

Improving Supply Chain Effectiveness: An Analysis of Bangladesh's Pharmaceutical Industry

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Abstract

This research study will improve supply chain efficiency in the pharmaceutical industry of Bangladesh by developing a systematic and efficient Supply Chain Management (SCM) model. The analysis is an evaluation of the supply chain system of a national pharmaceutical firm to find out those shortcomings that prevent efficient performance, such as high cost of transportation, poor communication of information, and slowness of the product to the market. A combination of the Various-criteria Decision-Making (MCDM) techniques of the Analytic Hierarchy Process (AHP) and the Fuzzy Technique of Order Preference to Similarity Ideal Solution (Fuzzy-TOPSIS) was used to get the 10 vital causes found by the cause-and-effect method of the experts. The survey resulted in those having the greatest effect on efficient performance, including high cost of transportation and poor data communication, which are vital variables of efficient performance and responsiveness, also to the supply chain. Following these results, a new development of the To-Be model is proposed, having several regional warehouses, improvement of depot networks, cross-docking stations, and utilization of reverse logistics. This improved version gives promise of better than the existing sufficient supply chains, with shorter lead times, lower production discrepancies, and lower costs of maintenance, and denotes better supply chain flexibility, greater access to customers, and product availability in the supply chain system. The research gives a feasible modus operandi for the amelioration of the pharmaceutical supply chains in Bangladesh from a centralized, inflexible system to a responsive, rather decentralized system in this case. It contributes to the background of the difficult decision-support systems in a developing country case, and how the AHP-TOPSIS mix may help SCM restructuring based on data in a developing market.

Keywords

Supply Chain Management, AHP, Fuzzy TOPSIS, Pharmaceutical Industry, Bangladesh.

1. Introduction

Supply chain management (SCM) is the coordination of all processes, from needs assessment to order fulfillment, directed toward customer satisfaction, which is achieved with as little waste as possible. SCM is an approach that involves all the activities pertaining to the movement and storage of a product from its point of origin to the time it reaches the consumer.

The supply chain process of products is transformed as people become more educated about the long-term sustainability of product value chains. These processes become more and more radical with every change in the supply chain. Under SCM, operations cover manufacturing, supply chains, logistics, distribution, and transportation (Ivanov et al., 2019). As Kazancoglu et al. (2020) have mentioned, the dynamic of the supply chain is a series of processes integrated in such a way that multiple business organizations (like as suppliers, manufacturers, distributors, and retailers) play significant roles to (a) extract raw materials, (b) transform those raw materials into wanted products, and (c) operationalize the process to deliver such products to retailers. There are a variety of stakeholders in the supply chain, such as raw material suppliers, manufacturers, warehouses, relevant facilities, distribution centers, retailers, and customers (Frazelle, 2020).

The Pharmaceutical Supply Chain (PSC) is a singularly influential and complicated part of the world's supply chain organizations, which deals with the production of new drugs, their deliveries, and their final consumption. The global network of the pharmaceutical industry's supply chain is not slowing down, and more options, such as cheaper goods and services, have been offered lately (Muha,,ad et al., 2024). Lowering production and service prices by the companies comes with a limitation of supply chain management operations, especially in countries with limited development like Bangladesh (Khayer et al., 2023). The PSC's intricate and complicated network is being researched actively by international organizations to provide customer-based services at reasonable prices.

The medical supply chain system, joining the manufacturers of pharmaceutical products and the final consumers through the right product, quantity, and time, is the most legal way of supplying the product (Goodarzian et al., 2020). Various barriers related to transportation (George & Elrashid, 2023), manufacturing, laws and regulations (van Duyse et al., 2021), infrastructural barriers (Baig et al., 2020), and environmental barriers (Gonzalez et al., 2022) play a role in carrying out various functions effectively. To the effect that controlling uncertainty and risk in the supply chain has become a major problem for the pharmaceutical companies. In the pharmaceutical supply chain, there are distinct barriers in terms of the supply of timely delivery, satisfaction of customers, improvement of efficiency, and lowering of costs (Wang & Jie, 2019). It is required to explore and understand the barriers to supply chain development. Also, it can understand the barriers in this industry, which will have a major impact on the growth of Bangladesh's economy, and cope with the world market problems.

