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Towards a Responsive Resilient Supply Chain based on Industry 5.0: A Case Study in Healthcare Systems

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Abstract: Executives and academics have presented the idea of Industry 5.0, which is an attempt to build upon the previous iteration, Industry 4.0, by including many important tenets such as human-centricity, resilience, and sustainability. Because of the significance of this idea, the current study provides a decision-making framework to examine a responsive supply chain dubbed responsive supply chain 5.0 for healthcare systems. This framework takes into consideration the aspects of Industry 5.0. In order to do this, at the onset, the most important connected factors and strategies are determined by consulting the relevant experts and body of published research. This problem has been considered a multi-criteria decision-making (MCDM) problem. Initially, the DEMATEL method was used to assess and prioritize the main criteria and their sub-indicators. Secondly, the CRADIS method was used to evaluate and rank the strategies used to make the supply chain more responsive. The results indicate that the collaboration and sharing of information strategy is the most appropriate strategy if applied.

Keywords: Supply chain 5.0; Responsiveness; Industry 4.0; Industry 5.0; MCDM; DEMATEL method; CRADIS method.

1. Introduction

In today's world, when there has been such a dramatic increase in the level of competitiveness in the market environment, supply chain management has developed into an essential component of each and every company [1]. In recent years, there has been a growing trend among scholars toward the issue of the supply chain, which can be traced back to the aforementioned argument. As a result of the fact that consumers are an essential component of any supply chain, meeting the customers' demands is often seen as one of the most important objectives of supply networks [2]. When seen from this angle, the idea of responsiveness stands out as one of the most essential criteria in the supply chain. The capability of a supply chain to satisfy the demand of consumers within a certain time frame is referred to as its responsiveness.

The substantial improvements that have been made in information technology and the digital industry over the course of the last decade have resulted in significant changes to the business settings that are associated with the so-called "Industry 4.0." Artificial intelligence and information technology have been the focus of efforts under the Industry 4.0 initiative, which aims to boost overall industrial productivity [3]. However, despite its many positive attributes, Industry 4.0 is only a techno-economic vision in nature that has centred its attention on the part that technology plays in enhancing the operational effectiveness of businesses. Therefore, as a result of the excessive focus that Industry 4.0 places on digitalization and technology powered by artificial intelligence, several vitally important concepts, such as sustainability and the role that people play in the sector, have been neglected. Researchers have recently presented Industry 5.0, which aims to complete and expand the characteristics of Industry 4.0. This is because of the concerns that were highlighted, as well as the vulnerabilities of today's industry, which were aggravated during the COVID-19 outbreak [4]. In this manner, the foundation for Industry 5.0 has been laid, and it is founded on the following three primary dimensions: (i) sustainability; (ii) resilience; and (iii) human-centricity. In general, the issue changes into a sustainable one when the social, environmental, and financial factors are all examined at the same time. On the other hand, the capacity of a supply chain to lessen the effects of prospective interruptions or the chance of such disruptions occurring, as well as to shorten the amount of time required to resume and restore operations, is what is meant by the term "resilience." In conclusion, human-centricity refers to the practice of taking into account the role that people play in both society and business, as well as giving precedence to the requirements of humans.

As a result of the COVID-19 epidemic, it has become clear how important health systems are to issues of public health, social cohesion, faith in governments, and economic development. Therefore, doing research into healthcare systems has the potential to enhance the circumstances of the aforementioned factors, particularly during current challenging times [5]. According to the studies that have been conducted, the primary focus in the healthcare supply chains that existed prior to the adoption of Industry 5.0 was on the implementation of contemporary technologies (such as the Internet of Things, Big Data, and Blockchain) in order to cut down on the amount of time spent on operations, cut down on the amount of money spent on operations, and increase the effectiveness of healthcare systems.

However, after the implementation of Industry 5.0, in addition to taking into account the beneficial role that technologies play, it will be necessary to include a number of other essential ideas, including human-centricity, sustainability, and resilience. As a result of this, those in charge of running healthcare systems should make use of newly developed technology in order to make their organizations more resilient and sustainable. For instance, the use of 3D printing in the production of goods such as medical gadgets may significantly cut down on waste and the harm it does to the environment [6]. The use of information-sharing systems may also lead to an improvement in the system's openness and visibility, which both contribute to an increase in the system's resilience. After the implementation of Industry 5.0, it is essential for managers of healthcare facilities to take into account a number of crucial factors, including the part that people play in both society and operations.

On the other hand, when it comes to responsiveness, the policies outlined in Industry 5.0 may be of great assistance. In this respect, for example, the power of a system to deal with disturbances or recover after disruptions significantly rises when resilience techniques are employed inside the system. As a result, this system does not go into maintenance mode following disturbances and is able to continue providing the services that users demand. This ensures that it keeps its responsiveness.

Concerning the aforementioned considerations, the present study explores the qualities of the responsive supply chain according to the dimensions of Industry 5.0 utilizing the multi-criteria decision-making (MCDM) methodologies [7]. This investigation was prompted by real-world case studies. In addition, since the significance of the medical devices business as one of the essential components of healthcare systems has been brought into the spotlight in a significant way in the aftermath of the coronavirus epidemic, this paper takes that industry into consideration as a case study. The following is a list of the most important goals that this research work aims to achieve:

- Looking at the primary components of a responsive supply chain in the age of Industry 5.0.
- Determining the primary approaches that may be used in order to get towards a responsive supply chain 5.0.

2. Criteria and Alternatives

In this section, the main criteria and their sub-indicators related to improving the response aspect of the supply chain are presented. Also, four strategies used as alternatives are presented in the study. Figure 1 presents the main objective of the study, evaluation criteria, and four solution strategies used in the study. It is worth noting that the standards of the sustainability, the resiliency, and human-centricity are basic elements in Industry 5.0.

