Int. J. Res. Ind. Eng. Vol. 8, No. 3 (2019) 225–242

International Journal of Research in Industrial Engineering

www.riejournal.com

Optimizing Supermarket Supply Chain using fuzzy AHP: A Study on Save 'n' Safe in Bangladesh

Azad Abbasi

Department of Industrial Engineering, Tehran University, Tehran, Iran.

A B S T R A C T

In today's business landscape, the concept of the supply chain has gained significant prominence. An efficient supply chain is essential for guiding a business in an organized manner. This importance extends to supermarkets, where effective supply chain management necessitates improved communication with suppliers, customers, and internal management. Each facet of the supply chain plays a pivotal role in its own right. This study aims to investigate the crucial factors within the supermarket supply chain, drawing insights from existing literature and input from supply chain experts. The objective is to construct a framework that prioritizes these factors, considering each facet of the supply chain and arranging them from most to least critical. This research focuses on the analysis of a specific supermarket in Bangladesh, namely Save 'n' Safe, utilizing the FAHP methodology, a Multi-Criteria Decision-Making (MCDM) tool, to identify the most influential factors. The findings highlight that inventory management, internal information sharing, and accurate demand forecasting are the key determinants for Save 'n' Safe, a supermarket. Furthermore, the paper offers recommendations to enhance the current supply chain situation. The implications of this study extend not only to other supermarkets but also to various retail and grocery stores.

Keywords: Supply Chain, Fuzzy AHP, Supermarket, Decision-making.

Article history: *Received: 23 May 2019* *Revised: 07 July 2019* *Accepted: 19 September 2019*

1. Introduction

A supermarket serves as a comprehensive marketplace offering a wide range of daily necessities, including food and household items. In 1930, Michael Cullen pioneered the first supermarket in the United States [1]. In Bangladesh, private organizations introduced retail chain stores with a focus on the global retail concept, marking the launch of the first Bangladeshi supermarket, "Agora," by Rahimafrooz Superstores Ltd. (RSL) in 2001 [2]. This innovative retail format has been rapidly transforming the urban lifestyle and is steadily gaining popularity. As a result, the supermarket landscape in Bangladesh has expanded significantly, intensifying competition and making it increasingly challenging to achieve higher profits. Numerous variables directly and indirectly influence profitability, many of which are intricately linked to the supermarket's supply chain. Furthermore, given market dynamics and heightened competition, supply chain performance has emerged as a critical driver for supermarket development. As a means of survival, the industry is increasingly emphasizing the importance of supply chain management.

The supply chain of an organization can be briefly defined as the network of entities involved in the flow of products, services, finances, and information, both upstream and downstream, from source to customer [3]. The supermarket's supply chain is particularly intricate, extending from suppliers to a diverse customer base. Supermarkets stock a wide variety of products to cater to customers from different demographic segments, making the management of this interconnected supply chain highly complex. Effective supply chain performance is pivotal in ensuring the supermarket's profitability.

"Safe 'n' Save" is a well-regarded supermarket located in Khulna, Bangladesh. They procure goods from both local and external suppliers, store them, and sell them directly to customers. The authors have conducted a study aimed at enhancing the efficiency of their supply chain. Various factors influencing the supermarket's supply chain have been identified, and performance evaluation methods have been employed. This paper employs the F-AHP Buckley method to rank these factors.

The Fuzzy Analytic Hierarchy Process (F-AHP) combines fuzzy theory and the Analytic Hierarchy Process (AHP) and is well-suited for decision-making. Guo Yuexian et al. [4] demonstrated the suitability of the FAHP model for evaluating supermarket service quality.

2. Literature Review

Supply chain management is recognized as a strategic business approach that has evolved from its early focus on optimizing an organization's internal processes. Lambert and Cooper [5] articulated that the overall performance of the supply chain is the result of a collaborative effort among integrated organizations within the supply chain management process. Mehmeti et al. [6] conducted a review of research papers, highlighting factors that directly or indirectly impact supply chain performance. They underscored the notion that supply chain performance is an aggregate outcome of each company within the chain, emphasizing the significance of the relationships among these entities. Nandi et al. [7] delved into the dynamics of smallholder farmers supplying fruits and vegetables to supermarkets, examining factors through the lens of transaction costs. Abunar et al. [8] presented a conceptual framework for the supermarket supply chain, aimed at assisting researchers in navigating the existing supply chain landscape. Abunar SM and Zerban AM [9] facilitated supply chain management between supermarkets by integrating information systems and technology. The application of information systems and technology holds a prominent role in enhancing the supply chain by fostering improved interactions among stakeholders, suppliers, and customers. Gunasekaran et al. [10] enhanced supply chain performance through proficient management capabilities. Their analysis considered factors such as supplier development capabilities, market understanding capabilities, information systems capability, and skills/talent management capabilities. Gupta and Abidi [11] explored the factors affecting the supply chain of IT products, categorizing them into two segments: Retailer-Supplier Relationship and Retailer-Customer Relationship. For the retailer-supplier relationship, they identified factors like strategic partnership, information sharing, and technology usage, while for retailer-customer relationship, factors included customer orientation, customer service, and innovation. Their study ultimately identified latent influences associated with both retailer-supplier and retailer-customer relationships.

Furthermore, [12] introduced an effective tool, AHP, for addressing complex decision-making challenges. Van Laarhoven and Pedrycz [13] proposed the initial solution involving fuzzy AHP, incorporating triangular fuzzy numbers and the Logarithmic Least Squares Method (LLSM) to derive priority vectors (fuzzy weights). Buckley [14] delved into fuzzy set theory and employed trapezoidal fuzzy numbers to express pairwise comparison values.

Meng [15] applied FAHP to evaluate service quality in rural supermarkets. He used AHP to establish weights and then employed multi-level fuzzy AHP to assess rural supermarket service quality. The results indicated that rural supermarkets received favorable ratings in terms of tangibles, with a comfortable shopping environment receiving a grade of 3.512, abundant commodities earning 3.562, and payments receiving a notably high grade of 4.072. The study concluded by recommending enhancements to the service image, increased employee knowledge, and heightened employee awareness of service. Gopalan [16] employed a fuzzy AHP approach to evaluate the service quality of retail services. Their research aimed to integrate fuzzy logic with the AHP approach to aid retailers in assessing and prioritizing service quality dimensions. The identified dimensions for judging service quality included personal interaction, physical aspects, reliability, and policies. The authors of this paper have applied FAHP to identify and analyze factors affecting the supermarket supply chain and have endeavored to propose potential mitigation strategies for the most critical factors.