The pharmaceutical industry in Bangladesh is growing rapidly as the market is shifting from a national to an international market. There are nearly 257 drug-manufacturing units in Bangladesh, of which 150 are in production. Bangladesh has a strong pharmaceutical industry, according to the perfect information received from the Bangladesh Association of Pharmaceutical Industries (BAPI) and the Directorate General of Drug Administration (DGDA) (BPIO, 2021). Nearly 98% of the total demand is supplied through the local manufacturers in Bangladesh (BPIO, 2021). At present, 90% of the local pharmaceutical industry is dominated by the local drug manufacturers, whereas the remaining 10% is under the control of the multinational companies. The worth of the pharmaceutical industry in Bangladesh was estimated at US \$3 billion approximately in the year 2020, which accounted for nearly 1.83% of the total GDP of the country (Hossan, 2023).

Bangladesh, being a developing economy, struggles hard to contribute to the international market after fulfilling its internal demands. At the present moment, over 1200 pharmaceuticals have been registered for export in Bangladesh during the last two years (Bangladesh Association of Pharmaceutical Industries). According to the Bangladesh Export Promotion Bureau, it is found that 60.3% of Bangladesh drug exports went to 147 countries in the year 2018-19, including Slovenia, Sri Lanka, Vietnam, Afghanistan, Philippines, Kenya, and Myanmar (Abdur Razzaque et al., 2020). The remaining 39.6% went to developed countries, including the USA, Canada, Germany, and Australia. In the year 2022 (during July-May), pharmaceutical exports amounting to US \$ 175.1 million were earned. Bangladesh has exported pharmaceuticals to more than 130 countries, including the UK, the USA, the Philippines, and the EU. The pharmaceutical industry is meeting 97% of the local demand in Bangladesh during 2022 (Farabi, 2022).

Developed nations have a more significant opportunity to contribute to global trade than developing countries. For example, Germany exported US \$60.8 billion, 14.9%, and Switzerland contributed US \$48.1 billion, 11.08% of the total amount of medications and pharmaceutical drugs in 2020 (Loomba, 2022).

Despite the remarkable expansion of Bangladesh's pharmaceutical sector, which takes advantage of cheap labor costs and low medication manufacturing costs, product and service quality remain a serious problem, given the perishability of pharmaceutical goods. Due to insufficient infrastructure, product quality may be compromised as it moves through the supply chain more intensively in developing countries than in developed countries. Due to tight worldwide rules, forthcoming legislation, and global rivalry, the sector confronts various issues, including control of transit, shipping, and disposal of expired items, among others (Vishwakarma et al., 2019). Given the dynamic nature of the pharmaceutical sector, there is a great need to investigate SCBs that are preventing PSCs from performing well. The study aims to cover the following questions for academic research:

RQ1: What are the specific problems faced by the existing supply chain in the pharmaceutical sector of Bangladesh?

RQ2: In which position can the problems be ranked in accordance with the impact on achieving supply chain resilience?

RQ3: What strategies can be adopted in a proper way to overcome the supply chain problems in the context of the pharmaceutical sector in Bangladesh?

1.1 Objectives

The main purpose of this research is to assess and enhance the current supply chain model applied to the pharmaceutical sector in Bangladesh in order to increase its efficiency, profitability, and customer satisfaction. In order to do that, the study aims at the following specific objectives:

- i. To assess the current supply chain management model of the pharmaceutical industry of Bangladesh.
- ii. To reveal the major issues and delays within the existing supply chain process.
- iii. To rank the identified issues through AHP and Fuzzy TOPSIS methods.
- iv. To create a better supply chain structure that would deal with the most crucial issues.
- v. To improve the general supply chain performance, profitability, and satisfaction of the customers.

2. Literature Review

The function of SCM in the pharmaceutical industry is essential, as it is used in order to enhance the operating efficiency, product integrity, and patients' safety (Haji et al., 2021). The review of literature contains a great deal of references to technological innovations developed in the environment of the pharmaceutical industry, which contain the three modes of reproducing and standardizing the characteristics of drugs, the effective magnification of expenses, and all the things needed for the flawless flow of medical supplies (Sarkis et al., 2021). Through good SCM practices, the pharmaceutical industry can improve both access and affordability of health care. At the same time, all logistical complexities and regulatory requirements are competently handled by the suitable management of the systems (Kumar et al., 2023).