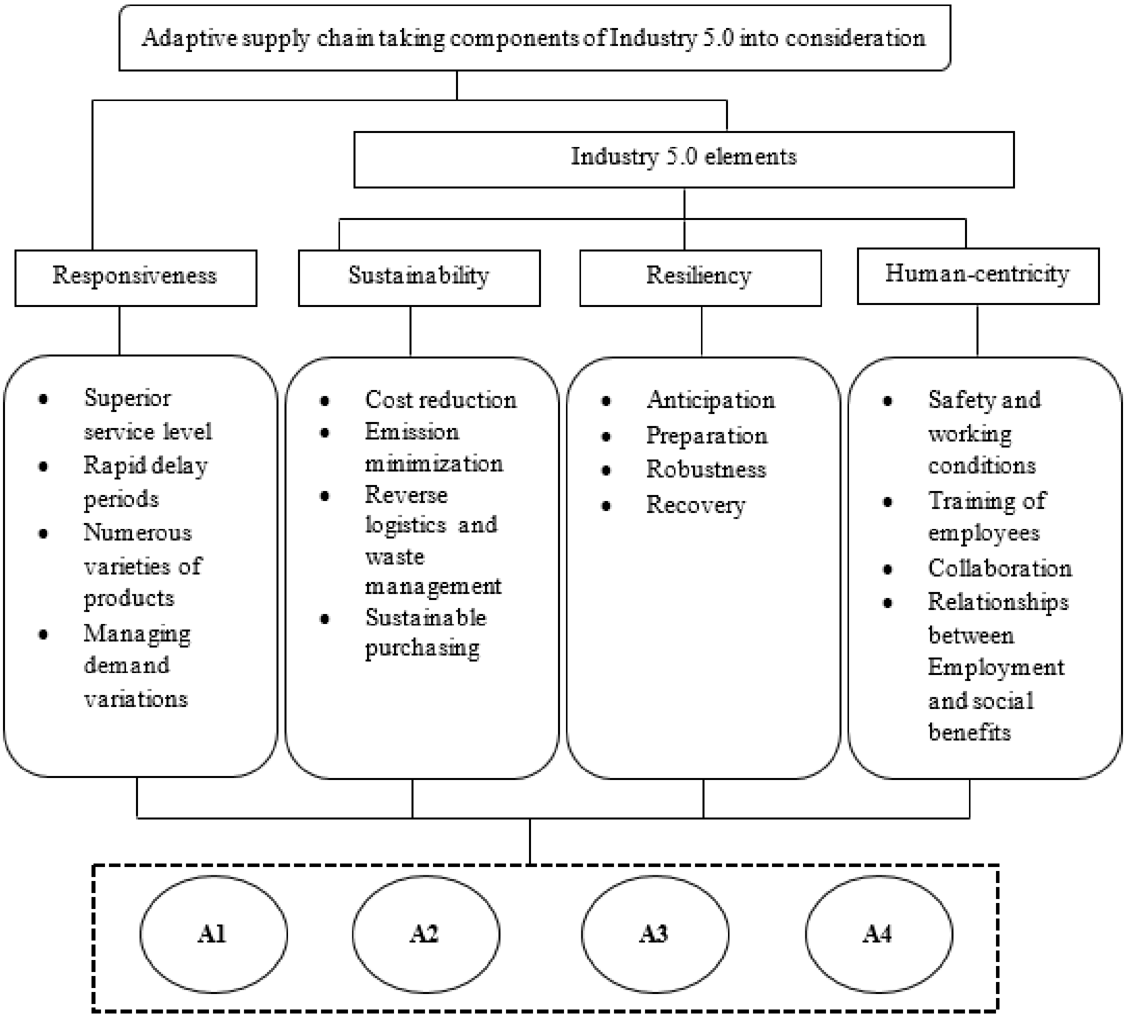

Figure 1. Elements of the research problem.

2.1 Criteria

2.1.1 Responsiveness criterion C_1

In general, the amount of responsiveness that a supply chain has may be characterized by how well it is able to satisfy the criteria that are posed by the customers. In this regard, the responsiveness criterion includes several sub-indicators, namely: superior service level (C_{1_1}), rapid delay periods (C_{1_2}), numerous varieties of products (C_{1_3}), and managing demand variations (C_{1_4}).

2.1.2 Sustainability criterion C_2

The economic, environmental, and social factors are all included in the sustainability element. In this regard, the sustainability criterion includes several sub-indicators, namely: cost reduction (C_{2_1}), emission minimization (C_{2_2}), reverse logistics and waste management (C_{2_3}), and sustainable purchasing (C_{2_4}).

2.1.3 Resiliency criterion C_3

According to the available research, supply chain resilience refers to an organization's capacity to rebound from interruptions and continue meeting the needs of its consumers. In this regard, the resiliency criterion includes several sub-indicators, namely: anticipation (C_{3_1}), preparation (C_{3_2}), robustness (C_{3_3}), and recovery (C_{3_4}).

2.1.4 Human-centricity criterion C_4

Researchers have regarded the human-centricity component as one of the primary pillars of Industry 5.0 in order to get rid of the flaw that was discussed with regard to Industry 4.0. This is because Industry 4.0 has placed an excessive emphasis on the role that technology plays in industries while ignoring the part that people play in such sectors. In this regard, the human-centricity criterion includes several sub-indicators, namely: safety and working conditions (C_{4_1}), training of employee (C_{4_2}), collaboration (C_{4_3}), and relationships between employment and social benefits (C_{4_4}).

2.2 Alternatives

In this part, the four strategies used in this research work to improve the responsiveness aspect of the supply chain are listed. The four strategies are using cutting-edge technology (A_1), collaboration and sharing of information (A_2), intelligent warehousing (A_3), and postponement (A_4).

2.2.1 Using cutting-edge technology

The use of more sophisticated technologies, which are characterized by greater adaptability and dependability, has the potential to boost the responsiveness of the supply chain.

2.2.2 Collaboration and sharing of information

It is possible to boost the responsiveness of the supply chain by using tactics that include cooperation and the exchange of information.

2.2.3 Intelligent warehousing

A structure that makes use of computers and other types of machinery and is used for the storage of finished goods and raw materials.

2.2.4 Postponement

A delay in the operations of assembly and distribution is the cause of the postponement. This delay will continue until there is sufficient information available regarding the client order.

3. Methodology

In this section, the proposed DEMATEL-CRADIS methodology is presented to evaluate several strategies to make the supply chain more responsive. The DEMATEL refers to the Decision Making Trial and Evaluation Laboratory Method. Also, the CRADIS method is a combination of several methods are the Additive Ratio Assessment (ARAS), the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and the Measurement of Alternatives and Ranking according to COmpromise Solution (MARCOS).