3. Problem Statement

The supply chain functions as an essential management network without which a business cannot operate effectively. It operates as an interconnected system, where issues that arise in any part of the chain can significantly impact the entire supply chain, leading to overall inefficiency.

Safe 'n' Save, a well-established supermarket in Khulna, Bangladesh, has been serving the community for over 15 years. However, in recent times, the supermarket business has grown highly competitive in this area. Prices, product quality, and other critical factors are relatively consistent across various supermarkets. In this context, when most aspects remain constant, the supply chain becomes a key differentiator. The question arises: Can the enhancement of a supermarket's supply chain potentially lead to improved business strategy outcomes? If so, which aspects of the supply chain should be focused on for the betterment of the business strategy? This paper addresses these questions through a case study conducted at Safe 'n' Save supermarket.

4. Research Methodology

In this study, the researchers have investigated a renowned supermarket in Bangladesh. To commence the research, they first identified issues related to the supermarket through a comprehensive review of existing literature and direct observations of the store. Subsequently, they embarked on a case study aimed at enhancing the supermarket's supply chain. Data collection occurred in two distinct stages, utilizing two different approaches. The initial stage involved interviews and surveys to gain insights into the current state of the supply chain and identify opportunities for improvement. In the subsequent stage, the researchers conducted direct interviews and surveys, meticulously filtering and preparing the gathered data for final analysis. The authors employed the FAHP technique to make informed decisions about which aspects and factors should be developed to enhance the overall supply chain. As a result of their analysis, the authors present a set of recommendations. The flowchart provided in ***Figure 1*** serves as a clear visual representation of the methodology employed in this paper.

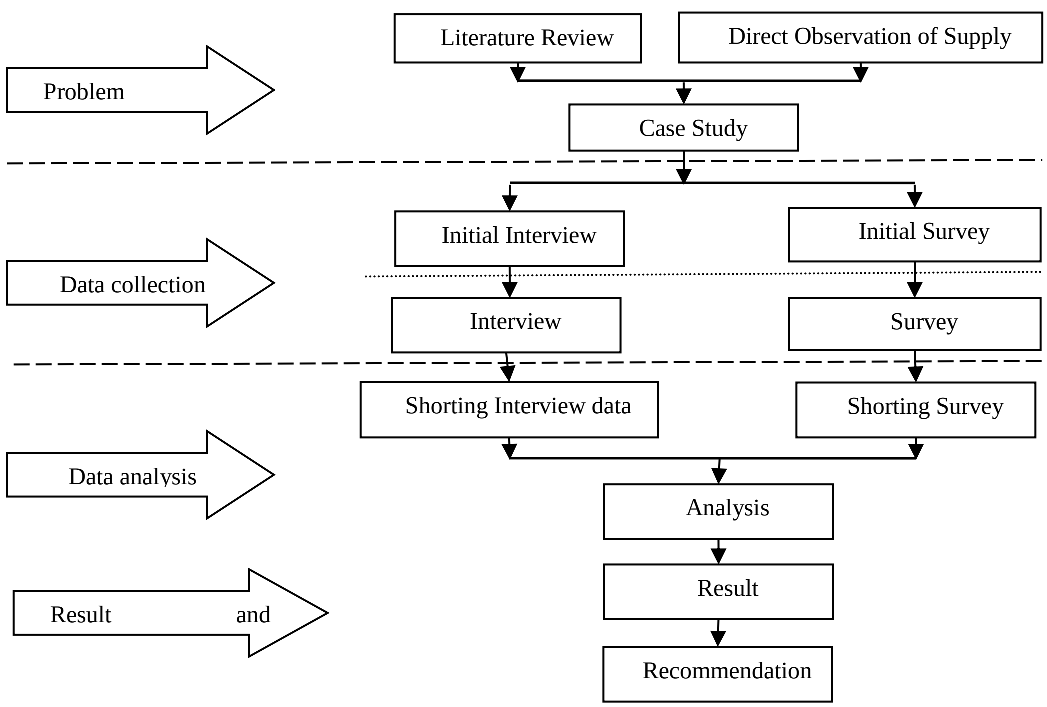

Figure 1. Methodology.

5. Fuzzy Analytic Hierarchy Process (F-AHP)

AHP, standing for Analytic Hierarchy Process, is a multi-criteria decision-making tool that primarily facilitates the comparison of different alternatives concerning various criteria. The analysis process is conducted in four distinct levels. The incorporation of a fuzzy logic approach has enhanced the decision-making capabilities of AHP, particularly in addressing ambiguity in personal judgments. Buckley [14] introduced the FAHP method, enabling decision makers to use fuzzy ratios in lieu of exact ratios. During this process, pairwise comparisons and criteria yield fuzzy positive reciprocal matrices. The final fuzzy weights for the alternatives are determined using the geometric mean method. The highest-ranking encompasses all the undominated elements, while the lowest-ranking includes all the dominated factors [14]. This method is employed to establish the relative importance weights for both criteria and alternatives, and the steps involved in the procedure are as follows:

Step 1. The decision maker compares the criteria or alternatives via linguistic terms shown in ***Table 1***.

Table 1. Linguistic terms and the corresponding triangular fuzzy numbers.

Saaty Scale	Definition	Fuzzy Triangular Scale
1	Equally important (Eq. Imp.)	(1, 1, 1)
3	Weakly important (W. Imp.)	(2, 3, 4)
5	Fairly important (F. Imp.)	(4, 5, 6)
7	Strongly important (S. Imp.)	(6, 7, 8)
9	Absolutely important (A. Imp.)	(9, 9, 9)
2		(1, 2, 3)
4	The intermittent values between	(3, 4, 5)
6	Two adjacent scales	(5, 6, 7)
8		(7, 8, 9)

According to the corresponding triangular fuzzy numbers of these linguistic terms, for example, if the decision maker states, "Criterion 1 (C1) is Weakly Important than Criterion 2 (C2)", then it takes the fuzzy triangular scale as (2, 3, 4). On the contrary, in the pairwise contribution matrix of the criteria, the comparison of C2 to C1 will take the fuzzy triangular scale as (1/4, 1/3, 1/2).

$$\tilde{A}^k = \begin{bmatrix} \tilde{d}_{11}^k & \tilde{d}_{12}^k & \cdots & \tilde{d}_{1n}^k \\ \tilde{d}_{21}^k & \tilde{d}_{22}^k & \cdots & \tilde{d}_{2n}^k \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{d}_{n1}^k & \tilde{d}_{n2}^k & \cdots & \tilde{d}_{nn}^k \end{bmatrix}. \qquad \textbf{(1)}$$

The pairwise contribution matrix is shown in ***Eq. (1)***, where $\tilde{d}_{ij}^k$ indicates the kth decision maker's preference of the ith criterion over the jth criterion via fuzzy triangular numbers. Here, "tilde" represents the triangular number demonstration and, for the example case, $\tilde{d}_{12}^1$ represents the first decision maker's preference of the first criterion over the second criterion, and equals to $\tilde{d}_{12}^{1}$ = (2, 3, 4).

