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A Fuzzy BWM Approach to Prioritize Distribution Network Enablers

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Abstract

In any country's economy, the distribution is one of the most important industries and infrastructure. The industry's 8% portion of national income, explains the wide range of this industry and consequently the key role of this industry in the supply chain of many industries in the country. Not using all the capabilities of the distribution network and ignorance about distribution enablers will lead to chain costs failure and increase supply. In today's condition, maintenance and continuity of activities in the distribution network are considered as important subjects in a supply chain, and the reliability of the distribution network in a supply chain is grounded in recognition of the enablers. Identifying and prioritizing the distribution network enablers precede the development and proper implementation of the strategies and plans of a distribution network. The fuzzy logic has become a convenient tool for prioritizing due to the necessity of the comprehensive view to the supply chain, the uncertain space of it, and inconsistency in the views of decision-makers. This research tries to identify and prioritize the empowerment in order to direct and supply resources and thus to increase the productivity and effectiveness of the country's industrial distribution network. The theoretical framework of the study is based on the extracted enablers from the literature and selecting a final set of them by using the Lawshe method. The group of experts is comprised of 11 experts in the welding and cutting industry. The enablers are prioritized using the fuzzy BWM method and Lingo software. The results indicate that the most influencing factor on the distribution network is "on-time delivery" and the "logistic infrastructures" factor is the least important among the factors. The resulted prioritization could be used as a guideline for a better perception of the activities related to the distribution network. By analyzing the studies in this topic, a research gap can be identified in the field of not recognizing the distribution network enablers. Another study gap is not paying attention to the prioritization of enablers. However, in the real world, it is not possible to consider and apply all enablers owing to limits, and each enabler has a distinct preference, demonstrating the importance of prioritizing enablers and employing multi-criteria decision-making techniques.

Keywords: Distribution network, Distribution enabler, Fuzzy best-worst.

1 | Introduction

Nowadays, most organizations accept the concept of Supply Chain Management (SCM) and use it as a tool for gaining competitive advantages. SCM could be considered as integration and coordination of materials, information, and financial flows for using supply chain resources in the whole logic of the value chain. In practice, SCM includes processes such as inventory control, production planning, and optimizing distribution network or tendering logistic services [1]. Distributing strategy has an important role in the sale system of a supply chain. The distribution network empowers the chain market by collaborating in the growth of product delivery to different sectors. Furthermore, it collaborates to make the needed products get in reach [2]. In SCM, distribution is a set of actions for delivering the consumer the final products. Customer satisfaction is due to the ability of delivery

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network to transfer the products as quickly and economically as possible. Organization's success in a competitive global market is by maintaining inventory at distribution network [3].

The distribution network is very complex and has an important role in the economy of a country. Developing the distribution network theories could be considerably collaborative to decision-making in this industry. Thus, it is vital to develop a comprehensive view of enablers in sharing theories and proper recognition of facilitators as a predecessor to achieve the goals of the distribution network. Many enablers are influential on the success of a supply chain. Identifying the most important enablers is important in the management of these processes. By introducing the enablers, managers would be able to improve them and use their resources for the enablers with higher priority [1]. Hence, what are the distributors in the supply chain? In this research, we are trying to answer this question. What is the order and importance of each empowerment? Answering these questions is essential for managers in order to achieve the ability to obtain the needed information for making decisions in today's competitive environment and its advantageous aspects.

Different studies have been done to identify and prioritize supply chain enablers but without focusing on the distribution network. Due to this important issue, the present study has taken steps to provide a comprehensive distribution network enablers and complete this research gap. This descriptive-practical case study develops a framework to demonstrate the distribution network enablers by using a test group and deploying a quantitative method. Identifying the distribution network enablers could collaborate in developing proper strategies in order to achieve the goals as much as possible and help managers in this industry with a better vision. Introducing effective enablers needs an applicable and comprehensive method to achieve a comprehensive and clear prioritizing considering the importance of the enablers.

Decision-making techniques are the main tools for prioritizing different problems [4]. BWM is one of the most efficient techniques in multi-criteria decision-making that aim to minimize the absolute difference of weights, the number of pairwise comparisons, and achieve more compatible pairwise comparison matrix by recognition of the dynamic processes prioritization by using classical methods does not achieve highly reliable results. Many decision areas have highly ambiguous.these ambiguities lead to the presentation information that is not suitable for decision making [5]. Integrated fuzzy-MCDM model is used to find out the most suitable option [6]. Therefore, this study aims to minimize the limitations of classical methods, by using fuzzy approach and multi-criteria decision-making prioritization of distribution network enablers. The remainder of this paper is as follows:

In Section 2, the literature review is presented. In Section 3, the theoretical basics are described and the study approach is presented in Section 4. Section 5 presents, analyze and discuss the distribution network enablers and finally, the results and their implications are presented in the last section of this paper.

2 | Literature Review (Survey on Related Work)

Distribution network management is so important along with the other parameters of the supply chain and the marketing mix; because of the fact that logistic costs are among the most significant costs of a distribution network. So that succeeding in the distribution network is one of the most important supply chain problems. Many studies have been done to prioritize the supply chain enablers but studies that aim to identify the distribution network enablers are scarce.

Andalib Ardakani and Shams [7] identified and modeled the enablers of green SCM in Small and Medium-sized Enterprises (SMEs). They used structural equation modeling in order to analyze data and prioritize criteria. The results of their study indicate that influencing factors on the SCM enablers could be classified into five criteria: "Electronic Commerce", "Internal Operations", "Logistic Success", "Total Quality Management", and "Innovation ". The results of prioritizing show that "Internal Operations" has the most effect on green SCM and "Innovation", "Logistic Success", “Electronic Commerce", and "Total Quality Management" are in next priorities.

Ostadi et al. [8] identified and prioritized the enablers of Supply Chain Quality Management (SCQM) based on weighting criteria using the Analytic Hierarchy Process (AHP) method. They identified the enablers through literature review then prioritized criteria based on pairwise comparison logic and AHP. The supply chain of a product should be focused on seven fields to implement SCQM and these fields should be developed and improved, simultaneously and in collaboration with each other, considering the correlation between them.