Step 1: A set of alternatives are identified to be used in the evaluation process. The set strategies = $(A_1, A_2, \dots, A_m)$ having i = 1, 2... m alternatives, is measured by n decision criteria and indicators of C_j = $(C_1, C_2, \dots, C_n)$, with j = 1, 2...n. Let $w = (w_1, w_2, \dots, w_n)$ be the vector set utilized for defining the criteria and indicators weights, $w_j > 0$ and $\sum_{j=1}^{n} w_j = 1$.

Step 2: A set of linguistic terms and their corresponding triangular neutrosophic numbers (TNNs) are defined to help participants prioritize the main criteria and their sub-indicators as provided in Table 1.

Table 1. Linguistic terms and their equivalent TNNs for evaluating criteria and alternatives.

Linguistic terms	Abbreviations	TNNs
Fully Low Value	FLV	⟨(0.1, 0.2, 0.3); 0.4, 0.1, 0.3⟩
Very Low Value	VLV	⟨(0.2, 0.3, 0.4); 0.5, 0.1, 0.3⟩
Low Value	LOV	⟨(0.3, 0.4, 0.5); 0.6, 0.2, 0.1⟩
Modest Low Value	MLV	⟨(0.4, 0.5, 0.6); 0.7, 0.3, 0.2⟩
Roughly Value	ROV	⟨(0.5, 0.6, 0.7); 0.8, 0.3, 0.3⟩
Modest High Value	MHV	⟨(0.6, 0.7, 0.8); 0.9, 0.4, 0.4⟩
High Value	HVV	⟨(0.7, 0.8, 0.9); 1.0, 0.3, 0.5⟩
Very High Value	VHV	⟨(0.8, 0.9, 1.0); 1.0, 0.2, 0.3⟩
Fully High Value	FHV	⟨(0.9, 1.0, 1.0); 1.0, 0.2, 0.2⟩

Step 3: Create a pairwise comparison matrix amongst the main criteria and itself by all experts to clarify their preferences for these criteria.

Step 4: Convert TNNs to real values by applying the score function according to Eq. (1).

$$S(\tilde{x}_{ij}) = \frac{1}{8}(l + m + u) \times (2 + \alpha_{\tilde{x}} - \theta_{\tilde{x}} - \beta_{\tilde{x}}) \quad (1)$$

Step 5: Calculating the generalized direct relation matrix (g) for all criteria by using Eqs. (2-3).

$$Q = \frac{1}{\mathrm{Max}_{1 \le i \le n} \sum_{j=1}^{n} x_{ij}} \quad (2)$$

$$g = Q \times P \quad (3)$$

Step 6: Calculating the total relation matrix (T) for all criteria by using Eq. (4).

$$T = g \times (I - g)^{-1} \quad (4)$$

Where I is the identity matrix.

Step 7: Calculating the sum of rows and columns expressed as R and C, respectively, in Eq. (5) and Eq. (6). Then, the horizontal axis vector R+C is calculated, and the vertical axis vector R–C.

$$R = \left[\sum_{i=1}^{n} t_{ij}\right]_{1 \times n} \quad (5)$$

$$C = \left[\sum_{j=1}^{n} t_{ij}\right]_{n \times 1} \quad (6)$$

Step 8: Attaining the weights of the main criteria $C_1, C_2, \dots, C_n$ based on the R and C that obtaining from expert opinions according to Eq. (7).

$$w = \frac{R+C}{\sum_{i=1}^{n} R+C} \quad (7)$$

Step 9: Constructing the assessment decision matrix by all experts between the determined sub-indicators and the available alternatives using the linguistic terms as presented in Table 1. Then, convert TNNs to real values by applying the score function according to Eq. (1).

Step 10: Calculating the normalized decision matrix for the benefit indicators according to Eq. (8), and for cost indicators according Eq. (9).

$$\text{normalized}_{ij} = \frac{y_{ij}}{y_{jmax}} \quad (8)$$

$$\text{normalized}_{ij} = \frac{y_{jmin}}{y_{ij}} \quad (9)$$

Step 11: Computing the weighted evaluation decision matrix by multiplying the value of the normalized decision matrix by the corresponding weights according to Eq. (10).

$$v_{ij} = \text{normalized}_{ij} \times w_j \quad (10)$$

Step 12: Determining the ideal and anti-ideal solution by using Eq. (11) and Eq. (12), respectively.

$$t_i = \max v_{ij} \quad (11)$$

$$t_{ai} = \min v_{ij} \quad (12)$$

Step 13: Computing of deviations from ideal and anti-ideal solutions, respectively according to Eq. (13) and Eq. (14).

$$d^{+} = t_i - v_{ij} \quad (13)$$

$$d^{-} = v_{ij} - t_{ai} \quad (14)$$

Step 14: Determining the degrees to which specific alternatives deviate from ideal and anti-ideal solutions and then computing those degrees according to Eq. (15) and Eq. (16).

$$s_i^{+} = \sum_{j=1}^{n} d^{+} \quad (15)$$

$$s_i^{-} = \sum_{j=1}^{n} d^{-} \quad (16)$$

Step 15: Computing of the utility function for each alternative in relation to the deviations from the optimal alternatives according to Eq. (17) and Eq. (18).

$$K_i^{+} = \frac{s_0^{+}}{s_i^{+}} \quad (17)$$

$$K_i^{-} = \frac{s_i^{-}}{s_0^{-}} \quad (18)$$

Step 16: Calculating the final order by looking for the average deviation of the alternatives from the degree of utility according to Eq. (19). Then, rank the alternatives, the best alternative is the one that has the greatest valueQ_i.

$$Q_i = \frac{K_i^{+} + K_i^{-}}{2} \quad (19)$$

4. Application

4.1 Case study

During the last two years, the epidemic of coronavirus has caused a significant amount of disturbance all across the globe. This illness has been responsible for a number of deaths as well as significant economic losses. The significance of medical gadgets has been brought into sharper focus as a direct result of the epidemic that was discussed. As a result, a business operating in the field of medical equipment and situated in Egypt has been chosen. This company manufactures a wide range of medical equipment, including the blood bank refrigerator, the vaccine refrigerator, the oxygen concentrator device, and a variety of other similar products. The current epidemic has presented this business with a number of significant hurdles. A significant rise in the number of people needing medical equipment has made it difficult for this organization to satisfy the needs of its clientele, which brings us to our first point. In this respect, the notion of responsiveness may be of assistance to the administrators of this organization in their efforts to address the aforementioned problem. To acquire a competitive edge, the management of this firm are interested, on the other hand, in applying the aspects of Industry 5.0 inside their organization.