Step 2. If there is more than one decision maker, the preferences of each decision maker ($\tilde{d}_{ij}^{k}$) are averaged, and ($\tilde{d}_{ij}$) is calculated as in ***Eq. (2)***.

$$\tilde{d}_{ij} = \frac{\sum_{k=1}^{k} \tilde{d}_{ij}^{k}}{k}. \qquad (2)$$

Step 3. According to averaged preferences, the pairwise contribution matrix is updated as shown in ***Eq. (3)***.

$$\tilde{A} = \begin{bmatrix} \tilde{d}_{11} & \tilde{d}_{12} & \cdots & \tilde{d}_{1n} \\ \tilde{d}_{21} & \tilde{d}_{22} & \cdots & \tilde{d}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{d}_{n1} & \tilde{d}_{n2} & \cdots & \tilde{d}_{nn} \end{bmatrix} \qquad (3)$$

Step 4. According to Buckley [14], the geometric mean of fuzzy comparison values of each criterion is calculated as shown in ***Eq. (4)***. Here, $\tilde{r}_i$ still represents triangular values.

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{d}_{ij} \right)^{\frac{1}{n}}, \quad i = 1, 2, 3, \ldots, n. \qquad (4)$$

Step 5. The fuzzy weights of each criterion can be found in ***Eq. (5)*** by incorporating the next 3 sub-steps.

Step 5a. Find the vector summation of each $\tilde{r}_i$.

Step 5b. Find the (-1) power of the summation vector. Replace the fuzzy triangular number to make it in an increasing order.

Step 5c. To find the fuzzy weight of criterion i ($\tilde{w}_i$), multiply each $\tilde{r}_i$ with this reverse vector.

$$\tilde{w}_i = \tilde{r}_i \times (\tilde{r}_1 + \tilde{r}_2 + \cdots\cdots + \tilde{r}_n)^{-1} = (lw_i, mw_i, uw_i). \qquad (5)$$

Step 6. Since $\tilde{w}_i$ are still fuzzy triangular numbers, they need to be de-fuzzified by the center of area method proposed via applying ***Eq. (6)***.

$$M_i = \frac{lw_i + mw_i + uw_i}{3}. \qquad (6)$$

Step 7. M_i is a non-fuzzy number. But it needs to be normalized by following ***Eq. (7)***.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i}. \tag{7}$$

These 7 steps are performed to find the normalized weights of both criteria and the alternatives. Then, by multiplying each alternative weight with related criteria, the scores for each alternative are calculated. According to these results, the alternative with the highest score is suggested to the decision-maker.

6. Finding and Data Analysis

Following a comprehensive examination of the supply chain and a thorough review of relevant literature, the authors have categorized the entire supermarket supply chain into three distinct segments: the Supplier Chain, Internal Chain, and Customer Chain. The Supplier Chain represents the flow of activities, goods, finances, and information between the supplier and the supermarket. The Internal Chain operates exclusively within the confines of the supermarket itself. The Customer Chain forms a network that extends from the supermarket to the end customers. To gather data pertaining to these three segments, three separate groups were dispatched for data collection.

6.1. Identify Factors and Construction of Structure

Discussing with supply chain experts and studying some research papers, the following factors have been identified. ***Table 2*** shows the identified factors for each chain with literature support. After identifying the important factors, the authors have developed a hierarchical model based on AHP. ***Figure 2*** shows the structure of the hierarchical model.

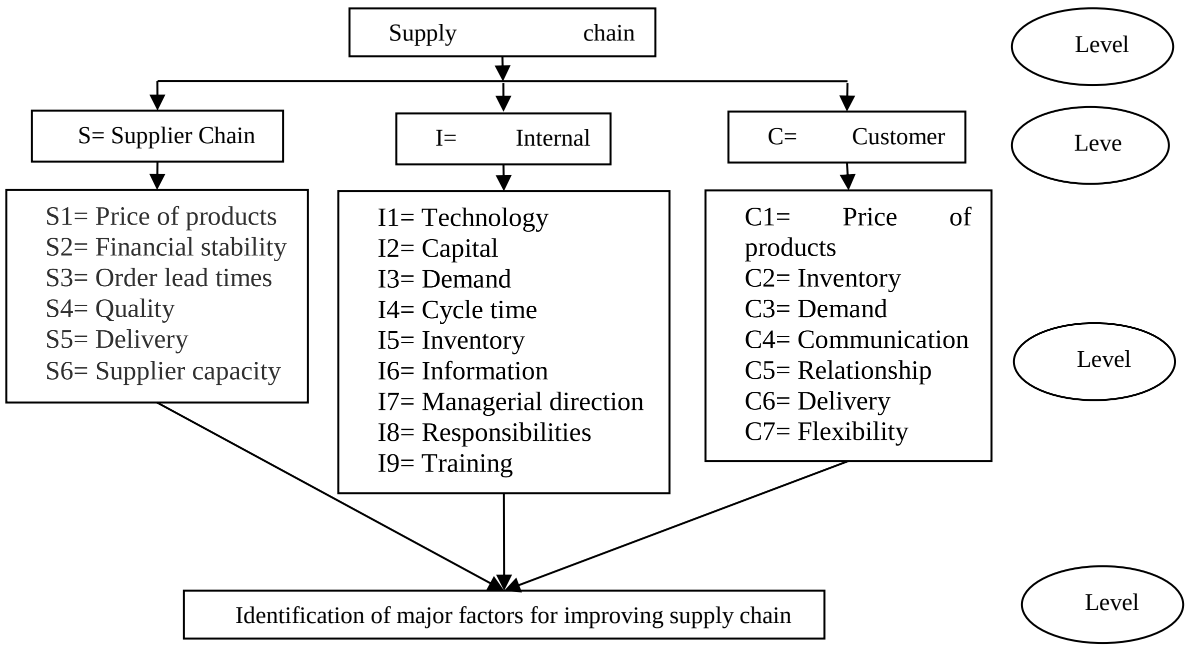

Figure 2. AHP framework for identifying major affected factors.

Table 2. List of factors.