Abedini et al. [9] prioritize the enablers of the medicine supply and distribution chain using the DEMATEL approach. Their study consists of two library searching and surveying phases. In the first phase, the enablers were identified in 25 aspects by searching in scholarly resources. In the second phase, nine aspects were selected, based on the Pareto principle, as the basis for pairwise comparisons of the factors in the DEMATEL approach. The results indicated that "support from senior management", "using information technology", and "government interfering" are the first three factors among influencing factors; moreover, "processes", "quality of services", and "trust" are the first three factors among influenced factors. Furthermore, "support from senior management" and "government interfering" have been known as the most and the least interactive factors, respectively.

Salehi Sadaghiani and Ghasem Zadeh [10] identified the enablers in the agile supply chain in dairy industries. The results indicate that the eleven main factors for succeeding in a supply chain could be classified into six levels. The first level implies the "customer satisfaction" factor, which increases the market share and profits of the organization. At the last level, there are three factors including "process aggregation", "suitable planning", and "employees' skills development".

Kumar et al. [11] studied the enablers in the Circular Supply Chain (CSC) Industry 4.0. They identified the enablers through literature review, then in the final step, the influencing and influenced factors were determined using the Fuzzy DEMATEL method. The results showed that to adopt Industry 4.0, "knowledge of supply chain and Industry 4.0" is the most important factor followed by "top management commitment".

Gokarn and Choudhary [12] identified the main influencing factors on wastages of the food supply chain. This empirical study identified eight influencing factors. They used interpretive structural modelling technique and Micmac analysis to study the enablers. "Supervising institutions", "policies and market infrastructures" are the most important factors.

Prasad et al. [13] studied the key factors for success in a sustainable supply chain. This research has been conducted based on scholarly documentaries and 145 experts' ideas. Structural modelling technique indicated that the "internal space of the organizations" is an important factor in Indian steel industry SCM approaches.

Meyer and Torres [1] studied the enablers in supply chain projects. In their study, ten enablers for supply chain projects were evaluated through semi-structural interviews with supply chain experts. The results indicated that "communications and stakeholder management", "project clear goals", " supporting from senior management project", and "internal organization of project team" have been identified as the most important factors.

Behl et al. [14] identified and prioritized the enablers in Humanitarian Supply Chain Management (HSCM) by using gray-based Fuzzy DEMATEL. They considered flood in India as the case study and investigate the important factors for a successful implementation of humanitarian SCM. Furthermore, they modeled the enablers and classified them using a gray-based decision-making approach.

Adabavazaeh and Nikbakht [15] have identified the enablers in the reverse supply chain. They identified 159 factors through literature review and reached 73 factors after a preliminary reduction. Finally, 24 main success factors were identified using the Lawshe technique and were classified using interpretive structural modelling technique and experts' views. The results showed that the most influencing factor related to "inventory management" and "logistic" are among the connector factors which any minor change in them would fundamentally change the whole system.

Aschemann-Witzel et al. [16] conducted research on supply chain enablers to deal with food wastages. The multi-case study was presented by analyzing success factors in 26 current programs for reducing food wastages. Their findings indicated that "cooperation between stakeholders", "innovations sequence and time", "innovation abilities" are key success factors. There are three main innovations that are different in goals and specifications: "information and opportunity making", "redistribution" and "supply chain".

Raut et al. [17] identified the enablers of Indian oil and gas sustainable supply chain. 32 enablers were identified through literature review and ideas of experts and academics. Interpretive structural modelling and Micmac analysis indicated that "global climate pressure", "ecologic lack of resources" are the most important factors which might make industries implement sustainable approaches. Coo [18] investigated the enablers to improve distributing in exports of SMEs. They aimed to find out the enablers for small and medium-sized exporting enterprises and create the factors which have positive impact on their export. 15 success factors were identified based on 258 questionaries.

Kumar et al. [19] studied the enablers in the supply chain of Indian SMEs. 13 enablers were identified in SMEs. The results indicated that "top management commitment", "long-term strategy", "focusing on strengths", "dedicated resources to supply chain" and "strategy development" are among the influencing factors in a supply chain. To measure the performance improvement by the factors "different actions related to services", "customer satisfaction", "innovation and growth", "financial performance", and "internal jobs" were taken into account.

Major purpose of [20] research is identification and evaluating of effective factors on implementation of Green Supply Chain Management (GSCM) at Fanavaran Petrochemical Company by using statistical methods of Kolmogorov-Smirnov, mean and decision making method by topic Stepwise Weight Assessment Ratio Analysis (SWARA). Research methodology of present research base on purpose is practical and based on data gathering method is descriptive-measurement. In order to extracting the effective factors on GSCM at the company, in first, by literature review, 22 factors were identified. Then data's were gathered by using of opinions of population members containing 55 persons of experts and senior managers in the first class of company. Finally after analyzing the questionnaires and statistical tests above, 11 factors were confirmed and selected. In continues, in order to evaluating the final factors and ranking them base on importance in success implementation of GSCM system, the SWARA technique is used. The aim of [21] study is to identify and prioritize a list of key digitization enablers that can improve SCM. This study seems to be the first of its kind in which 25 digitization enablers categorized in four main categories are ranked using a Multi Criteria Decision Making (MCDM) tool. This study is also first of its kind in ranking the organizations in their SC performance based on weights/ranks of digitization enablers. The BWM has been applied to evaluate, rank and prioritize the key digitization and IT enablers beneficial for the improvement of SC performance.

Della Valle and Oliver [22] study provided solid contributions to understanding blockchain innovation and presents some main features and guidelines for how to boost blockchain implementation in industry. As explorative research, this paper presents a grounded theory analysis based on 18 expert interviews. Renowned worldwide experts provided us with powerful input to run this analysis and with a general overview of the current situation.

Bamel and Bamel [23] paper aimed to identify the Big Data Analytics (BDA) based enablers of Supply Chain Capabilities (SCC) and competitiveness of firms. This paper also models the interaction among identified enablers and thus projects the relationship strength of these enablers with SCC and a firm's competitiveness. In order to achieve the research objectives of this paper, we employed fuzzy Total

Interpretive Structural Modeling (TISM), an integrated approach of an interpretive structural model and TISM. In a brief view, the supply chain/distribution network enablers from experts' perspective could be concluded in the following table.