4.2 Application of the suggested approach

In this part, the steps of the proposed methodology DEMATEL-CRADIS are applied. The proposed approach is applied under a neutrosophic environment.

Step 1: A pairwise comparison matrix was created amongst the main criteria and itself by all experts to clarify their preferences for these criteria using linguistic terms as presented in Table 2. Then, TNNs were converted to real values by applying the score function according to Eq. (1).

Step 2: The generalized direct relation matrix was computed for all main criteria by using Eqs. (2-3), as presented in Table 3.

Step 3: The total relation matrix was determined for all main criteria by using Eq. (4), as presented in Table 4.

Step 4: The weights of the main criteria were obtained according to Eq. (7), as presented in Table 4 and shown in Figure 2.

Table 2. Evaluation of main criteria using linguistic terms by all experts.

Expert_s	C_1	C_2	C_3	C_4
C_1	*	MLV	LOV	FHV
C_2	VLV	*	MHV	FLV
C_3	VHV	MHV	*	ROV
C_4	ROV	VHV	VHV	*

Table 3. Generalized relation matrix of main criteria by all experts.

Expert_s	C_1	C_2	C_3	C_4
C_1	0.1866	0.1530	0.1306	0.3507
C_2	0.0896	0.1866	0.2052	0.0560
C_3	0.3134	0.2052	0.1866	0.1866
C_4	0.1866	0.3134	0.3134	0.1866

Table 4. Total relation matrix of main criteria by all experts.

	C_1	C_2	C_3	C_4	R_i	C_i	$R_i + C_i$	$R_i - C_i$	Identity	Weight
C_1	1.0428	1.1193	1.0744	1.2043	4.441	4.033	8.473	0.408	Cause	0.252
C_2	0.6105	0.7487	0.7536	0.5564	2.669	4.449	7.118	-1.779	Effect	0.212
C_3	1.2095	1.1912	1.1463	1.0957	4.643	4.338	8.981	0.305	Cause	0.267
C_4	1.1698	1.3895	1.3638	1.1422	5.065	3.999	9.064	1.067	Cause	0.269

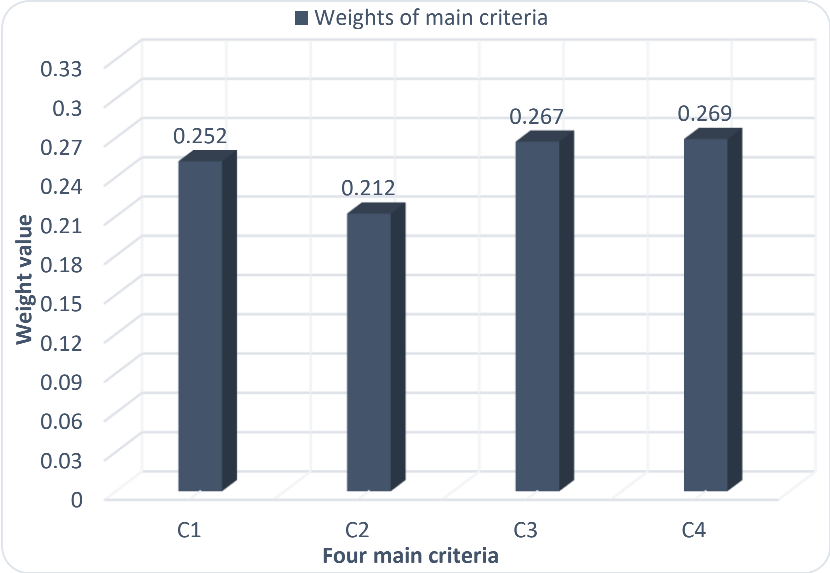

Figure 2. Final weights of main criteria.

Step 5: A pairwise comparison matrix was created amongst the responsiveness criterion's sub-indicators and itself by all experts to clarify their preferences for these indicators using linguistic terms as presented in Table 5. Then, TNNs were converted to real values by applying the score function according to Eq. (1).

Step 6: The generalized direct relation matrix was computed for responsiveness criterion's sub-indicators by using Eqs. (2-3), as presented in Table 6.

Step 7: The total relation matrix was determined for responsiveness criterion's sub-indicators by using Eq. (4), as presented in Table 7.

Step 8: The weights of the responsiveness criterion's sub-indicators were obtained according to Eq. (7), as presented in Table 7 and shown in Figure 3.

Table 5. Evaluation of responsiveness criterion's sub-indicators using linguistic terms.

Expert_s	C_{1_1}	C_{1_2}	C_{1_3}	C_{1_4}
C_{1_1}	*	MLV	VHV	MHV
C_{1_2}	MLV	*	FHV	HVV
C_{1_3}	VHV	MHV	*	VHV
C_{1_4}	ROV	HVV	VHV	*

Table 6. Generalized relation matrix of responsiveness criterion's sub-indicators.

Expert_s	C_{1_1}	C_{1_2}	C_{1_3}	C_{1_4}
C_{1_1}	0.1832	0.1502	0.3077	0.2015
C_{1_2}	0.1502	0.1832	0.3443	0.2418
C_{1_3}	0.3077	0.2015	0.1832	0.3077
C_{1_4}	0.1832	0.2418	0.3077	0.1832

Table 7. Total relation matrix of responsiveness criterion's sub-indicators.