There are numerous studies that have been undertaken, where obstacles of the pharmaceutical industry to attaining sustainability have been in focus. In the sources, the aims of traceability technology and multi-objective mixed-integer linear programming models (Sazvar et al., 2021) are discussed. The problems in regard to international management of the supply chain in the pharmaceutical sector are caused by rules and regulations, accurate forecasting of the demand, and risk management, which influences the efficacy, reliability, and resilience of the pharmaceutical supply chains at large in the world (Rowan & Laffey, 2020).

A comparative analysis of Bangladesh's pharmaceutical sector unmasks both specific and universal constraints, thus highlighting the need to localize global SCM practices within domestic constraints (Orubu et al., 2021). Through this comparison, the general intricacy of pharmaceutical SCM is emphasized, and region-sensitive strategies should be adjustable and effective for countering challenges, thereby adding to the positive performance of global healthcare systems. (Papi Lexi et al., 2021).

The entire supply chain process is critically evaluated in this work. Certain major aspects are diagnosed that are responsible for the entire inefficiency of this supply chain. The remedy for the problem is investigated. These problems are ranked from experience and distilled the experience through the assistance of Multi-Criteria Decision Making

(MCDM) methodologies, (a) Analytic Hierarchy Process (AHP) and (b) Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS).

Analytic Hierarchy Process (AHP) and Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS) are popular Multi-Criteria Decision Making (MCDM) Techniques which are being widely used in different fields for various decision-making problems (Saaty, 1977; Hwang & Yoon, 1981; Chen, 1992). This study applies the methods in the Pharmaceutical Industry, esp. with reference to the Supply Chain, whereby it facilitates the decision-making process regarding the improvement of Quality, Efficiency, and Reduction of Cost, which are involved in these areas of concern.

This AHP is a decision-making technique introduced by Saaty in the 1970s, which gives a disciplined technique for solving complex decisions where several Inputs and Outputs are considered (Saaty, 1977). AHP can take a complex decision and unravel the whole into a hierarchical framework of criteria, sub-criteria, and alternatives, and submit to a pair-wise comparison of the same, which will ultimately produce priority weights for the decision variables (Rahman et al., 2023). The application of AHP to the Pharmaceutical Supply Chain is in the form of producing a priority ranking of various criteria, such as priority ranking of suppliers, priority ranking of transport modes, priority ranking of inventory management, priority ranking of distribution networks, etc. (Kayani et al., 2023). Thus, AHP assists the Pharmaceutical Industries in formulating the decisions, regulating their operations, and affecting the judicious allocation of resources by making them firm, solid, and quantifiable in terms of subjective experience-indalings and preferences, thus leading to a complementary solution in formulating the aspects of the requisition of an efficient management System of the supply chain.

Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS) is another MCDM approach frequently used in the pharmaceutical industry to address uncertainties and vagueness present in the decision-making process (Hwang & Yoon, 1981; Chen, 1992). Fuzzy TOPSIS incorporates fuzzy logic into the traditional TOPSIS method in order to make assessments of uncertain and ambiguous information. It ranks alternatives according to their closeness to the ideal solution and farness from the negative ideal solution with respect to the criteria. Fuzzy TOPSIS has been used in different pharmaceutical sectors in supply chain management, in supplier selection, evaluating manufacturing processes, creating a distribution network, and warehouse location selection (Singh et al., 2017; Kayani et al., 2023). Fuzzy TOPSIS enables sound decision-making and enhancement of supply chain resilience to disturbances in the pharmaceutical industry through accommodating uncertainties and subjective judgment.

There are limited reports about the application of AHP and Fuzzy TOPSIS in the optimization of the supply chain, particularly in the case of pharmaceutical industries in Bangladesh. Nevertheless, with the vagaries of the sector and increasing complexities, there is a growing awareness about the importance of the application of advanced decision-making methodologies like AHP and Fuzzy TOPSIS for solving problems and improving performance. The present study attempts to contribute useful accounts to the literature through the application of AHP and Fuzzy TOPSIS methodologies for assessing and prioritizing challenges in the supply chain process of an ABC pharmaceutical company in Bangladesh. This will provide useful insights for improving operational effectiveness and competitiveness in the sector.