Aazami and Saidi-Mehrabad [24] investigated the generation and distribution planning of perishable products with fixed lifetime in seller and buyer systems. This research studied three solutions, and because the problem is NP-hard, a novel hierarchical approach based on Genetic Algorithm (GA) is provided. Hendalianpour et al. [25] presented a hybrid optimization approach for a multi-channel, multi-product, multi-level distribution system. The goal of this article is to improve the flow of product transportation inside a multi-channel, multi-product, multi-level distribution network under uncertain conditions. A hybrid approach based on Benders Decomposition (BD) and Lagrangian Relaxation (LR) is designed to solve the given model. Five distinct scenarios with varying degrees of service are studied, and numerical results are reviewed in relation to earlier findings.

Identifying the distribution network enablers would improve the balanced capacity of all the memberships of a supply chain. The distribution network needs stakeholders' support, developing related regulations and policies, accurate planning, needs assessment, and providing resources and facilities. In a distribution network, sufficient human resources, facilities, and requirements, a product tracking information system, sufficient financial resources, and a proper management and leadership system are needed to provide on-time and high-quality services. The performance of a distribution network could be improved by using the suggested enablers.

The literature review indicates that many studies have briefly investigated the supply chain enablers, but a few of them considered the distribution network enablers. The fuzzy logic has become a convenient tool for prioritizing due to the necessity of the comprehensive view to the supply chain, the uncertain space of it, and inconsistency in the views of decision-makers. By analyzing the studies in this topic, a research gap can be identified in the field of not recognizing the distribution network enablers. Another study gap is not paying attention to the prioritization of enablers. However, in the real world, it is not possible to consider and apply all enablers owing to limits, and each enabler has a distinct preference, demonstrating the importance of prioritizing enablers and employing multi-criteria decision-making techniques.

Table 1. The research gap of the supply chain/distribution network enablers.

Researcher/ Researchers (Year)	Research Tools	Study Approach		Research Results		Studied Industry
		Fuzzy	Classic	Introducing Enablers	Presenting Model/Pattern	
Andalib Ardakani and Shams [7]	PLS	-	✓	✓	✓	GSM
Abedini et al. [9]	DEMATEL	-	✓	✓	-	Medicine
Ostadi et al. [8]	AHP	-	✓	✓	-	SCQM
Salehi Sedighiani et al. [10]	ISM	-	✓	✓	✓	Diary
Kumar et al. [11]	Fuzzy DEMATEL	✓	-	✓	-	CSC Industry 4.0
Gokarn and Choudhary [12]	ISM	-	✓	✓	✓	Food
Prasad et al. [13]	SEM	-	✓	✓	✓	Steel
Meyer and Torres [1]	Semi Structured Interviews	-	✓	✓	-	SCM
Behl et al. [14]	Grey DEMATEL	-	✓	✓	-	HSCM

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Table 1. Continued.

Researcher/ Researchers (Year)	Research Tools	Study Approach Fuzzy	Classic	Research Results Introducing Enablers	Presenting Model/Pattern	Studied Industry
Adabavazaeh and Nikbakht [15]	ISM	-	✓	✓	✓	Aerial
Aschemann-Witzel et al. [16]	Multiple Case Study	-	✓	✓	-	Food
Raut et al. [17]	ISM	-	✓	✓	✓	Oil and Gas
Coo [18]	PPML, Regression Analysis	-	✓	✓	-	SMEs
Kumar et al. [19]	Statistical Tools	-	✓	✓	-	SMEs
Nasiri el al. [20]	SWARA	-	✓	✓	-	Petrochemical
Gupta et al. [21]	BWM	-	✓	✓	-	
Della Valle and Oliver [22]		-	✓	✓	-	blockchain technology
Bamel and Bamel [23]	TISM	✓	-	✓	-	
Aazami and Saidi-Mehrabad [24]	BDA & GA	-	✓	-	✓	perishable products
Hendalianpour et al. [25]	BD-LR	-	✓	-	✓	supply chain distribution
This Study	Fuzzy BWM	✓		✓	✓	supply chain distribution

3 | Theoretical Basics

3.1 | Fuzzy Set

Assume $A_1 = l_1, m_1, u_1)$, $A_2 = l_2, m_2, u_2)$ are two triangular fuzzy numbers and $k > 0$ is a constant number. In this case, calculations on fuzzy numbers are as *Eqs. (1)-(5)* [26]:

$$\tilde{A}_1 + \tilde{A}_2 = l_1 + l_2, m_1 + m_2, u_1 + u_2). \tag{1}$$

$$\tilde{A}_1 - \tilde{A}_2 = l_1 - u_2, m_1 - m_2, u_1 - l_2). \tag{2}$$

$$\tilde{A}_1 \times \tilde{A}_2 = l_1 \times l_2, m_1 \times m_2, u_1 \times u_2). \tag{3}$$

$$kx\tilde{A}_1 = kxl_1, kxm_1, kxu_1), \quad k > 0). \tag{4}$$

$$\frac{\tilde{A}_1}{k} = \left(\frac{l_1}{k}, \frac{m_1}{k}, \frac{u_1}{k}\right), \quad k > 0. \tag{5}$$

In order to compare triangular fuzzy numbers, the Graded Mean Integration Representation (GMIR) is defined as follows.

$$R\left(\tilde{A}_1\right) = \frac{l_i + 4m_i + u_i}{6}. \tag{6}$$

3.2 | Fuzzy Best-Worst Method

The fuzzy BWM was developed by Guo and Zhao [27] for the first time. This method includes five main steps.

Step 1. In this step the decision-making criteria set, which is used to reach the goal decision, should be determined.

Step 2. In this step the decision-makers determine the best and worst criteria by considering the problem and the related views. The best criterion indicates the most suitable or important influencing criterion on the decision and the worst criterion has the minimum utility and importance for decision-making.

Step 3. In this step, pairwise comparisons are made between the best criterion and other criteria. The preference of the best criterion than other criteria is determined using 5-degrees triangular fuzzy numbers and the Best to Others (BO) matrix should be created according to the *Table 2*. This step aims to determine the preference and importance of the best criterion in comparison to other criteria.