	C_{1_1}	C_{1_2}	C_{1_3}	C_{1_4}	R_i	C_i	$R_i + C_i$	$R_i - C_i$	Identity	Weight
C_{1_1}	2.5991	2.3621	3.4368	2.8813	11.279	11.305	22.584	-0.026	Effect	0.230
C_{1_2}	2.7994	2.6116	3.7752	3.1814	12.368	10.395	22.762	1.973	Cause	0.232
C_{1_3}	3.1024	2.7766	3.8491	3.4135	13.142	14.775	27.917	-1.634	Effect	0.285
C_{1_4}	2.8041	2.6444	3.7145	3.0976	12.261	12.574	24.835	-0.313	Effect	0.253

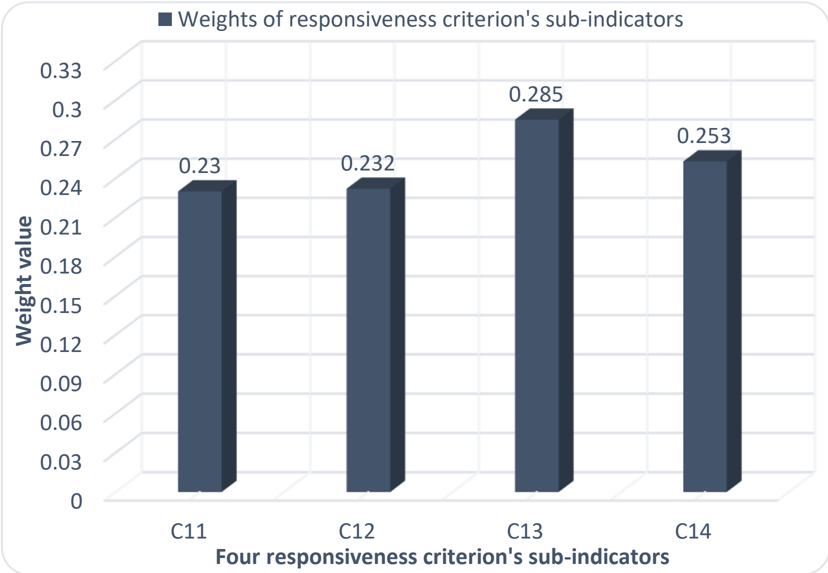

Figure 3. Final weights of responsiveness criterion's sub-indicators.

Step 9: A pairwise comparison matrix was created amongst the sustainability criterion's sub-indicators and itself by all experts to clarify their preferences for these indicators using linguistic terms as presented in Table 8. Then, TNNs were converted to real values by applying the score function according to Eq. (1).

Step 10: The generalized direct relation matrix was computed for sustainability criterion's sub-indicators by using Eqs. (2-3), as presented in Table 9.

Step 11: The total relation matrix was determined for sustainability criterion's sub-indicators by using Eq. (4), as presented in Table 10.

Step 12: The weights of the sustainability criterion's sub-indicators were obtained according to Eq. (7), as presented in Table 10 and shown in Figure 4.

Table 8. Evaluation of sustainability criterion's sub-indicators using linguistic terms.

$Expert_s$	C_{2_1}	C_{2_2}	C_{2_3}	C_{2_4}
C_{2_1}	*	FHV	HVV	MHV
C_{2_2}	FLV	*	FLV	HVV
C_{2_3}	FLV	LOV	*	VHV
C_{2_4}	ROV	LOV	FHV	*

Table 9. Generalized relation matrix of sustainability criterion's sub-indicators.

$Expert_s$	C_{2_1}	C_{2_2}	C_{2_3}	C_{2_4}
C_{2_1}	0.1887	0.3547	0.2491	0.2075
C_{2_2}	0.0566	0.1887	0.0566	0.2491
C_{2_3}	0.0566	0.1321	0.1887	0.3170
C_{2_4}	0.1887	0.1321	0.3547	0.1887

Table 10. Total relation matrix of sustainability criterion's sub-indicators.

	C_{2_1}	C_{2_2}	C_{2_3}	C_{2_4}	R_i	C_i	$R_i + C_i$	$R_i - C_i$	Identity	Weight
C_{2_1}	0.6667	1.1055	1.1138	1.2009	4.087	2.042	6.129	2.045	Cause	0.235
C_{2_2}	0.3367	0.6015	0.5640	0.7981	2.300	3.161	5.461	-0.861	Effect	0.210
C_{2_3}	0.4148	0.6514	0.8562	1.0313	2.954	3.696	6.650	-0.743	Effect	0.255
C_{2_4}	0.6238	0.8026	1.1624	1.0927	3.681	4.123	7.804	-0.442	Effect	0.300

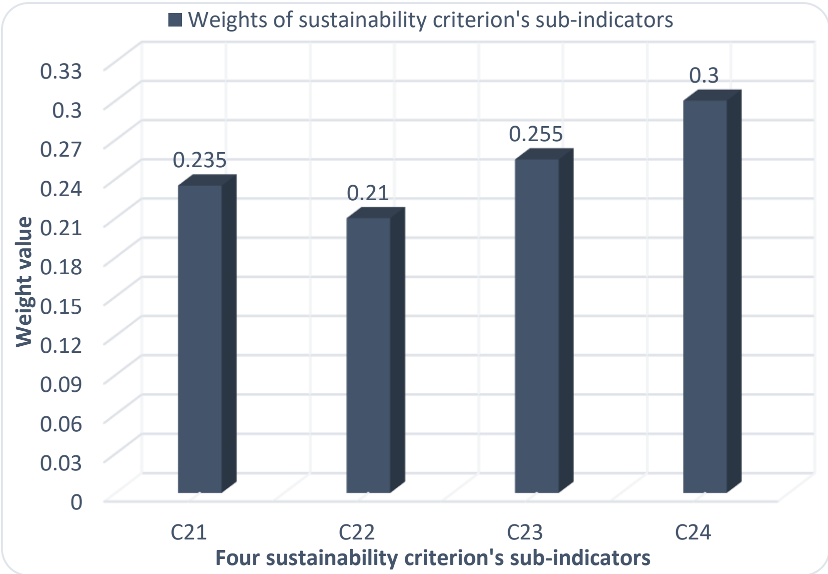

Figure 4. Final weights of sustainability criterion's sub-indicators

Step 13: A pairwise comparison matrix was created amongst the resiliency criterion's sub-indicators and itself by all experts to clarify their preferences for these indicators using linguistic terms as presented in Table 11. Then, TNNs were converted to real values by applying the score function according to Eq. (1).

Step 14: The generalized direct relation matrix was computed for resiliency criterion's sub-indicators by using Eqs. (2-3), as presented in Table 12.

Step 15: The total relation matrix was determined for resiliency criterion's sub-indicators by using Eq. (4), as presented in Table 13.

Step 16: The weights of the resiliency criterion's sub-indicators were obtained according to Eq. (7), as presented in Table 13 and shown in Figure 5.

