
	C_{54}	((2.118,4.241,4.241,8.48;1,1),(2.757,4.241,4.241,5.322;0.8,0.8))	((-0.266,-0.402,-0.402,-0.652;1,1),(-0.301,-0.402,-0.402,-0.455;0.8,0.8))	4.24	-0.39	0.3816	-0.0351
	C_{55}	((2.332,4.565,4.565,8.937;1,1),(2.984,4.565,4.565,5.642;0.8,0.8))	((0.037,0.057,0.057,0.158;1,1),(0.058,0.057,0.057,0.11;0.8,0.8))	4.54	0.07	1.4528	0.0224
C_6	C_{61}	((2.42,5.795,5.795,16.296;1,1),(3.284,5.795,5.795,7.662;0.8,0.8))	((-0.191,-0.337,-0.337,-0.758;1,1),(-0.224,-0.337,-0.337,-0.4;0.8,0.8))	6.32	-0.35	1.3272	-0.0735
	C_{62}	((2.904,6.65,6.65,18.218;1,1),(3.851,6.65,6.65,8.678;0.8,0.8))	((0.252,0.444,0.444,1.005;1,1),(0.296,0.444,0.444,0.531;0.8,0.8))	7.20	0.46	1.944	0.1242
	C_{63}	((2.922,6.68,6.68,18.285;1,1),(3.871,6.68,6.68,8.713;0.8,0.8))	((-0.064,-0.113,-0.113,-0.259;1,1),(-0.076,-0.113,-0.113,-0.137;0.8,0.8))	7.23	-0.12	3.1812	-0.0528
	C_{64}	((2.807,6.478,6.478,17.833;1,1),(3.738,6.478,6.478,8.474;0.8,0.8))	((0.003,0.006,0.006,0.012;1,1),(0.004,0.006,0.006,0.006;0.8,0.8))	7.02	0.01	0.5616	0.0008
C_7	C_{71}	((2.653,5.867,5.867,14.338;1,1),(3.496,5.867,5.867,7.516;0.8,0.8))	((0.191,0.324,0.324,0.646;1,1),(0.222,0.324,0.324,0.376;0.8,0.8))	6.14	0.33	1.5964	0.0858
	C_{72}	((2.746,6.025,6.025,14.653;1,1),(3.604,6.025,6.025,7.699;0.8,0.8))	((-0.267,-0.451,-0.451,-0.901;1,1),(-0.309,-0.451,-0.451,-0.525;0.8,0.8))	6.30	-0.45	0.819	-0.0585
	C_{73}	((2.654,5.868,5.868,14.341;1,1),(3.497,5.868,5.868,7.517;0.8,0.8))	((0.173,0.293,0.293,0.587;1,1),(0.201,0.293,0.293,0.342;0.8,0.8))	6.14	0.29	2.7016	0.1276
	C_{74}	((2.74,6.014,6.014,14.632;1,1),(3.597,6.014,6.014,7.687;0.8,0.8))	((-0.098,-0.166,-0.166,-0.331;1,1),(-0.114,-0.166,-0.166,-0.193;0.8,0.8))	6.29	-0.17	1.0064	-0.0272

Step 14. Designing the causal diagram: The causal diagrams of the dimensions and indicators of the success of the implementation of electronic supply chain management in electronics industry in Yazd province are shown in Figs. 2 and 3.