Step 4. The pairwise comparison between the worst criterion and other criteria should be made. In this step the preference of other criteria than the worst criterion is determined using 5 degrees triangular fuzzy numbers and the Others to Worst (OW) matrix would be created according to the *Table 2*.

Table 2. Pairwise comparisons for triangular fuzzy numbers.

Spoken Variables	Membership Function
Equal Importance (EI)	(1,1,1)
Weak Importance (WI)	(2/3,1,1.5)
Fairly Important (FI)	(1.5,2,2.5)
Very Important (VI)	(2.5,3,3.5)
Absolutely Important (AI)	(3.5,4,4.5)

The BO and OW fuzzy vectors are defined according to *Eq. (7)*:

$$a_{Bj} = \left(l_{Bj}, m_{Bj}, u_{Bj}\right), a_{jW} = \left(l_{jW}, m_{jW}, u_{jW}\right),\ \widetilde{\omega}_B = l_B^{\omega}, m_B^{\omega}, u_B^{\omega}),\ \widetilde{\omega}_W = l_W^{\omega}, m_W^{\omega}, u_W^{\omega}). \quad (7)$$

Step 5. In this step, the optimal weight vector $w_1^*, \dots, w_n^*)$ would be determined. The optimal weight of the criteria is a weight that for each pair the statement comes true, all parameters of the model are defined as triangular fuzzy numbers:

$$
\begin{aligned}
&\text{Min}\,\xi^* \\
&\text{s.t.} \quad \left|\frac{(l_B^w,\ m_B^w,\ u_B^w)}{(l_j^w,\ m_j^w,\ u_j^w)} - (l_{Bj},\ m_{Bj},\ u_{Bj})\right| \le (k^*,\ k^*,\ k^*), \\
&\left|\frac{(l_j^w,\ m_j^w,\ u_j^w)}{(l_W^w,\ m_W^w,\ u_W^w)} - (l_{jw},\ m_{jw},\ u_{jw})\right| \le\ k^*,\ k^*,\ k^*), \\
&\textstyle\sum_j R(\widetilde{\omega}_j) = 1, \\
&l_j^w \le m_j^w \le u_j^w, \\
&l_j^w \ge 0, \qquad j = 1, \dots, n.
\end{aligned}
\quad (8)
$$

Using $\xi^* =\ k^*,\ k^*,\ k^*)$ as the compatibility ratio, the compatibility would increase by higher amount of ξ^* and comparisons would be more reliable.

4 | Methodology

This study is practical and descriptive-surveying research from goal and research methodology perspectives. The experts' group includes 11 experts in the welding and cutting industry. The enablers have been adopted and identified through an extensive study on "supply chain" and "distribution network" literature. The fuzzy BWM is used to prioritize the distribution network enablers. The fuzzy BWM is a modern method in multi-criteria decision-making that is a suitable alternative for pairwise comparison-based methods.

This method has specifications such as the reduced number of pairwise comparisons and higher reliability in the results [28].

The current study is divided into two parts. The appropriate enablers were retrieved in the first half through an in-depth review of the subject literature. The expertise of specialists was employed to screen and rank the enablers. The Lawshe questionnaire was used as a research tool in this step, and expert members were asked to rate the components' necessity and relevance. The Lawshe technique was used to confirm the questionnaire's content validity and reliability. The best-worst method was employed as one of the novel multi-indicator decision-making techniques in the final part of the research to weight the components. To create the questionnaire, the best and worst fuzzy criteria were selected first, followed by the most important and least important criteria. Experts then made pairwise comparisons of criteria. Lingo software was used to analyze the data of this part and solve the model.

5 | Results

Defining the evaluation criteria of distribution network enablers

The most important step is identifying the influencing criteria for selecting and prioritizing. The influencing criteria on a distribution network have been identified and extracted by reviewing similar studies and available data. In this step, the content validity analysis questionnaire has been given to experts to reduce the number of criteria. To reduce the uncertainty, the quantitative Lawshe method is used. The results of the data analysis are presented in *Table 3*.

Table 3. The distribution network enablers.

Features	Reference	CVR	Features	Reference	CVR
Trust	[29]-[31]	0.52	Speed and agility	[31], [50]-[55]	0.55
EN_1 responsibility	[32]	0.78	Planning	[30], [56]	0.58
Performance	[32]	0.48	Stakeholders' role	[57]-[59]	0.51
EN_2 flexibility	[32]-[37]	0.82	Employees' ability	[44]	0.55
EN_3 coordination	[32]	0.91	Fund	[34], [58]	0.55
EN_4 information flow	[32]	0.91	Innovation	[39], [43], [46], [60]-[62]	0.55
Motivation	[32]	0.55	Employees' sufficiency	[44]	0.52
Customers' services	[33]-[34], [38]-[43]	0.58	EN_7 logistic infrastructures	[45]	0.67
EN_5 inventory management	[44]	0.91	EN_8 on-time delivery	[45]	0.97
Customer satisfaction	[32], [46]-[47]	0.58	Commercial infrastructure quality	[45]	0.45
EN_6 transportation	[37], [48]-[49]	0.91	EN_9 product tracking	[45]	0.72
Quality management	[35], [44]	0.50	Coordinating with the policy of the organization	[44]	0.48

Considering 11 number of members in experts' group, the minimum acceptable Content Validity Ratio (CVR) is 0.59. According to the results, " responsibility", "supply chain flexibility", "supply chain coordination", "information flow", "inventory management", "transportation", "logistic infrastructures", "on-time delivery", and "product tracking" are the final criteria.

Determining the best and worst criteria for evaluating the distribution network enablers

The experts have identified "on-time delivery" as the best and "logistic infrastructures" as the worst criteria, regarding the vast specification of a distribution network.

Determining the preference of the best criterion in comparison to other criteria

In this step, the experts have evaluated the preference of the best criterion in comparison to other criteria using a 5-degree fuzzy spectrum. *Table 4* shows the resulting BO matrix based on experts' ideas. To create the matrix, it is needed to calculate the mean of preference number of the best criterion in comparison to other criteria. Vector a_B indicates the preference of the best criterion B than the criterion j.

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Table 4. Pairwise comparisons between the best criterion and other criteria.