SL	Factors	Explanation	Literature Support
		Factors for supplier chain problems	
1	Price of products	Price is the amount of money at which the buyer and supplier agree to buy and sell of the products.	[17]
2	Financial stability	It is the supplier financial health to continue the business.	[18]
3	Order lead times	It is the time between orders placed to supplier and receive by supermarket.	[17]
4	Quality	It is the degree to which a product meets the requirements of the customer and makes satisfy them.	[17]
5	Delivery	Transferring way and time of goods from one party to another party.	[18]
6	Supplier capacity	It is the ability of the supplier to meet the demand for the supermarket.	[19]
		Factors for internal chain problems	
1	Technology	Adaption of technology makes the supply chain simpler.	[20]
2	Capital	Limitation of capital funding of the supermarket effects on supply chain.	[17]
3	Demand	Accurate demand management attracts more customers.	[21]

4	Cycle time	It is the time elapsed in between the customer order to delivery of goods.	[18]
5	Inventory	Managing inventory keeps good relation with both suppliers and customers.	[21]
6	Information	Information sharing with each other effects on supply chain performance.	[22]
7	Managerial direction	Top management takes all the decision related to supply chain.	[23]
8	Responsibilities	It is the ability to do work eagerly by yourself which improve supply chain.	[24]
9	Training	Teach to the employee to do work accurately.	[25-27]
10	Relationship	It includes internal relationship among employees.	[23]
		Factors for customer chain problems	
1	Price of products	According to customer chain, it is the amount of money customer pay for the products.	[17]
2	Inventory	Stock out or higher inventory effect on supply chain.	[17]
3	Demand	Rapid changes in demand effects on supply chain.	[28]
4	Communication	Communicate with customers to know about market situation.	[17]
5	Relationship	Relationship with all types of customer.	[29]
6	Delivery	An increase in delivery performance means increase in service performance too.	[18]
7	Flexibility	Flexibility to customers ensure better sale of goods and return.	[18] and [29]
8	Satisfaction	Future business actually depends on customer satisfaction.	[23] and [30-31]

6.2. Determining Weights for parts

In order to determine the weights for major parts of the supply chain, three groups were developed, including the manager of the supermarket. Group A, group B, and Group C sequentially observed each part of the supply chain of the supermarket and provided the weight of each part against others. According to their preferences, the averaged pairwise comparison of the criteria is represented by following ***Table 3***. After receiving the data, the next step is to develop a pairwise comparison matrix. According to ***Table 3***, the pairwise comparison matrix is formed in ***Table 4*** for the major parts of the entire supply chain. This table usually provides the clear numeric weight of each part against other parts. In the next step, pairwise contribution matric is updated by using ***Eq. (2)*** and shown in ***Table 5***. In this table, the numerical weight value of the three groups is averaged. Now, using ***Eq. (4),*** the geometric mean of fuzzy comparison values of each part is calculated. For instance, $\tilde{r}_1$ the geometric mean of fuzzy comparison values of the "Supplier Chain" part is calculated as ***Eq. (4)***.

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{d}_{ij}\right)^{\frac{1}{n}} = \left[\left(1\times\frac{10}{7}\times\frac{4}{5}\right)^{\frac{1}{3}};\left(1\times\frac{16}{9}\times\frac{7}{6}\right)^{\frac{1}{3}};\left(1\times\frac{9}{5}\times\frac{11}{7}\right)^{\frac{1}{3}}\right] = [1.0484;\ 1.2801;\ 1.4193].$$

Table 3. Pairwise comparisons of major parts.

SL	A.Imp. (9,9,9)	S.Imp. (6,7,8)	F.Imp. (4,5,6)	W.Imp. (2,3,4)	CRITERION	Eq. Imp. (1,1,1)	CRITERION	W.Imp. (2,3,4)	F.Imp. (4,5,6)	S.Imp. (6,7,8)	A.Imp. (9,9,9)
Group A											
1					S		I			✓	
2					S		C		✓		
3			✓		I		C				
Group B											
SL	A.Imp. (9,9,9)	S.Imp. (6,7,8)	F.Imp. (4,5,6)	W.Imp. (2,3,4)	CRITERION	Eq. Imp. (1,1,1)	CRITERION	W.Imp. (2,3,4)	F.Imp. (4,5,6)	S.Imp. (6,7,8)	A.Imp. (9,9,9)
1			✓		S		I				
2					S		C	✓			
3					I	✓	C				
Group C											
SL	A.Imp. (9,9,9)	S.Imp. (6,7,8)	F.Imp. (4,5,6)	W.Imp. (2,3,4)	CRITERION	Eq. Imp. (1,1,1)	CRITERION	W.Imp. (2,3,4)	F.Imp. (4,5,6)	S.Imp. (6,7,8)	A.Imp. (9,9,9)
1					S		I		✓		
2				✓	S		C				
3				✓	I		C				

Similarly, the geometric means of fuzzy comparison values of all parts are calculated and shown in ***Table 6***. In addition, the total values and the reverse values are also presented. In the last row of the same table, since the fuzzy triangular number should be in increasing order, the order of the numbers is changed. In the last stage of the fifth step, the fuzzy weight of the "Supplier Chain" is calculated by using ***Eq. (5)***.

$$\tilde{w}_1 = \left\lfloor (1.0484\times 0.1894);(1.2801\times 0.2125);(1.4193\times 0.2478) \right\rfloor = [0.1986;\ 0.272;\ 0.3517].$$

Table 4. Pairwise comparison matric of the major part.

	Supplier Chain	Internal Chain	Customer Chain
Group A			
	Supplier Chain	Internal Chain	Customer Chain
Supplier Chain	(1,1,1)	(1/8,1/7,1/6)	(1/6,1/5,1/4)
Internal Chain	(6,7,8)	(1,1,1)	(4,5,6)
Customer Chain	(4,5,6)	(1/6,1/5,1/4)	(1,1,1)
Group B			
	Supplier Chain	Internal Chain	Customer Chain
Supplier Chain	(1,1,1)	(4,5,6)	(1/4,1/3,1/2)
Internal Chain	(1/6,1/5,1/4)	(1,1,1)	(1,1,1)
Customer Chain	(2,3,4)	(1,1,1)	(1,1,1)
Group C			
	Supplier Chain	Internal Chain	Customer Chain
Supplier Chain	(1,1,1)	(1/6,1/5,1/4)	(2,3,4)
Internal Chain	(4,5,6)	(1,1,1)	(2,3,4)
Customer Chain	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1,1,1)

Table 5. Updated pairwise comparison matric of major part.

	Supplier Chain	Internal Chain	Customer Chain

Supplier Chain	(1,1,1)	(10/7,16/9,9/5)	(4/5,7/6,11/7)
Internal Chain	(17/5,4,19/4)	(1,1,1)	(7/3,3,11/3)
Customer Chain	(2,25/9,7/2)	(1/2,1/2,3/5)	(1,1,1)

Table 6. Geometric means of fuzzy comparison of each part.