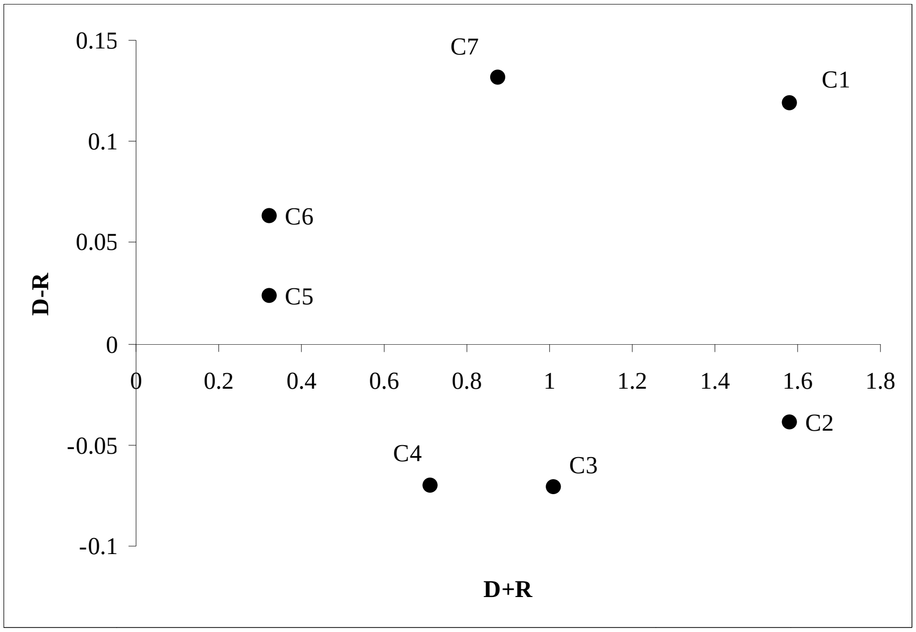

Fig. 2. Diagram of the dimensions of the implementation of ESCM

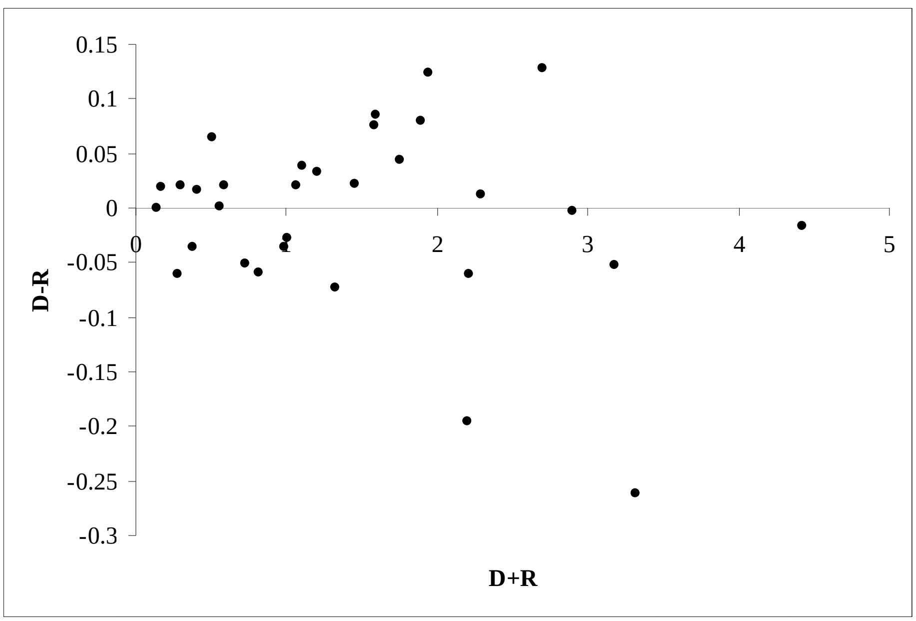

Fig. 3. Diagram of the indicators of the implementation of ESCM

5. Conclusions

In this paper, an integration model of type-2 fuzzy AHP and interval type-2 fuzzy DEMATEL was proposed to prioritize factors affecting the success of implementation of E-Supply Chain Management. The aim of this study was to modify DEMATEL results by considering the weight of different indicators, and an integration model of type-2 fuzzy AHP and interval type-2 fuzzy DEMATEL were used for this purpose. However, when the study aims to determine the final weight of indicators, the AHP weight vector can be multiplied by the normalized relationship matrix to determine the final weight of indicators. After obtaining the weights of indicators using type-2 fuzzy AHP method, they are multiplied by D+R and D-R values obtained from interval type-2 fuzzy DEMATEL method to examine whether each dimension or indicator is a cause or effect; indicators with positive D-R values are effective indicators or causes and those with negative D-R values are impressible indicators or effects.

Based on this approach, factors affecting the success of implementation of E-Supply Chain Management can be divided into two categories. This means that this technique, in addition to having the ability to prioritize factors, makes it possible for managers and decision-makers to manage their capital and time to consider the results of the research and continue to move in an intelligent and purposeful manner. In other words, if decision-makers, depending on the subject and according to the results of the research, intend to yield early, yet superficial, results, they can focus on the priorities that are placed in the effects category. However, if the purpose of the decision-makers is the implementation of basic measures or their focus is on the basic issues, they can focus on the priorities that are placed in the causes or influencers' category and set their plans accordingly. This is more accurate and reliable and provides more reasonable results when the technique is combined with the type-2 fuzzy approach.