EN_1	EN_2	EN_3	EN_4	EN_5	EN_6	EN_7	EN_8	EN_9	$\tilde{a}_B$	EN9
(2/3,1,1.5)	(2/3,1,1.5)	(2/3,1,1.5)	(2/3,1,1.5)	(1.5,2,2.5)	(2/3,1,1.5)	(3.5,4,4.5)	(2/3,1,1.5)	(2/3,1,1.5)		

Determining the preference of the other criteria in comparison to the worst criterion

The experts determine the preference of the other criteria in comparison to the worst criterion. The OW matrix is presented in *Table 5* based on experts' ideas. To create the OW matrix, it is needed to calculate the mean of preference number of the other criteria in comparison to the worst criterion. Vector a_W indicates the preference of the criteria than the worst criterion$W$.

Table 5. Pairwise comparisons between other criteria and the worst criterion.

	EN7
EN_1	(3.5,4,4.5)
EN_2	(3.5,4,4.5)
EN_3	(3.5,4,4.5)
EN_4	(3.5,4,4.5)
EN_5	(3.5,4,4.5)
EN_6	(3.5,4,4.5)
EN_7	(1,1,1)
EN_8	(3.5,4,4.5)
EN_9	(2.5,3,3.5)

Calculating the optimal criteria weight

A linear programming *Model (8)* is presented based on BO and OW vectors:

$$
\begin{aligned}
&\text{Min } \xi\\
&\left|\frac{(l_8^w,\ m_8^w,\ u_8^w)}{(l_1^w,\ m_1^w,\ u_1^w)}-(l_{81},\ m_{81},\ u_{81})\right| \le\ k^*,\ k^*,\ k^*),\\
&\left|\frac{(l_8^w,\ m_8^w,\ u_8^w)}{(l_2^w,\ m_2^w,\ u_2^w)}-(l_{82},\ m_{82},\ u_{82})\right| \le (k^*,\ k^*,\ k^*),\\
&\left|\frac{(l_8^w,\ m_8^w,\ u_8^w)}{(l_3^w,\ m_3^w,\ u_3^w)}-(l_{83},\ m_{83},\ u_{83})\right| \le\ k^*,\ k^*,\ k^*),\\
&\left|\frac{(l_8^w,\ m_8^w,\ u_8^w)}{(l_4^w,\ m_4^w,\ u_4^w)}-(l_{84},\ m_{84},\ u_{84})\right| \le\ k^*,\ k^*,\ k^*),\\
&\left|\frac{(l_8^w,\ m_8^w,\ u_8^w)}{(l_5^w,\ m_5^w,\ u_5^w)}-(l_{85},\ m_{85},\ u_{85})\right| \le (k^*,\ k^*,\ k^*),\\
&\left|\frac{(l_8^w,\ m_8^w,\ u_8^w)}{(l_6^w,\ m_6^w,\ u_6^w)}-(l_{86},\ m_{86},\ u_{86})\right| \le (k^*,\ k^*,\ k^*),\\
&\left|\frac{(l_8^w,\ m_8^w,\ u_8^w)}{(l_7^w,\ m_7^w,\ u_7^w)}-(l_{87},\ m_{87},\ u_{87})\right| \le (k^*,\ k^*,\ k^*),\\
&\left|\frac{(l_8^w,\ m_8^w,\ u_8^w)}{(l_8^w,\ m_8^w,\ u_8^w)}-(l_{88},\ m_{88},\ u_{88})\right| \le (k^*,\ k^*,\ k^*),\\
&\left|\frac{(l_8^w,\ m_8^w,\ u_8^w)}{(l_9^w,\ m_9^w,\ u_9^w)}-(l_{89},\ m_{89},\ u_{89})\right| \le (k^*,\ k^*,\ k^*),\\
&\left|\frac{(l_{f1}^w,\ m_1^w,\ u_1^w)}{(l_7^w,\ m_7^w,\ u_{f7}^w)}-(l_{17},\ m_{17},\ u_{17})\right| \le\ k^*,\ k^*,\ k^*),\\
&\left|\frac{l_2^w,\ m_2^w,\ u_2^w)}{(l_7^w,\ m_7^w,\ u_7^w)}-\ l_{27},\ m_{27},\ u_{27})\right| \le\ k^*,\ k^*,\ k^*),\\
&\left|\frac{(l_4^w,\ m_4^w,\ u_4^w)}{(l_7^w,\ m_7^w,\ u_7^w)}-(l_{47},\ m_{47},\ u_{47})\right| \le\ k^*,\ k^*,\ k^*),
\end{aligned}
\tag{9}
$$

$$\left|\frac{l_5^w,\ m_5^w,\ u_5^w)}{(l_7^w,\ m_7^w,\ u_7^w)} - l_{57},\ m_{57},\ u_{57})\right| \leq k^*,\ k^*,\ k^*),$$
$$\left|\frac{(l_6^w,\ m_6^w,\ u_6^w)}{(l_7^w,\ m_7^w,\ u_7^w)} - (l_{67},\ m_{67},\ u_{67})\right| \leq k^*,\ k^*,\ k^*),$$
$$\left|\frac{(l_7^w,\ m_7^w,\ u_7^w)}{(l_7^w,\ m_7^w,\ u_7^w)} - (l_{77},\ m_{77},\ u_{77})\right| \leq k^*,\ k^*,\ k^*),$$
$$\left|\frac{(l_8^w,\ m_8^w,\ u_8^w)}{(l_7^w,\ m_7^w,\ u_7^w)} - (l_{87},\ m_{87},\ u_{87})\right| \leq k^*,\ k^*,\ k^*),$$
$$\left|\frac{(l_9^w,\ m_9^w,\ u_9^w)}{(l_7^w,\ m_7^w,\ u_7^w)} - (l_{97},\ m_{97},\ u_{97})\right| \leq k^*,\ k^*,\ k^*),$$
$$\textstyle\sum_{j=1}^{9} R(\widetilde{\omega}_j) = 1,$$
$$l_{fj}^w \leq m_{fj}^w \leq u_{fj}^w, \qquad l_{fj}^w \geq 0,\ \ j = 1, \dots, 9.$$