Methodology justification: To support the implementation of a hybrid MCDM framework, one should mention that the research goal demands (i) the identification of the relative (or comparative) significance of evaluation criteria and (ii) the classification of real-world SCM problems with subjective and uncertain expert expectations. AHP can be effectively used in the achievement of weights on criteria using structured pairwise comparisons and Fuzzy-TOPSIS can be used to rank solutions in the context of linguistic vagueness by modeling judgments using fuzzy number and comparing alternatives with ideal solutions. The complementary application of the two techniques helps to minimize the shortcomings of adopting one approach and enhances the strength of the practical application in an environment where professional evaluations are inaccurate by nature. The recent research also justifies the hybrid AHP (Fuzzy) TOPSIS-style to take advantage of systematic decision-making by integrating weighting and ranking considering uncertainty.

3. Methods

The broad objective of this study is to remodel the supply chain management of the pharmaceutical industry. The study consists of 3 basic stages:

- i. Evaluation and problem identification.

- ii. Problem ranking.
- iii. Suggestions.

In the first stage, the current supply chain management model is evaluated, and problems are identified. In this paper, initially, the current SCM model of the industry is identified by studying and analyzing many of the published research papers. Then that model is evaluated. After completing the evaluation, the problems are identified in every step of the model. In step two, the most critical problems among the total problems are identified. Then the critical problems are ranked as the most critical and the least critical problems by using the MCDM approach (Halder et al., 2018). In this paper, the AHP and Fuzzy TOPSIS MCDM approaches are used to rank critical problems. In step three, a new SCM model for the company is suggested. This model is constructed by solving critical problems one after another based on the ranking (Figure 1- Figure 2, Table 1).