Table 11. Evaluation of resiliency criterion's sub-indicators using linguistic terms.

$Expert_s$	C_{3_1}	C_{3_2}	C_{3_3}	C_{3_4}
C_{3_1}	*	LOV	HVV	MHV
C_{3_2}	LOV	*	FLV	LOV
C_{3_3}	FLV	LOV	*	VHV
C_{3_4}	ROV	LOV	FHV	*

Table 12. Generalized relation matrix of resiliency criterion's sub-indicators.

$Expert_s$	C_{3_1}	C_{3_2}	C_{3_3}	C_{3_4}
C_{3_1}	0.2183	0.1528	0.2882	0.2402
C_{3_2}	0.1528	0.2183	0.0655	0.1528
C_{3_3}	0.0655	0.1528	0.2183	0.3668
C_{3_4}	0.2183	0.1528	0.4105	0.2183

Table 13. Total relation matrix of resiliency criterion's sub-indicators.

	C_{3_1}	C_{3_2}	C_{3_3}	C_{3_4}	R_i	C_i	$R_i + C_i$	$R_i - C_i$	Identity	Weight
C_{3_1}	1.1071	1.0828	1.7501	1.6804	5.620	3.887	9.508	1.733	Cause	0.233
C_{3_2}	0.7176	0.8051	0.9515	1.0199	3.494	4.064	7.558	-0.570	Effect	0.185
C_{3_3}	0.8744	0.9969	1.5595	1.6647	5.096	6.280	11.376	-1.185	Effect	0.279
C_{3_4}	1.1881	1.1789	2.0190	1.8224	6.208	6.187	12.396	0.021	Cause	0.304

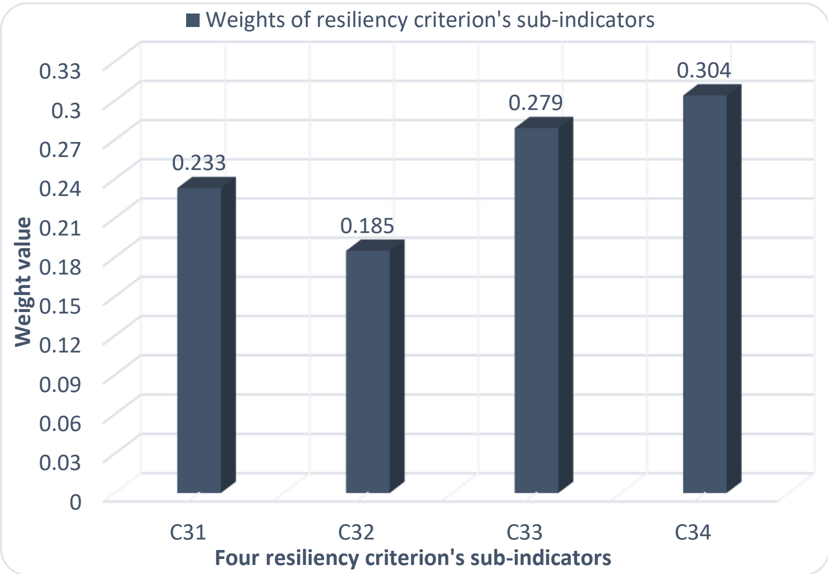

Figure 5. Final weights of resiliency criterion's sub-indicators.

Step 17: A pairwise comparison matrix was created amongst the human-centricity criterion's sub-indicators and itself by all experts to clarify their preferences for these indicators using linguistic terms as presented in Table 14. Then, TNNs were converted to real values by applying the score function according to Eq. (1).

Step 18: The generalized direct relation matrix was computed for human-centricity criterion's sub-indicators by using Eqs. (2-3), as presented in Table 15.

Step 19: The total relation matrix was determined for human-centricity criterion's sub-indicators by using Eq. (4), as presented in Table 16.

Step 20: The weights of the human-centricity criterion's sub-indicators were obtained according to Eq. (7), as presented in Table 16 and shown in Figure 6.

Step 21: The global weights of the sub-indicators are calculated by multiplying the weights of the main criteria by the weights of the local criteria for the sub-indicators, as in Figure 7.

Table 14. Evaluation of human-centricity criterion's sub-indicators using linguistic terms.

$Expert_s$	C_{4_1}	C_{4_2}	C_{4_3}	C_{4_4}
C_{4_1}	*	LOV	HVV	MHV
C_{4_2}	HVV	*	FLV	LOV
C_{4_3}	FLV	VHV	*	LOV
C_{4_4}	HVV	VHV	FLV	*

Table 15. Generalized relation matrix of human-centricity criterion's sub-indicators.

$Expert_s$	C_{4_1}	C_{4_2}	C_{4_3}	C_{4_4}
C_{4_1}	0.2326	0.1628	0.3070	0.2558
C_{4_2}	0.3070	0.2326	0.0698	0.1628
C_{4_3}	0.0698	0.3907	0.2326	0.1628
C_{4_4}	0.3070	0.3907	0.0698	0.2326

Table 16. Total relation matrix of human-centricity criterion's sub-indicators.

	C_{4_1}	C_{4_2}	C_{4_3}	C_{4_4}	R_i	C_i	$R_i + C_i$	$R_i - C_i$	Identity	Weight
C_{4_1}	2.3472	2.6551	1.7670	2.0537	8.823	8.848	17.671	-0.025	Effect	0.271
C_{4_2}	2.0530	2.2124	1.2617	1.6334	7.161	10.289	17.450	-3.128	Effect	0.267
C_{4_3}	1.8917	2.4971	1.4392	1.6777	7.506	6.039	13.544	1.467	Cause	0.207
C_{4_4}	2.5560	2.9245	1.5709	2.1086	9.160	7.473	16.633	1.687	Cause	0.255