$\xi^* = (l^\xi, m^\xi, u^\xi)$ and $R(\omega_j^{\sim})$ indicate the defuzzied of $\omega_j^{\sim}$ which could be determined according to *Eq. (6)*. The optimal fuzzy weight could be calculated by using the presented mathematical model by Guo and Zhao [27]. By applying fuzzy comparisons in mathematical *Model (8)*, the mathematical *Model (9)* would be developed:

$$\begin{aligned}
&\text{Min } k^* \\
&l_8 - 2/3 \times u_1 - u_1 \times k \leq 0,\ l_8 - 2/3 \times u_1 + u_1 \times k \geq 0,\ m_8 - 1 \times m_1 - m_1 \times k \leq 0,\\
&m_8 - 1 \times m_1 + m_1 \times k \geq 0,\ u_8 - 1.5 \times l_1 - l_1 \times k \leq 0,\ u_8 - 1.5 \times l_1 + l_1 \times k \geq 0,\\
&l_8 - 2/3 \times u_2 - u_2 \times k \leq 0,\ l_8 - 2/3 \times u_2 + u_2 \times k \geq 0,\ m_8 - 1 \times m_2 - m_2 \times k \leq 0,\\
&m_8 - 1 \times m_2 + m_2 \times e \geq 0,\ u_8 - 1.5 \times l_2 - l_2 \times k \leq 0,\ u_8 - 1.5 \times l_2 + l_2 \times k \geq 0,\\
&l_8 - 2/3 \times u_3 - u_3 \times e \leq 0,\ l_8 - 2/3 \times u_3 + u_3 \times k \geq 0,\ m_8 - 1 \times m_3 - m_3 \times k \leq 0,\\
&m_8 - 1 \times m_3 + m_3 \times k \geq 0,\ u_8 - 1.5 \times l_3 - l_3 \times k \leq 0,\ u_8 - 1.5 \times l_3 + l_3 \times k \geq 0,\\
&l_8 - 2/3 \times u_4 - u_4 \times k \leq 0,\ l_8 - 2/3 \times u_4 + u_4 \times k \geq 0,\ m_8 - 1 \times m_4 - m_4 \times k \leq 0,\\
&m_8 - 1 \times m_4 + m_4 \times k \geq 0,\ u_8 - 1.5 \times l_4 - l_4 \times k \leq 0,\ u_8 - 1.5 \times l_4 + l_4 \times k \geq 0,\\
&l_8 - 1.5 \times u_5 - u_5 \times k \leq 0,\ l_8 - 1.5 \times u_5 + u_5 \times k \geq 0,\ m_8 - 2 \times m_5 - m_5 \times k \leq 0, \qquad (9)\\
&m_8 - 2 \times m_5 + m_5 \times k \geq 0,\ u_8 - 2.5 \times l_5 - l_5 \times k \leq 0,\ u_8 - 2.5 \times l_5 + l_5 \times k \geq 0,\\
&l_8 - 2/3 \times u_6 - u_6 \times k \leq 0,\ l_8 - 2/3 \times u_6 + u_6 \times k \geq 0,\ m_8 - 1 \times m_6 - m_6 \times k \leq 0,\\
&m_8 - 1 \times m_6 + m_6 \times k \geq 0,\ u_8 - 1.5 \times l_6 - l_6 \times k \leq 0,\ u_8 - 1.5 \times l_6 + l_6 \times k \geq 0,\\
&l_8 - 3.5 \times u_7 - u_7 \times k \leq 0,\ l_8 - 3.5 \times u_7 + u_7 \times k \geq 0,\ m_8 - 4 \times m_7 - m_7 \times k \leq 0,\\
&m_8 - 4 \times m_7 + m_7 \times k \geq 0,\ u_8 - 4.5 \times l_7 - l_7 \times k \leq 0,\ u_8 - 4.5 \times l_7 + l_7 \times k \geq 0,\\
&l_8 - 2/3 \times u_9 - u_9 \times k \leq 0,\ l_8 - 2/3 \times u_9 + u_9 \times k \geq 0,\ m_8 - 1 \times m_9 - m_9 \times k \leq 0,\\
&m_8 - 1 \times m_9 + m_9 \times k \geq 0,\ u_8 - 1.5 \times l_9 - l_9 \times k \leq 0,\ u_8 - 1.5 \times l_9 + l_9 \times k \geq 0,\\
&l_1 - 3.5 \times u_7 - u_7 \times k \leq 0,\ l_1 - 3.5 \times u_7 + u_7 \times k \geq 0,\ m_1 - 4 \times m_7 - m_7 \times k \leq 0,\\
&m_1 - 4 \times m_7 + m_7 \times k \geq 0,\ u_1 - 4.5 \times l_7 - l_7 \times k \leq 0,\ u_1 - 4.5 \times l_7 + l_7 \times k \geq 0,\\
&l_2 - 3.5 \times u_7 - u_7 \times k \leq 0,\ l_2 - 3.5 \times u_7 + u_7 \times k \geq 0,\ m_2 - 4 \times m_7 - m_7 \times k \leq 0,\\
&m_2 - 4 \times m_7 + m_7 \times k \geq 0,\ u_2 - 4.5 \times l_7 - l_7 \times k \leq 0,\ u_2 - 4.5 \times l_7 + l_7 \times k \geq 0,\\
&l_3 - 3.5 \times u_7 - u_7 \times k \leq 0,\ l_3 - 3.5 \times u_7 + u_7 \times k \geq 0,\ m_3 - 4 \times m_7 - m_7 \times k \leq 0,\\
&m_3 - 4 \times m_7 + m_7 \times k \geq 0,\ u_3 - 4.5 \times l_7 - l_7 \times k \leq 0,\ u_3 - 4.5 \times l_7 + l_7 \times k \geq 0,\\
&l_4 - 3.5 \times u_7 - u_7 \times k \leq 0,\ l_4 - 3.5 \times u_7 + u_7 \times k \geq 0,\ m_4 - 4 \times m_7 - m_7 \times k \leq 0,\\
&m_4 - 4 \times m_7 + m_7 \times k \geq 0,\ u_4 - 4.5 \times l_7 - l_7 \times k \leq 0,\ u_4 - 4.5 \times l_7 + l_7 \times k \geq 0,\\
&l_5 - 3.5 \times u_7 - u_7 \times k \leq 0,\ l_5 - 3.5 \times u_7 + u_7 \times k \geq 0,\ m_5 - 4 \times m_7 - m_7 \times k \leq 0,
\end{aligned}$$