Parts	$\tilde{r}_i$		
Supplier Chain	1.0484	1.2801	1.4193
Internal Chain	1.9923	2.3021	2.5921
Customer Chain	0.9946	1.1239	1.2686
Total	4.0352	4.7061	5.2800
Reverse(Power of -1)	0.2478	0.2125	0.1894
Increasing order	0.1894	0.2125	0.2478

Hence, the relative fuzzy weights of each criterion are calculated and shown in ***Table 7***. After completing the first five steps of the methodology, the relative non-fuzzy weight of each part (M_i) is calculated using ***Eq. (6)***. By using non-fuzzy (M_i), the normalized weights of each part are calculated in the seventh step applying ***Eq. (7)*** and tabulated in ***Table 8***. Here, it is found that the internal chain absorbs the highest weight, which is 0.4911, and the lowest weight, which is 0.2413, is consumed by the customer chain.

Table 7. Fuzzy weights of each part.

Parts	$\tilde{w}_i$		
Supplier Chain	0.1986	0.2720	0.3517
Internal Chain	0.3773	0.4892	0.6424
Customer Chain	0.1884	0.2388	0.3144

Table 8. Relative non-fuzzy and normalized weights of each part.

Parts	M_i	N_i
Supplier Chain	0.2741	0.2676
Internal Chain	0.5030	0.4911
Customer Chain	0.2472	0.2413
sum	1.0242	1.00

6.3. Determining Weights of Factors with Respect to Main Parts

The same methodology is applied to find the respective values for factors. That means this analysis should be repeated for factors of each part. Updated pairwise contribution matric for factors of the supplier chain is represented in ***Table 9***. Geometric mean, fuzzy weight, non-fuzzy weight, and normalized weight for supplier chain factors are represented in ***Table 10***. After finding the normalized weight of the supplier chain, the same procedure is also applied to find the weight of internal chain factors. From the pairwise contribution matrix for the factors of "Internal Chain" in ***Table 11***, the authors calculated the geometric mean, fuzzy weight, non-fuzzy weight, and normalized weight, which are represented in ***Table 12***.

In the same way, ***Table 13*** shows the pairwise contribution matrix for the factors of the "Customer Chain". The geometric mean, fuzzy weight, non-fuzzy weight, and normalized weight for customer chain factors are represented in ***Table 14***. In order to get the final result, multiply the normalized weight of major parts with the normalized weight of their factors. ***Table 15*** displays the final score of the factors and their rank.

Table 9. Pairwise contribution matric "Supplier Chain.

	S_1	S_2	S_3	S_4	S_5	S_6
S_1	(1,1,1)	(4,43/9,11/2)	(11/4,31/9,25/6)	(8/3,3,10/3)	(4/5,7/6,11/7)	(2,11/4,17/5)
S_2	(3/4,1,13/9)	(1,1,1)	(5/7,3/4,3/4)	(10/7,7/4,19/9)	(2,22/9,14/5)	(4/3,5/3,2)
S_3	(7/9,8/7,3/2)	(2,7/3,8/3)	(1,1,1)	(13/9,9/5,13/6)	(1,7/5,7/4)	(1,13/9,11/6)
S_4	(5/7,5/7,5/7)	(4,19/4,38/7)	(19/7,17/5,4)	(1,1,1)	(7/5,2,11/4)	(5,49/9,35/6)
S_5	(2,25/9,7/2)	(27/8,4,33/7)	(7/4,19/9,5/2)	(3/2,17/9,7/3)	(1,1,1)	(4,5,6)
S_6	(3/2,11/6,9/4)	(3/4,7/9,5/6)	(1,13/9,11/6)	(3/4,1,10/7)	(1/6,2/9,1/3)	(1,1,1)

Table 10. Relative non-fuzzy and normalized weights of supplier chain.

Factors	$\tilde{r}_i$			$\tilde{w}_i$			M_i	N_i
S_1	1.9167	2.3274	2.7292	0.1536	0.2169	0.3046	0.2250	0.2170
S_2	1.1357	1.3394	1.5301	0.0910	0.1248	0.1708	0.1289	0.1243
S_3	1.1703	1.4585	1.7406	0.0938	0.1359	0.1943	0.1413	0.1363
S_4	1.9514	2.2488	2.5203	0.1564	0.2096	0.2813	0.2157	0.2081
S_5	2.0482	2.4647	2.8866	0.1642	0.2297	0.3222	0.2387	0.2302
S_6	0.7376	0.8928	1.0696	0.0591	0.0832	0.1194	0.0872	0.0841
Total	8.9598	10.7316	12.4763					
Reverse(Power of -1)	0.1116	0.0932	0.0802					
Increasing order	0.0802	0.0932	0.1116					

Table 11. Pairwise contribution matric for the factors of "Internal Chain".

	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}
I_1	(1,1,1)	(10/7,19/9,17/6)	(13/9,9/5,13/6)	(1/6,1/5,1/4)	(1/6,1/5,2/7)	(3/4,7/9,5/6)	(1/6,2/9,1/3)	(4/9,1/2,1/2)	(4/5,7/6,11/7)	(3/4,7/9,5/6)
I_2	(5/6,11/9,5/3)	(1,1,1)	(1/2,5/9,2/3)	(12/7,2,12/5)	(1/6,2/9,1/3)	(1/5,1/4,1/3)	(4/5,8/7,3/2)	(5/7,3/4,3/4)	(10/3,13/3,16/3)	(2,25/9,7/2)
I_3	(19/7,17/5,4)	(5/3,7/3,3)	(1,1,1)	(10/3,13/3,16/3)	(3/4,10/9,3/2)	(5/7,5/7,5/7)	(7/9,8/7,3/2)	(3,11/3,13/3)	(6,7,8)	(4,5,6)
I_4	(4,5,6)	(12/7,2,12/5)	(1/5,1/4,1/3)	(1,1,1)	(3/2,11/6,9/4)	(10/7,16/9,15/7)	(5/7,5/7,5/7)	(2/9,2/7,3/7)	(10/3,13/3,16/3)	(12/5,25/9,19/6)