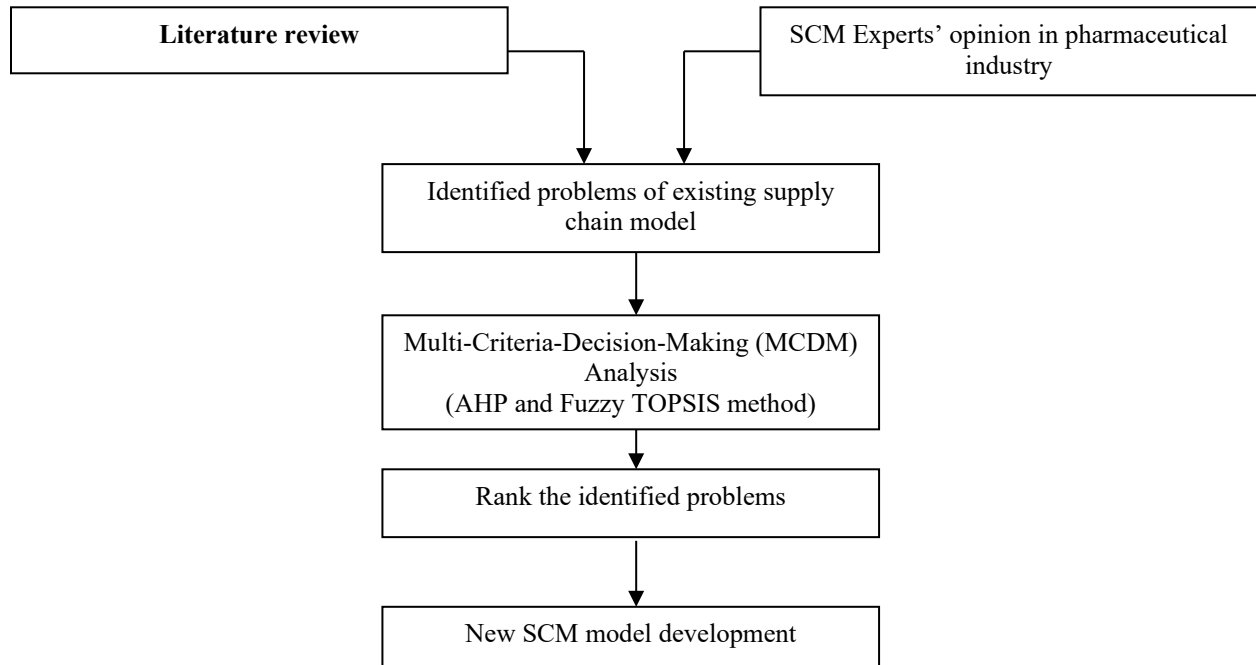


Figure 1. Research Methodology

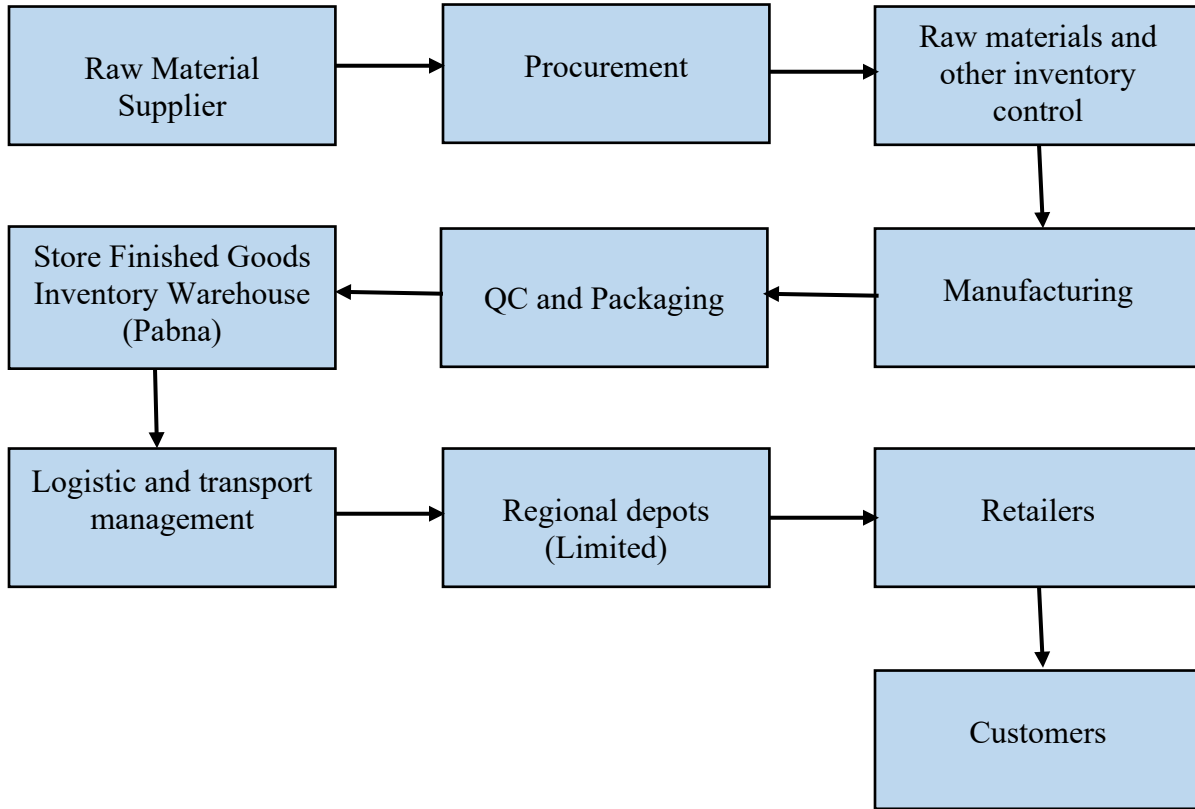


Figure 2. Existing SCM model of ABC Pharmaceutical Ltd.

Table 1. Regional Depots of ABC Pharmaceutical Ltd.

Regional Depots			
Dhaka	Barisal	Feni	Pabna
Rangpur	Mymensingh	Tangail	Bogra
Maizdee	Comilla	Faridpur	Narayangonj
Dinajpur	Brahammanbaria	Jessore	Rajshahi

3.2 Critical Problems

Figure 3 shows the critical problems of the current SCM of ABC Pharmaceutical Ltd. To identify the critical problems, a fishbone diagram, also known as an Ishikawa diagram, is used.