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$m_5 - 4 \times m_7 + m_7 \times k \geq 0,\ u_5 - 4.5 \times l_7 - l_7 \times k \leq 0,\ u_5 - 45 \times l_7 + l_7 \times k \geq 0,$
$l_6 - 3.5 \times u_7 - u_7 \times k \leq 0,\ l_6 - 3.5 \times u_7 + u_7 \times k \geq 0,\ m_6 - 4 \times m_7 - m_7 \times k \leq 0,$
$m_6 - 4 \times m_7 + m_7 \times k \geq 0,\ u_6 - 4.5 \times l_7 - l_7 \times k \leq 0,\ u_6 - 4.5 \times l_7 + l_7 \times k \geq 0,$
$l_9 - 2.5 \times u_7 - u_7 \times k \leq 0,\ l_9 - 2.5 \times u_7 + u_7 \times k \geq 0,\ m_9 - 3 \times m_7 - m_7 \times k \leq 0,$
$m_9 - 3 \times m_7 + m_7 \times k \geq 0,\ u_9 - 3.5 \times l_7 - l_7 \times k \leq 0,\ u_9 - 3.5 \times l_7 + l_7 \times k \geq 0,$
$l_1 \leq m_1 \leq u_1,$
$l_2 \leq m_2 \leq u_2,\ l_3 \leq m_3 \leq u_3,\ l_4 \leq m_4 \leq u_4,\ l_5 \leq m_5 \leq u_5,\ l_6 \leq m_6 \leq u_6, l_7 \leq m_7 \leq u_7,$
$l_8 \leq m_8 \leq u_8,\ l_9 \leq m_9 \leq u_9,$

$\frac{1}{6} \times (l_1 + 4 \times m_1 + u_1) + 1/6 \times (l_2 + 4 \times m_2 + u_2) + 1/6 \times (l_3 + 4 \times m_3 + u_3) +$

$\frac{1}{6} \times (l_{f4} + 4 \times m_{f4} + u_{f4}) + \frac{1}{6} \times\ l_{f5} + 4 \times m_{f5} + u_{f5}) + 1/6 \times (l_{f6} + 4 \times m_{f6} + u_{f6}) +$

$1/6 \times (l_{f7} + 4 \times m_{f7} + u_{f7}) + \frac{1}{6} \times\ l_{f8} + 4 \times m_{f8} + u_{f8}) + \frac{1}{6} \times\ l_{f9} + 4 \times m_{f9} + u_{f9}) = 1,$

$l_1 \geq 0, l_2 \geq 0,\ l_3 \geq 0, l_4 \geq 0l,\ l_5 \geq 0, l_6 \geq 0l, l_7 \geq 0, l_8 \geq 0l,\ l_9 \geq 0,\ k \geq 0.$

Table 6. The optimal weights of criteria for evaluating the distribution network enablers based on fuzzy BWM.

Enablers	Wj*
EN_1 responsibility	ω*1 =(0.09045471, 0.1064450, 0.1224353) = 0.106445003
EN_2 flexibility	ω*2 =(0.09045471, 0.1064450, 0.1224353) = 0.106445003
EN_3 coordination	ω*3 =(0.09045471. 0.1064450, 0.1224353)= 0.106445003
EN_4 information flow	ω*4 =(0.09045471, 0.1064450, 0.1224353) = 0.106445003
EN_5 inventory management	ω*5 =(0.09045471, 0.1064450, 0.1224353) = 0.1117751
EN_6 transportation	ω*6 =(0.09045471. 0.1064450, 0.1224353)= 0.106445003
EN_7 logistic infrastructures	ω*7 =(0.03198057, 0.03198057, 0.03198057) = 0.03198057
EN_8 on-time delivery	ω*8 =(0.1014287, 0.1414044, 0.1653898) = 0.1360743
EN_9 product tracking	ω*9 =(0.07616132, 0.08459363, 0.09045471) = 0.083736553
ξ*= (0.6715729, 0.6715729, 0.6715729), CI=8.0, CR= 0.6715729/8.04= 0.08352897	

Computing the compatibility ratio is an important criterion to check the compatibility of pairwise comparisons in fuzzy BWM. Regarding to the a_{BW} = (3.5,4,4.5) interval, the compatibility ratio has been calculated equal to 0.084 which indicate a high compatibility in comparisons. The results of prioritizing of criteria by experts is presented in *Table 6* and *Fig. 1*. The most important identified enablers in a distribution network are "on-time delivery", "inventory management", "transportation", "information flow", "coordination", "flexibility", "responsibility", product tracking", and "logistic infrastructure", respectively.

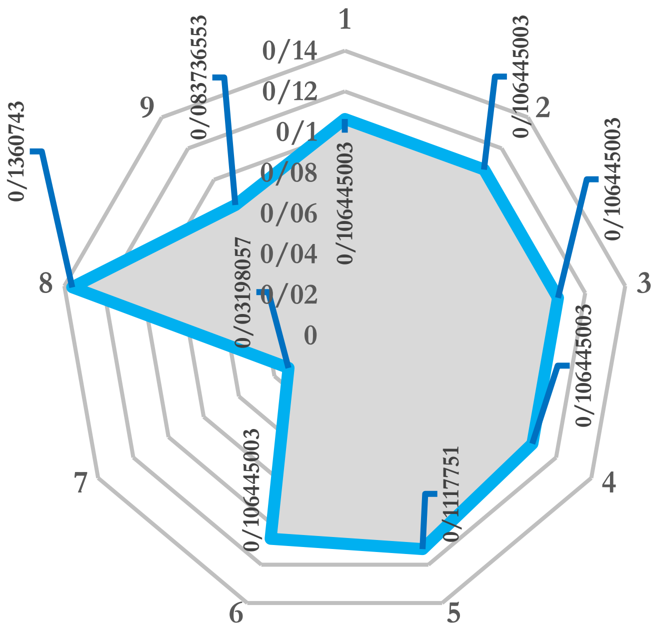

Fig. 1. The Radar (spider) chart of prioritizing of the distribution network enablers.