I_5	(14/3,17/3,20/3)	(4,5,6)	(17/5,37/9,29/6)	(2,11/4,17/5)	(1,1,1)	(4,13/3,14/3)	(19/8,19/7,3)	(7/5,2,11/4)	(14/3,17/3,20/3)	(10/3,13/3,16/3)
I_6	(4/3,5/3,2)	(10/3,13/3,16/3)	(8/3,3,10/3)	(17/5,4,19/4)	(4/9,1/2,1/2)	(1,1,1)	(2,7/3,8/3)	(3,11/3,13/3)	(10/3,13/3,16/3)	(3,11/3,13/3)
I_7	(4,5,6)	(15/4,37/9,9/2)	(11/4,31/9,25/6)	(8/3,3,10/3)	(12/5,11/4,3)	(5/7,3/4,3/4)	(1,1,1)	(2,25/9,7/2)	(2,19/7,27/8)	(5/7,3/4,3/4)
I_8	(4,13/3,14/3)	(2,7/3,2,2/3)	(4/9,1/2,1/2)	(8/3,11/3,14/3)	(3/2,17/9,7/3)	(4/9,1/2,1/2)	(4/5,7/6,11/7)	(1,1,1)	(3/2,17/9,7/3)	(4/3,5/3,2)
I_9	(2,25/9,7/2)	(1/5,1/4,2/5)	(1/8,1/7,1/6)	(1/5,1/4,1/3)	(1/6,1/5,2/7)	(1/5,1/4,2/5)	(22/7,19/6,13/4)	(7/5,2,11/4)	(1,1,1)	(11/3,13/3,5)
I_{10}	(4/3,5/3,2)	(4/5,7/6,11/7)	(1/6,2/9,1/3)	(1,11/8,12/7)	(1/5,1/4,1/3)	(1/2,1/2,5/9)	(2,7/3,8/3)	(3/4,7/9,5/6)	(3/7,4/9,1/2)	(1,1,1)

Table 12. Relative non-fuzzy and normalized weights of the internal chain.

Factors	$\tilde{r}_i$			$\tilde{w}_i$			M_i	N_i
I_1	0.5400	0.6432	0.7738	0.0285	0.0398	0.0574	0.0419	0.0403
I_2	0.7939	0.9759	1.1939	0.0419	0.0604	0.0885	0.0636	0.0612
I_3	1.8455	2.2908	2.7139	0.0973	0.1417	0.2012	0.1467	0.1412
I_4	1.1359	1.3533	1.6116	0.0599	0.0837	0.1195	0.0877	0.0844
I_5	2.7732	3.3720	3.9484	0.1462	0.2086	0.2927	0.2158	0.2077
I_6	2.0132	2.3774	2.7442	0.1061	0.1471	0.2034	0.1522	0.1465
I_7	1.8900	2.1728	2.4462	0.0996	0.1344	0.1813	0.1385	0.1333
I_8	1.2612	1.4971	1.7372	0.0665	0.0926	0.1288	0.0960	0.0924
I_9	0.5981	0.7274	0.9041	0.0315	0.0450	0.0670	0.0478	0.0461
I_{10}	0.6405	0.7544	0.8934	0.0338	0.0467	0.0662	0.0489	0.0470
Total	13.4916	16.1642	18.9668					
Reverse(Power of -1)	0.0741	0.0619	0.0527					
Increasing order	0.0527	0.0619	0.0741					

Table 13. Pairwise contribution matric for the factors of "Customer Chain".

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	(1,1,1)	(17/5,17/5,17/5)	(7/5,2,11/4)	(16/3,19/3,22/3)	(14/3,17/3,20/3)	(7/3,3,11/3)	(7/5,2,11/4)	(3/2,11/6,20/9)
C_2	(12/7,2,19/8)	(1,1,1)	(1,13/9,11/6)	(2,25/9,7/2)	(7/5,2,11/4)	(1,1,1)	(4/5,7/6,11/7)	(1/2,1/2,3/5)
C_3	(3/2,17/9,7/3)	(12/5,25/9,19/6)	(1,1,1)	(4,5,6)	(3,11/3,13/3)	(4/3,5/3,2)	(13/9,9/5,13/6)	(3/2,11/6,9/4)
C_4	(1/7,1/6,1/5)	(4/5,7/6,11/7)	(1/6,2/9,1/3)	(1,1,1)	(1,1,1)	(1/6,2/9,1/3)	(1/6,2/9,2/7)	(1/8,1/8,1/7)
C_5	(1/7,1/6,2/9)	(3/2,17/9,7/3)	(1/2,1/2,2/5)	(1,1,1)	(1,1,1)	(1/5,1/4,1/3)	(2/9,2/7,3/7)	(1/6,2/9,1/3)
C_6	(1/2,1/2,3/5)	(1,1,1)	(3/4,7/9,5/6)	(4,5,6)	(10/3,13/3,16/3)	(1,1,1)	(15/7,5/2,3)	(12/7,2,12/5)
C_7	(3/2,17/9,7/3)	(2,25/9,7/2)	(19/7,17/5,4)	(5,17/3,19/3)	(8/3,11/3,14/3)	(2,19/7,17/5)	(1,1,1)	(4/9,1/2,1/2)
C_8	(19/7,17/5,4)	(7/3,3,11/3)	(2,11/4,17/5)	(7,23/3,25/3)	(4,5,6)	(12/5,11/4,3)	(3,11/3,13/3)	(1,1,1)

Table 14. Relative non-fuzzy and normalized weights of customer chain.

Factors	$\tilde{r}_i$			$\tilde{w}_i$			M_i	N_i
C_1	2.2024	2.7035	3.1737	0.1350	0.1928	0.2707	0.1995	0.1924

C_2	1.0926	1.3363	1.5790	0.0670	0.0953	0.1347	0.0990	0.0955
C_3	1.8255	2.1916	2.5649	0.1119	0.1563	0.2188	0.1623	0.1566
C_4	0.3062	0.3589	0.4324	0.0188	0.0256	0.0369	0.0271	0.0261
C_5	0.4113	0.4769	0.5529	0.0252	0.0340	0.0472	0.0355	0.0342
C_6	1.4276	1.6061	1.7963	0.0875	0.1146	0.1532	0.1184	0.1142
C_7	1.7847	2.1575	2.5284	0.1094	0.1539	0.2156	0.1596	0.1540
C_8	2.6748	3.1895	3.6873	0.1639	0.2275	0.3145	0.2353	0.2270
Total	11.7252	14.0205	16.3148					
Reverse(Power of -1)	0.0853	0.0713	0.0613					
Increasing order	0.0613	0.0713	0.0853					

Table 15. Aggregated results for each factor according to each part of the supply chain.