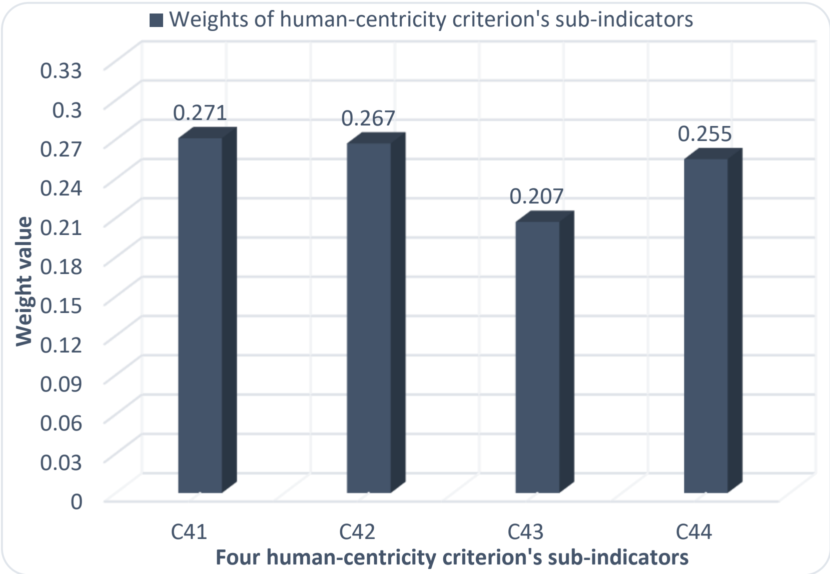

Figure 6. Final weights of human-centricity criterion's sub-indicators.

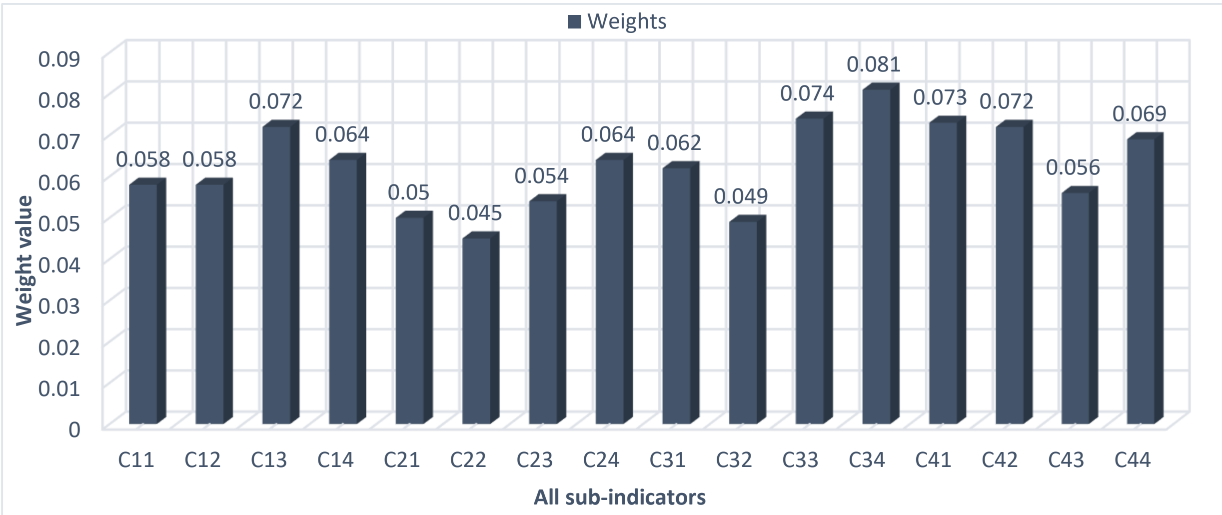

Figure 7. Final global weights of all sub-indicators.

Step 22: The assessment decision matrix was constructed by all experts between the determined sub-indicators and the available alternatives using the linguistic terms provided in Table 1, as presented in Table 17. Then, the TNNs were converted to real values by applying the score function according to Eq. (1).

Step 23: The normalized decision matrix was constructed for the benefit indicators according to Eq. (8), and for cost indicators according Eq. (9), as presented in Table 18.

Step 24: The weighted evaluation decision matrix was computed by multiplying the value of the normalized decision matrix by the corresponding weights according to Eq. (10), as exhibited in Table 19.Then, the ideal and anti-ideal solution were determined by using Eq. (11) and Eq. (12), respectively.

Step 25: The degrees to which specific alternatives deviate from ideal and anti-ideal solutions were determined and then computing those degrees according to Eq. (15) and Eq. (16), as presented in Table 20.

Step 26: The final order by looking for the average deviation of the alternatives were determined from the degree of utility according to Eq. (19), as presented in Table 21 and shown in Figure 8.

Table 17. Evaluation matrix of four strategies regarding all sub-indicators using linguistic terms.

Experts	C_{1_1}	C_{1_2}	C_{1_3}	C_{1_4}	C_{2_1}	C_{2_2}	C_{2_3}	C_{2_4}
A_1	HVV	FHV	MHV	VHV	ROV	HVV	FLV	VLV
A_2	FHV	VHV	VHV	FHV	HVV	VHV	FHV	FHV
A_3	VHV	FLV	MLV	FLV	MHV	MLV	VLV	VLV
A_4	MHV	MHV	ROV	VHV	FHV	MHV	VHV	HVV
Experts	C_{3_1}	C_{3_2}	C_{3_3}	C_{3_4}	C_{4_1}	C_{4_2}	C_{4_3}	C_{4_4}
A_1	MLV	MLV	MHV	FLV	VLV	MHV	ROV	HVV
A_2	FHV	VHV	HVV	FHV	VHV	VHV	FHV	FHV
A_3	VLV	LOV	ROV	LOV	HVV	MHV	HVV	VHV
A_4	FHV	ROV	VLV	HVV	FHV	MLV	LOV	MHV

Table 18. Normalized matrix of four strategies regarding all sub-indicators.

Experts	C_{1_1}	C_{1_2}	C_{1_3}	C_{1_4}	C_{2_1}	C_{2_2}	C_{2_3}	C_{2_4}
A_1	0.835	1.000	0.653	0.178	1.000	0.782	0.159	0.251
A_2	0.585	0.895	1.000	0.159	0.750	1.000	1.000	1.000
A_3	0.653	0.159	0.489	1.000	0.898	0.489	0.251	0.251
A_4	1.000	0.585	0.587	0.178	0.525	0.653	0.895	0.700
Experts	C_{3_1}	C_{3_2}	C_{3_3}	C_{3_4}	C_{4_1}	C_{4_2}	C_{4_3}	C_{4_4}
A_1	0.438	0.836	0.429	1.000	0.251	0.653	0.525	0.835
A_2	1.000	0.409	0.358	0.159	0.895	1.000	1.000	0.585
A_3	0.251	1.000	0.477	0.435	0.700	0.653	0.700	0.653
A_4	1.000	0.697	1.000	0.227	1.000	0.489	0.366	1.000

Table 19. Weighted normalized matrix of four strategies regarding all sub-indicators.