According to the results of the above-mentioned approach in Figs. 2 and 3, causes or influential dimensions were the dimensions of the computer-based technology, infrastructure, inter-organizational relationships, and information due to the positive D-R. In other words, they are regarded as the infrastructural and essential factors on which the development of the electronic supply chain management depends. For instance, one of the principles of the electronic supply chain management is the use of information technology. Therefore, the computer-based technology and the use of IT are essential to the implementation of the electronic supply chain management. Otherwise, the implementation will fail. Furthermore, the impressible factors or effects were the business environment, demand accountability, and relationships with supplier due to the negative D-R. They were regarded as the superstructure factors. The causes result in the effects. For instance, demand accountability and relationships with suppliers result from basic causes such as IT structures.

Regarding the computer-based technology, influential factors or causes include the Internet, web-based electronic markets, the selection of appropriate electronic markets, process reengineering, and the use of new technologies due to the positive D-R. In other words, the development of the computer-based technology depends on these infrastructural and essential factors. For instance, one of the principles of this technology includes the internet and web-based electronic markets. Therefore, they are essential to the implementation of the computer-based technology. In the absence of appropriate electronic markets, the implementation of such a technology will fail. The formation of virtual collaborations is an effect due to the negative D-R. For instance, virtual collaborations are regarded as a factor resulting from the fundamental causes such as the use of new technologies.

Regarding the business environment, causes were the uncontrollable factors imposed by the external environment and natural disasters due to the positive D-R. In other words, they are regarded as the essential factors on which the development of the business environment depends. For instance, coping with natural disasters is a principle of the business environment. Therefore, it is essential to deal with natural disasters in order to achieve the business environment. The effects included governmental measures (currency exchange rate, taxes, etc.) and market sensitivity due to the negative D-R.

Regarding demand accountability, causes were the approval or rejection of a new product and the transparency of an SCM system due to the positive D-R. In other words, they are regarded as the fundamental factors on which demand accountability depends. For instance, the transparency of an SCM system is a principle of demand accountability. Therefore, it is essential to demand accountability. Moreover, the effects were responsiveness to today's quick and intense changes, product lifecycle, and reaction to the sudden abortion of orders due to the negative D-R. For instance, increasing the lifecycle of products and dealing with the sudden abortion of orders are the factors resulting from the transparency of an SCM system.

Regarding the relationships with suppliers, causes were the nature of a product or purchased material, communications, and technology-based transportation due to the positive D-R. In other words, they are regarded as the infrastructural factors on which the relationships with suppliers depend. For instance, one of the principles of relationships with suppliers is the technology-based transportations and communications. Therefore, the technology-based transportations and communications are essential to the relationships with suppliers. Moreover, the effects include the supply market and business strategic unanimity due to the negative D-R.

Regarding infrastructures, software readiness is the cause due to the positive D-R. In other words, it is regarded as the basic factor on which the creation of infrastructures depends. For instance, a principle of infrastructures is software readiness. Therefore, it is essential to the creation of infrastructures. Furthermore, the effects included the exchange or combination of an old system, fundamental technologies, economy, and the commitment of senior director due to the negative D-R.

Regarding the inter-organizational relationships, the cause is adherence to obligations due to the positive D-R. In other words, it is regarded as an infrastructural factor on which the inter-organizational relationships depend. For instance, a principle of inter-organizational relationships is adherence to obligations. Therefore, it is essential to such relationships. Moreover, the effects are honesty in relationships, trust in subordinate co-workers, and the integration of resources due to the negative D-R.

Regarding information, the causes include the quality and capability of citation due to the positive D-R. On the other hand, the effects include security and rate of sharing due to the negative D-R. Finally, the aim of this study was to use type-2 fuzzy AHP and type-2 fuzzy DEMATEL to analyze the factors influencing electronic supply chain management and to draw a relevant model.

It is suggested that other researchers deal with the other aspects of electronic supply chain management, which are as follows:

1. Investigating and analyzing the factors of electronic supply chain management in other industries.
2. Investigating and analyzing the obstacles influencing the implementation of electronic supply chain management.
3. Using other multi-criteria decision-making managements, such as fuzzy TOPSIS, to analyze the effective factors and obstacles in the implementation of electronic supply chain management.

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