Factor	Major part	Relative weight of major part	Relative weight of factor	Total Score	Rank
S_1	Supplier Chain	0.2676	0.2170	0.0581	6
S_2	Supplier Chain	0.2676	0.1243	0.0333	15
S_3	Supplier Chain	0.2676	0.1363	0.0365	14
S_4	Supplier Chain	0.2676	0.2081	0.0557	7
S_5	Supplier Chain	0.2676	0.2302	0.0616	5
S_6	Supplier Chain	0.2676	0.0841	0.0225	21
I_1	Internal Chain	0.4911	0.0403	0.0198	22
I_2	Internal Chain	0.4911	0.0612	0.0300	16
I_3	Internal Chain	0.4911	0.1412	0.0693	3
I_4	Internal Chain	0.4911	0.0844	0.0414	11
I_5	Internal Chain	0.4911	0.2077	0.1020	1
I_6	Internal Chain	0.4911	0.1465	0.0719	2
I_7	Internal Chain	0.4911	0.1333	0.0654	4
I_8	Internal Chain	0.4911	0.0924	0.0453	10
I_9	Internal Chain	0.4911	0.0461	0.0226	20
I_{10}	Internal Chain	0.4911	0.0470	0.0231	18
C_1	Customer Chain	0.2413	0.1924	0.0464	9
C_2	Customer Chain	0.2413	0.0955	0.0230	19
C_3	Customer Chain	0.2413	0.1566	0.0378	12
C_4	Customer Chain	0.2413	0.0261	0.0063	24
C_5	Customer Chain	0.2413	0.0342	0.0083	23
C_6	Customer Chain	0.2413	0.1142	0.0276	17
C_7	Customer Chain	0.2413	0.1540	0.0372	13
C_8	Customer Chain	0.2413	0.2270	0.0548	8

7. Result and Discussion

In this research, the authors have identified six factors within the Supplier Chain, ten factors within the Internal Chain, and eight factors within the Customer Chain. The hierarchy structure, as per AHP methodology, is depicted in ***Figure 2***. Microsoft Excel was employed to resolve the FAHP matrices, yielding non-fuzzy and normalized weights for each major segment, as presented in ***Table 8***. Notably, the Internal Chain carries the highest normalized weight, standing at 0.4911. Meanwhile, the weights of the other two segments are very close, with the Supplier Chain assigned a weight of 0.2676 and the Customer Chain holding a weight of 0.2413. Similarly, the weights for all factors related to the main segments have been determined using Microsoft Excel software.

They are documented in ***Tables 10, 12, and 14***, representing the non-fuzzy weights and normalized weights for factors within the "Supplier Chain," "Internal Chain," and "Customer Chain," respectively.

The final results were derived by aggregating the relative weight of major segments and the relative weight of factors, as shown in ***Table 15***. Employing the Buckley FAHP method, inventory management within the Internal Chain received the highest score. Inventory management significantly impacts the overall supply chain of this supermarket, garnering a total score of 0.1020. Therefore, the primary focus for the store's management should be improving inventory management. Information and demand within the Internal Chain secured the second and third ranks, with scores of 0.0719 and 0.0693, respectively. Communication with customers received the lowest score, suggesting that it should be the subsequent area of focus for the management.

8. Recommendation

The authors have identified potential recommendations for enhancing the top eight factors. To formulate these recommendations, they conducted a thorough analysis and engaged in discussions with both experts and supermarket managers to devise improvement strategies. Table 16 outlines the suggestions for these eight major factors.

Table 16. Suggestions for major eight factors.

Improvement factor	Major part	Suggestions
Inventory	Internal Chain	- Be careful to do accurate forecasting of demand. - Classify all the products into suitable categories using ABC, FNS techniques. - Use EOQ model before ordering goods. - Keep monitoring on goods. - Strictly maintain the safety stock limit.
Information	Internal Chain	- Solve the internal issues like incentive and facilities among the employers. - Install reliable and user-friendly IT equipment for sharing information. - Develop a trusted network for individuals to share information. - Provide better training to the employers.
Demand	Internal Chain	- Decision on demand management should be taken from group analysis rather than a single manager. - Gather appropriate knowledge of market and customers behavior to do accurate demand forecast. - Identify seasonal demand accurately. - Consider the discounts with demand calculation.

		- Identify the targeted consumer groups.
Managerial Direction	Internal Chain	- Goal and objective should be identified and fixed. - Design the better operating strategies including pricing methods, sales objectives, and advertising budgets. - Proper allocation of capital. - Redesign of store layout, product mix, promotion, process of packaging, and delivery of products.
Delivery	Supplier Chain	- Measure the capacity of supplier before selecting. - Avoid third parties as a supplier to get faster delivery. - Ensure the reliability of delivery. - Develop delivery strategies and appropriate transportation way.
Price of product	Supplier Chain	- Avoid third parties as a supplier to reduce product cost. - Improve dimensional weight during shipping. - Try to remove excess materials as much as possible. - Develop a long term relationship with suppliers to get price negotiation.
Quality	Supplier Chain	- Check the quality of products before receiving from supplier. - Prepare the right environment to the warehouse. - Periodical benchmarking of product quality with the products of other suppliers.
Satisfaction	Customer Chain	- Advice the customers to buy the best products depending on their needs. - Provide training to the staff on well behavior. - Avoid selling expired products.

9. Conclusion and Future Work

This study delved into the analysis of a supermarket's supply chain, encompassing performance assessment and improvement initiatives spanning the entire supply chain. The research included participation from all stakeholders in the supply chain, united by a shared commitment to common objectives. The findings underscore that every factor, irrespective of its origin within the supply chain, exerts a substantial impact on the overall supply chain's performance. To enhance and optimize the supply chain, it is imperative to identify the most influential factors. This task is further complicated by the fact that the prioritization of factors often varies based on the specific requirements of the involved stakeholders.

However, in this paper, the authors systematically identified potential factors from all aspects of the supply chain. They subsequently employed the fuzzy-AHP technique to assign weights to each factor, considering the significance of each segment within the chain. The key takeaways from this research advise the management of the "Save 'n' Safe" supermarket to initially concentrate on inventory management, information sharing, demand forecasting, and managerial direction. Once improvements in these areas have been implemented, the focus should shift to the Supplier Chain, aiming to enhance product delivery time, pricing strategies, and product quality.

Previous research typically presented overarching criteria or factors for the entire supply chain, posing a significant challenge for top-level management in pinpointing precisely where improvements are needed. This study, however, combines the fuzzy logic approach with AHP methodology, enabling a granular examination of the supply chain factors specific to the "Save 'n' Safe" supermarket, sector by sector. As a result, the supermarket's supply chain performance was enhanced through the implementation of these tailored recommendations. This research's flexibility allows for the potential identification of additional critical factors or the subdivision of the supply chain into more specific segments in the future.