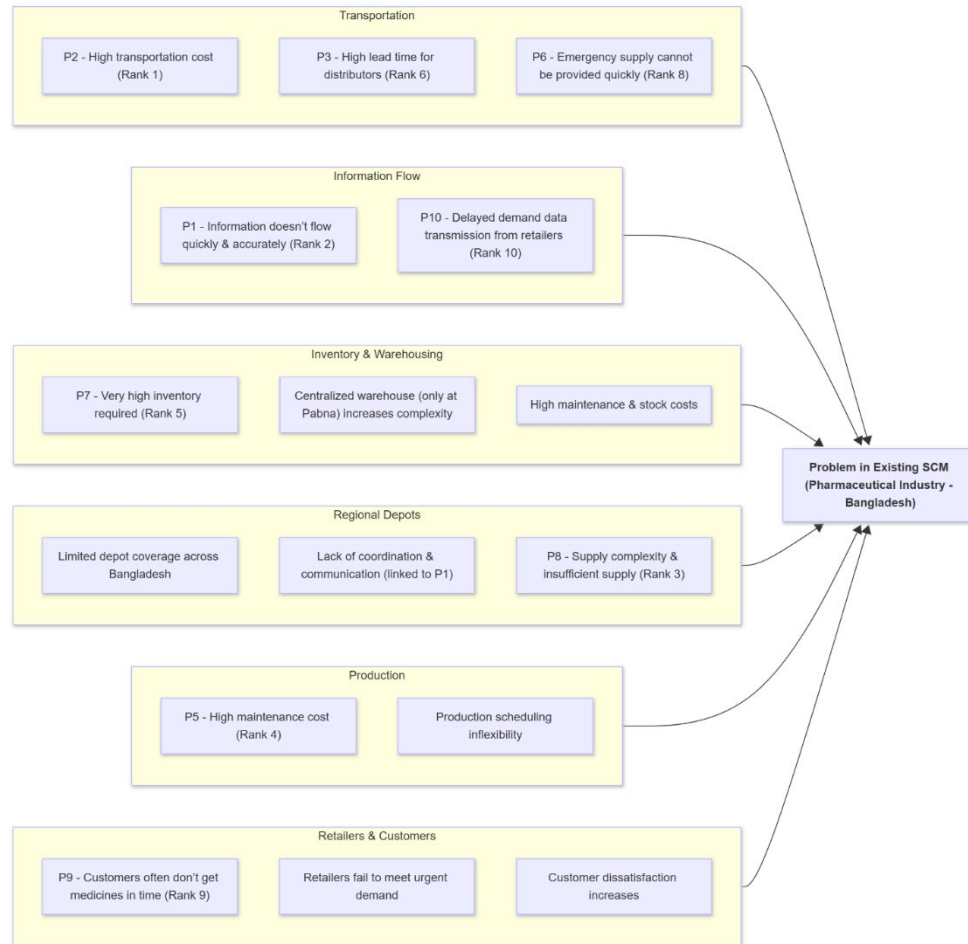


Figure 3. Fishbone (Ishikawa) diagram for critical problems identification.

Ranking of the Existing Problems through AHP and Fuzzy TOPSIS Method

In collaboration with leading supply chain management (SCM) experts in the ABC Pharmaceutical Industry, we have identified the following critical challenges that disrupt the smooth operation of the supply chain.

- The information doesn't flow quickly and accurately (P1)
- High transportation cost from warehouse to retailers (P2)
- Required lead time is high for the distributors (P3)
- Sometimes product stockouts occur in the market (P4)
- Maintenance costs are high. (P5)
- Emergency supply cannot be provided quickly (P6)
- Very high inventory is required (P7)
- Supply of products faces complexity & sufficient supply cannot be provided (P8)
- Sometimes customers don't find the necessary medicines in time, thus customer dissatisfaction creates (P9)
- Delayed transmission of demand data from retailers to distributors (P10)

The three criteria for this calculation are below:

- Impact on Supply Chain Performance (C1): Assesses how a problem affects the supply chain's overall performance, including responsiveness, resilience, and efficiency.
- Severity of Consequences (C2): Evaluates the problem's possible unsolved financial, operational, regulatory, and reputational effects.
- Feasibility of Resolution (C3): Assesses how feasible it is to solve a problem while taking time, complexity, resource availability, and potential obstacles into account.

3.3 AHP Calculation

The analytical hierarchy process evaluation scale is given in the following Table 2- Table 5.

Table 2. Analytical hierarchy process evaluation scale.

Value of a_{jk}	Interpretation
1	j and k are equally important
3	j is slightly more important than k
5	j is more important than k
7	j is strongly more important than k
9	j is absolutely more important than k
2, 4, 6, 8	Intermediate values

Step 1: Pairwise comparison of Criteria

Table 3. Pairwise comparison of Criteria.