Fig. 1 shows how distribution network enablers are prioritized. Each axis in the diagram represents an enabler whose priority has been determined by experts. As can be observed, the highest priority is associated with the eighth enabler, while the lowest priority is associated with the seventh enabler. The total priority can be determined based on the area filled by each enabler.

6 | Discussion

The current study investigated the significance of effective distribution network enablers. A broad study of the research literature yielded nine enablers. The enablers were then weighted and prioritized using the fuzzy BWM approach. The BWM method's findings also show that "on-time delivery" is the most important factor in the distribution network. In Iran, the aspect of "transport infrastructure facilities" is less important.

According to the analysis, the optimum option in the distribution network is "on-time delivery," which weights 0.1360743. Compliance with customer-oriented needs is the primary condition of stability in today's non-monopoly and competitive market. Customers will be dissatisfied, and additional expenditures will be incurred if products are not delivered on time. As a result, project delays and proposing ways to resolve them are regarded as major issues in enterprises.

The second option is inventory management, which weights 0.1117751. Increasing attention to customer requests in the product manufacturing process and the characteristics and unavoidable expenses of manufacturing processes has driven researchers and artisans to manage orders and select the best inventory management policy. One of the most significant strategic decisions in the manufacturing process is the optimal inventory management policy.

The third solution, with a weight of 0.106445003, is the enablers of "responsiveness, flexibility, coordination, information flow, and transportation". SCM is one way to respond to long-term relationships. Because of the changing competitive environment, organizations are turning to lean and agile supply chain concepts to increase efficiency and responsiveness. The rapid changes and dynamics of the environment, changes in how companies interact with suppliers and customers, the complexity of markets, the shortening of product life cycles, and the importance of finding the time to respond to customers have doubled the importance of supply chain flexibility as a critical factor for an organization's competitiveness. As a result, flexibility has become one of the most useful and necessary tools in today's competitive and uncertain environments. Many studies in the last decade have focused on supply chain coordination to align the policies of chain members and use the maximum possible profit for the supply chain. Various mechanisms can be used to achieve coordination, with contracts being one of the most important. The information flow in the supply chain, along with the flow of goods and the flow of finance, are the main arteries of a supply chain, and the information flow is especially important in the meantime because it provides a suitable platform for creating a uniform flow of goods and financial exchanges. As a result, one of the most important aspects of efficient SCM is properly controlling information flow. The goal of the transportation network is to meet customer demands at the minimum cost, which necessitates an integrated approach in the fields of supply chain planning, distribution management, and product production planning based on capacity constraints considering various transportation parameters.

The fourth option is the "goods tracking" enabler, which weights 0.083736553. Today, blockchain technology is a new and growing technology that offers product transparency, traceability, and data security.

Finally, transportation infrastructure is known as a last-place option based on the country's situation. Building necessary facilities to support the national economy has received special attention. The availability of sufficient infrastructure, the establishment of limited and enclosed specialized functions, and the removal of the hurdles these regions are now encountering are prerequisites for the successful operation of these areas. The efficient utilization of transportation infrastructure facilities will surely expand the transportation industry and the country's economic development.

7 | Conclusions

The distribution network is influenced by many enablers, considering its importance and its activities at local, national, and international levels. Therefore, the distribution network should be properly planned and coordinated such that servicing to customers would not stop. The distribution network which is able to provide optimal services would gain a rapid growth in demand. Thus, the required facilities for providing services in a distribution network should be established. Managers and staff of a distribution network should be trained to provide services to final customers.

This research was carried out by using the fuzzy BWM to prioritize the distribution network enablers. The results indicate that the most important enablers in a distribution network are "on-time delivery", "inventory management", "transportation", "information flow", "coordination", "flexibility", "responsibility", product tracking", and "logistic infrastructure", respectively.

According to the results, the most important factor is "on-time delivery", so it is suggested that industry owners improve the process of "on-time delivery" as much as possible. The results of this study are correspondent to the results of the other studies in introducing the strategic requirement of organizations in "on-time delivery" as a competitive priority.

Determining optimal inventory policies has always been a challenge in inventory management. Nowadays, traditional inventory management has been replaced by "production management", "distribution" and "inventory" as the SCM system. Deploying mathematical tools in modeling and controlling the inventory management problem would be so useful.

The transportation section is one of the infrastructural sections of all countries, which its activities influence the economic development process of a country. As a result, the conditions of this factor and succeeding in that are important criteria of the development level and are determining factors in changing process of a distribution network.

Organizations should try to integrate their processes by adopting and implementing information systems technologies. The distribution network must manage the whole network from supplier to end customer to achieve the best output of the system. The goal is to communicate mutually between products and information of different memberships of the supply chain by doing managerial and operational activities.

Cooperation between the flexibility processes in a supply chain has an impact on agility and production flexibility is an important reference for chain agility. Flexibility does not directly guarantee cost productivity. But flexible production and agility through product variety management strategy influence significantly customers services.

Network responsibility influences the performance of a network. Responsibility and efficiency are the two main aspects of customers' expectations. Thus, determining the required responsibility level for the supply chain to design its suitable supply chain, is very useful. The results of this approach could be a reliable platform to develop the supply chain strategies in different fields such as inventory, transportation, locating, and information flow.

The supply chain can operate in an integrated way, if coordinated and accurate information of product status is in reach for all partners of the chain and every partner can receive this information and track their product whenever he needs.

The increase in transportation demand would bring difficulties in the transportation network. Focusing on the role of physical infrastructures in reducing transportation problems, supply chain security and proper responding are very important.

Also, the following suggestions are given for future studies:

I. The proposed enablers are theoretical. It is recommended to evaluate the distribution network through a case study and present appropriate approaches.
II. The mutual effects of the recognized enablers on each other have not been studied; therefore, it is recommended to study the mutual effect of the recognized enablers in future studies.
III. The development of distribution network enablers helps the efficiency and performance of the distribution network.
IV. For future studies, it is suggested to investigate other enablers in different industries by using different modern fuzzy methods and compare the results with this study.

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