10. Acknowledgement

The authors extend their heartfelt gratitude to the dedicated staff of "Save 'n' Safe" supermarket in Khulna, Bangladesh, for their valuable contributions. They would also like to convey their sincere thanks and appreciation to the experts, suppliers, and customers who offered valuable insights and information. Lastly, the research team wishes to express their profound appreciation to MD. Safran Hazi, the managing director of "Save 'n' Safe" supermarket, whose unwavering support and guidance were instrumental at every stage of this research endeavor.

References

[1] Ellickson, P. B. (2011). *The evolution of the supermarket industry: From A&P to Wal&Martm.* Simon Graduate School of Business Working Paper No. FR 11&17.

[2] Farid, M. S., Alam, M. J., Rahman, M. M., Barua, S., & Sarker, B. (2018). Direct and associated factors influencing the growth in supermarket activity in Bangladesh. *Asian research journal of arts & social sciences*, 1-12.

[3] Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). Defining supply chain management. *Journal of business logistics*, *22*(2), 1-25.

[4] GUO, Y. X., & YANG, Y. B. (2008). Research on comprehensive assessment model of service quality in rural supermarkets based on FAHP. *Journal of shijiazhuang railway institute (social science)*, *4*.

[5] Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. *Industrial marketing management*, *29*(1), 65-83.

[6] Mehmeti, G., Musabelliu, B., & Xhoxhi, O. (2016). The review of factors that influence the supply chain performance. *Academic journal of interdisciplinary studies*, *5*(2), 181.

[7] Nandi, R., Gowdru, N. V., & Bokelmann, W. (2017). Factors influencing smallholder farmers in supplying organic fruits and vegetables to supermarket supply chains in Karnataka, India: a transaction cost approach. *International journal of rural management*, *13*(1), 85-107.

[8] Abunar, S. M., Ali, M., Fazelrabbi, M., & Ismail, H. (2016). A study of state of food retail supply chain in Saudi Arabia: a conceptual framework. *Engineering management research*, *5*(2), 1.

[9] Abunar, Z., & Zerban, A. M. (2016). Enhancing accounting information systems to facilitate supply chain management between supermarkets/suppliers: The case of Saudi Arabia. *Journal of accounting and marketing*, *5*(2).

[10] Gunasekaran, A., Subramanian, N., & Rahman, S. (2017). Improving supply chain performance through management capabilities. *Production planning & control, 28*(6–8), 473–477.

[11] Gupta, V., & Abidi, N. (2017). Exploring factors affecting supply chain of IT products: a retailer's perspective. *Procedia computer science*, *122*, 969-976.

[12] Karayalcin, I. I. (1982). *The analytic hierarchy process: Planning, priority setting, resource allocation.* Thomas L. SAATY McGraw-Hill, New York, 1980, xiii+ 287 pages,£ 15.65.

[13] Van Laarhoven, P. J., & Pedrycz, W. (1983). A fuzzy extension of Saaty's priority theory. *Fuzzy sets and systems*, *11*(1-3), 229-241.

[14] Buckley, J. J. (1985). Fuzzy hierarchical analysis. *Fuzzy sets and systems*, *17*(3), 233-247.
[15] Meng, T. (2014). A FAHP-based comprehensive evaluation on rural supermarket service quality: a case study of Jiangsu province. *Computer modelling & new technologies*, *11*(12), 1.
[16] Gopalan, R., Sreekumar., & Satpathy, B. (2015). Evaluation of retail service quality–a fuzzy AHP approach. *Benchmarking: an international journal*, *22*(6), 1058-1080.
[17] Naude, M. J., & Badenhorst-Weiss, J. A. (2011). The effect of problems on supply chain wide efficiency. *Journal of transport and supply chain management*, *5*(1), 278-298.
[18] Cancro, J., & Mc Ginnis, M. (2004). Evaluating the financial condition of suppliers. *89th annual international supply management conference*.
[19] Gunasekaran, A., Patel, C., & McGaughey, R. E. (2004). A framework for supply chain performance measurement. *International journal of production economics*, *87*(3), 333-347.
[20] Ding, F. Y., Raghavan, B., & Pollard, S. (2007). Supplier capacity analysis for a manufacturing firm with a case study. *Production planning and control*, *18*(6), 514-525.
[21] Bhandari, R. (2014). Impact of technology on logistics and supply chain management. *IOSR journal of business and management*, *2*, 17.
[22] Mentzer, J. T., Myers, M. B., & Stank, T. P. (2006). *Handbook of global supply chain management*. Sage Publications.
[23] Koçoğlu, İ., İmamoğlu, S. Z., İnce, H., & Keskin, H. (2011). The effect of supply chain integration on information sharing: Enhancing the supply chain performance. *Procedia-social and behavioral sciences*, *24*, 1630-1649.
[24] Kanji, G. K., & Wong, A. (1999). Business excellence model for supply chain management. *Total quality management*, *10*(8), 1147-1168.
[25] Awasthi, A., & Grzybowska, K. (2014). Barriers of the supply chain integration process. *Logistics operations, supply chain management and sustainability* (pp. 15-30). Springer, Cham.
[26] Rouibah, K., Hamdy, H. I., & Al-Enezi, M. Z. (2009). Effect of management support, training, and user involvement on system usage and satisfaction in Kuwait. *Industrial management & data systems*, *109*(3), 338-356.
[27] Meehan, J., & Muir, L. (2008). SCM in Merseyside SMEs: benefits and barriers. *The TQM journal*, *20*(3), 223-232.
[28] Manzouri, M., Rahman, M. N. A., Arshad, H., & Ismail, A. R. (2010). Barriers of supply chain management implementation in manufacturing companies: a comparison between Iranian and Malaysian companies. *Journal of the chinese institute of industrial engineers*, *27*(6), 456-472.
[29] Mahmood, W. H. W., Muhamad, M. R., & Tahar, N. M. (2009). Supply chain management: after business process re-engineering. *International journal of industrial and systems engineering*, *3*(5), 411-416.
[30] Al-Shboul, M. D. A. R., Barber, K. D., Garza-Reyes, J. A., Kumar, V., & Abdi, M. R. (2017). The effect of supply chain management practices on supply chain and manufacturing firms' performance. *Journal of manufacturing technology management*, *28*(5), 577-609.
[31] Ou, C. S., Liu, F. C., Hung, Y. C., & Yen, D. C. (2010). A structural model of supply chain management on firm performance. *International journal of operations & production management*, *30*(5), 526-545.
[32] Li, S., Rao, S. S., Ragu-Nathan, T. S., & Ragu-Nathan, B. (2005). Development and validation of a measurement instrument for studying supply chain management practices. *Journal of operations management*, *23*(6), 618-641.