	$C1$	$C2$	$C3$
$C1$	1	0.33	0.167
$C2$	3	1	0.33
$C3$	6	3	1
Total	10	4.33	1.5

Step 2: Consistency test

Table 4. Normalized matrix and consistency check of the comparison matrix

	$C1$	$C2$	$C3$	Wights	AW	Lambda (λ)	λ_{max}	CI	RI	CR
$C1$	0.10	0.08	0.11	0.10	0.2877	2.9996	3.0133	0.0066	0.58	0.0115
$C2$	0.30	0.23	0.22	0.25	0.7539	3.0101				
$C3$	0.60	0.69	0.67	0.65	1.9805	3.0301				

$$C. I. = \frac{\lambda_{max} - n}{n - 1} = \frac{3.0133 - 3}{3 - 1} = \frac{0.0133}{2} = 0.0066$$

$$C. R. = \frac{C. I.}{RI} = \frac{0.0066}{0.58} = 0.0115 = 1.15\% < 10\%$$

So, this comparison is acceptable.

Step 3: Pairwise comparison of the existing SCM problems

Pairwise comparison of the existing SCM problems for the criteria Impact on Supply Chain Performance ($C1$)

Table 5. Pairwise comparison of the existing SCM problems for the criteria Supply Chain Performance ($C1$)

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	Weight
P_1	1	0.33	3	5	3	7	0.2	3	7	9	0.17
P_2	3	1	3	5	3	7	5	3	7	9	0.23

P_3	0.33	0.33	1	0.2	0.33	0.11	1	3	0.14	0.2	0.05
P_4	0.2	0.2	5	1	0.2	3	0.2	0.14	3	5	0.06
P_5	0.33	0.33	3	5	1	5	3	1	3	7	0.11
P_6	0.14	0.14	9	0.33	0.2	1	0.33	0.2	3	5	0.06
P_7	5	0.2	1	5	0.33	3	1	0.2	0.33	5	0.10
P_8	0.33	0.33	0.33	7	1	5	5	1	5	7	0.13
P_9	0.14	0.14	7	0.33	0.33	0.33	3	0.2	1	3	0.06
P_{10}	0.11	0.11	5	0.2	0.14	0.2	0.2	0.14	0.33	1	0.03

Pairwise comparison of the existing SCM problems for the criteria Severity of Consequences (C2) (Table 6)

Table 6. Pairwise comparison of the existing SCM problems for the criteria Severity of Consequences (C2)

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	Weight
P_1	1	0.33	1	5	3	7	0.2	3	7	9	0.16
P_2	3	1	3	5	3	5	7	7	3	7	0.23
P_3	1	0.33	1	0.2	0.33	0.2	1	3	0.14	0.2	0.05
P_4	0.2	0.2	5	1	0.2	3	0.2	0.14	3	5	0.06
P_5	0.33	0.33	3	5	1	5	3	1	3	7	0.11
P_6	0.14	0.2	5	0.33	0.2	1	0.33	0.2	3	5	0.05
P_7	5	0.14	1	5	0.33	3	1	0.2	0.33	7	0.10
P_8	0.33	0.14	0.33	7	1	5	5	1	5	9	0.13
P_9	0.11	0.33	7	0.33	0.33	0.3	3	0.2	1	3	0.06
P_{10}	0.14	0.11	5	0.2	0.14	0.2	0.14	0.11	0.33	1	0.03

Pairwise comparison of existing SCM problems for the criterion Feasibility of Resolution (C3) (Table 7)

Table 7. Pairwise comparison of the existing SCM problems for the criterion Feasibility of Resolution (C3)

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	Weight
P_1	1	0.33	5	5	3	3	5	3	7	5	0.18
P_2	3	1	3	5	3	5	7	5	3	7	0.24
P_3	0.2	0.33	1	0.2	0.33	0.2	5	3	1	0.2	0.06
P_4	0.2	0.2	5	1	0.33	3	0.2	0.14	3	5	0.07
P_5	0.33	0.33	3	3	1	5	3	0.33	3	7	0.10
P_6	0.33	0.2	5	0.33	0.2	1	0.33	0.2	3	5	0.06
P_7	0.2	0.143	0.2	5	0.33	3	1	0.14	0.33	7	0.06
P_8	0.33	0.2	0.33	7	3	5	7	1	5	9	0.15

P_9	0.143	0.33	1	0.33	0.33	0.33	3	0.2	1	3	0.04
P_{10}	0.2	0.11	5	0.2	0.14	0.2	0.14	0.11	0.33	1	0.03

Step 4: Ranking the existing SCM problems (Table 8).