Experts	C_{1_1}	C_{1_2}	C_{1_3}	C_{1_4}	C_{2_1}	C_{2_2}	C_{2_3}	C_{2_4}
A_1	0.048	0.058	0.047	0.011	0.050	0.035	0.009	0.016
A_2	0.034	0.052	0.072	0.010	0.037	0.045	0.054	0.064
A_3	0.038	0.009	0.035	0.064	0.045	0.022	0.014	0.016
A_4	0.058	0.034	0.042	0.011	0.026	0.029	0.048	0.045
t_i	0.058	0.058	0.072	0.064	0.050	0.045	0.054	0.064
t_{ai}	0.034	0.009	0.035	0.010	0.026	0.022	0.009	0.016
Experts	C_{3_1}	C_{3_2}	C_{3_3}	C_{3_4}	C_{4_1}	C_{4_2}	C_{4_3}	C_{4_4}
A_1	0.027	0.041	0.032	0.081	0.018	0.047	0.029	0.057
A_2	0.062	0.020	0.027	0.013	0.065	0.072	0.056	0.040
A_3	0.016	0.049	0.036	0.035	0.051	0.047	0.039	0.045
A_4	0.062	0.034	0.074	0.018	0.073	0.035	0.020	0.069

t_{i}	0.062	0.049	0.074	0.081	0.073	0.072	0.056	0.069
t_{ai}	0.016	0.020	0.027	0.013	0.018	0.035	0.020	0.040

Table 20. The grades of the deviation of individual alternatives from ideal and anti-ideal solutions.

Experts	C_{1_1}	C_{1_2}	C_{1_3}	C_{1_4}	C_{2_1}	C_{2_2}	C_{2_3}	C_{2_4}
A_1	0.015	0.000	0.025	0.001	0.024	0.010	0.045	0.048
A_2	0.000	0.006	0.000	0.000	0.011	0.000	0.000	0.000
A_3	0.004	0.049	0.037	0.054	0.019	0.023	0.041	0.048
A_4	0.024	0.024	0.030	0.001	0.000	0.015	0.006	0.019
Experts	C_{3_1}	C_{3_2}	C_{3_3}	C_{3_4}	C_{4_1}	C_{4_2}	C_{4_3}	C_{4_4}
A_1	0.035	0.021	0.005	0.068	0.055	0.025	0.026	0.017
A_2	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000
A_3	0.047	0.029	0.009	0.022	0.022	0.025	0.017	0.005
A_4	0.000	0.014	0.048	0.006	0.000	0.037	0.035	0.028

Table 21. Final ranking of the four strategies.

Strategies	S^{+}_{i}	S^{-}_{i}	K^{+}_{i}	K^{-}_{i}	Q_i	Rank
A_1	0.269	0.151	0.458	0.712	0.585	2
A_2	0.014	0.011	0.476	0.738	0.607	1
A_3	0.307	0.141	0.347	0.538	0.443	4
A_4	0.166	0.121	0.428	0.653	0.540	3

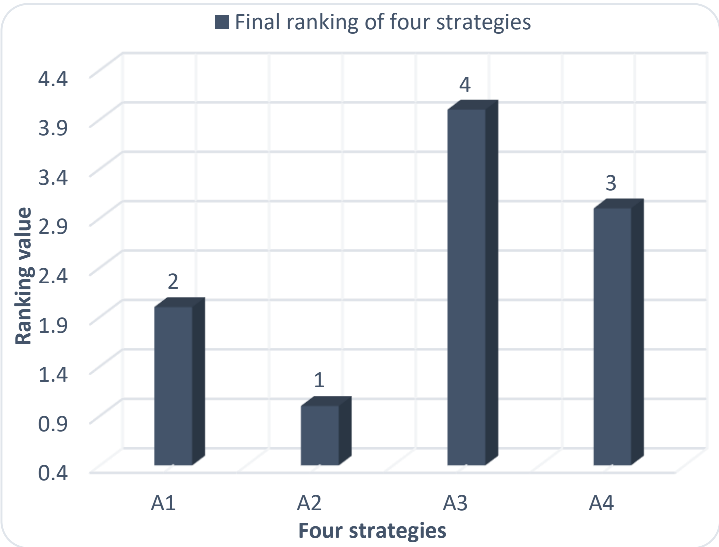

Figure 8. Final ranking of four strategies using CRADIS method.

4.3 Discussion

In this part, the results obtained from the application of the proposed methodology DEMATEL-CRADIS under the neutrosophic environment are discussed.

Initially, the four main criteria were evaluated and prioritized using the DEMATEL method. The results indicate that the human-centricity criterion is the most influential criterion with a weight of 0.269, followed by the resiliency criterion, while the sustainability criterion is the least influential with a weight of 0.212.

Also, the responsiveness criterion's sub-indicators were evaluated and prioritized using the DEMATEL method. The results indicate that the numerous varieties of products indicator is the most influential criterion with a weight of 0.285, followed by the managing demand variations indicator, while the superior service level indicator is the least influential with a weight of 0.230.

5. Conclusion

In this research, the responsive supply chain was investigated based on the Industry 5.0 dimensions, which were given the moniker responsive supply chain 5.0. Both the indicators and the alternatives have been determined. After that, the necessary data were collected, the weights of the indicators were calculated, and the alternatives were prioritized while taking into consideration a case study of the healthcare systems. In further research, several aspects of Industry 5.0, such as global supply chains and agile supply chains, might be the subject of investigation. In this respect, researchers have the opportunity to add aspects of the global supply chain, such as the capability of the supply chain to link to other supply networks located all over the world. On the other hand, there are aspects of an agile supply chain that may be modified, such as lead time flexibility and dependability. The use of MCDM in conjunction with artificial intelligence as a methodology for researching the research subject is yet another potential path for future research. Finally, researchers are able to create a supply chain network based on the pillars proposed by Industry 5.0 using the mathematical programming methods that they have proposed.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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