Table 8. Ranking the existing SCM problems

	C1	C2	C3	GW	Rank
P_1	0.17	0.159	0.18	0.1706	2
P_2	0.23	0.235	0.24	0.2392	1
P_3	0.05	0.052	0.06	0.0601	7
P_4	0.06	0.060	0.07	0.0655	6
P_5	0.11	0.112	0.10	0.1062	4
P_6	0.06	0.052	0.06	0.0580	8
P_7	0.10	0.103	0.06	0.0758	5
P_8	0.13	0.126	0.15	0.1427	3
P_9	0.06	0.061	0.04	0.0485	9
P_{10}	0.03	0.026	0.03	0.0296	10

3.4 Fuzzy TOPSIS Calculation

The logistic variables and their corresponding Fuzzy numbers

- Negligible - (1,2,3)
- Medium minor - (2,3,4)
- Minor - (3,4,5)
- Medium major - (4,5,6)
- Major - (5,6,7)
- Critical - (6,7,8)
- Extreme critical - (7,8,9)
- The three decision makers are DM_1, DM_2, DM_3

Step 1: Assignment of ratings to the criteria and the existing problems (Table 9)

Table 9. Assignment of ratings to the criteria and the existing problems

		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
C_1	DM_1	(1,2,3)	(2,3,4)	(3,4,5)	(6,7,8)	(5,6,7)	(6,7,8)	(4,5,6)	(6,7,8)	(2,3,4)	(7,8,9)
	DM_2	(2,3,4)	(3,4,5)	(2,3,4)	(4,5,6)	(5,6,7)	(1,2,3)	(2,3,4)	(5,6,7)	(6,7,8)	(5,6,7)
	DM_3	(1,2,3)	(4,5,6)	(3,4,5)	(2,3,4)	(3,4,5)	(6,7,8)	(5,6,7)	(4,5,6)	(5,6,7)	(4,5,6)
C_2	DM_1	(5,6,7)	(7,8,9)	(3,4,5)	(6,7,8)	(6,7,8)	(7,8,9)	(5,6,7)	(5,6,7)	(4,5,6)	(3,4,5)
	DM_2	(2,3,4)	(7,8,9)	(6,7,8)	(7,8,9)	(5,6,7)	(6,7,8)	(4,5,6)	(3,4,5)	(1,2,3)	(5,6,7)
	DM_3	(2,3,4)	(6,7,8)	(5,6,7)	(6,7,8)	(7,8,9)	(7,8,9)	(4,5,6)	(3,4,5)	(5,6,7)	(4,5,6)

C ₃	DM ₁	(4,5,6)	(7,8,9)	(5,6,7)	(4,5,6)	(4,5,6)	(7,8,9)	(6,7,8)	(5,6,7)	(5,6,7)	(4,5,6)
	DM ₂	(1,2,3)	(7,8,9)	(4,5,6)	(5,6,7)	(3,4,5)	(7,8,9)	(5,6,7)	(3,4,5)	(4,5,6)	(6,7,8)
	DM ₃	(1,2,3)	(7,8,9)	(3,4,5)	(5,6,7)	(5,6,7)	(7,8,9)	(5,6,7)	(3,4,5)	(4,5,6)	(3,4,5)

Step 2: Compute aggregate FUZZY ratings for the existing SCM problems (Table 10).

Table 10. Compute aggregate FUZZY ratings for the existing SCM problems.

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈	P ₉	P ₁₀
C ₁	(1, 2.33, 4)	(2, 4, 6)	(2, 3.66, 5)	(2, 5, 8)	(3, 5.33, 7)	(1, 4.66, 8)	(2, 5.33, 7)	(4, 6, 8)	(2, 5.3, 8)	(4, 6.33, 9)
C ₂	(2, 4, 7)	(6, 7.66, 9)	(3, 5.66, 5)	(6, 7.33, 9)	(5, 7.33, 9)	(6, 8, 9)	(4, 5.3, 3,7)	(3, 4.6, 6, 7)	(1, 4.33, 7)	(3, 5, 7)
C ₃	(1, 3, 4)	(7, 8, 9)	(3, 5, 7)	(4, 5.66, 7)	(3, 5, 7)	(7, 8, 9)	(5, 6.33, 8)	(3, 4.66, 7)	(4, 5.33, 7)	(3, 5.33, 8)

Step-3: Normalize the FUZZY decision matrix (Table 11)

Table 11. Normalize the FUZZY decision matrix

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈	P ₉	P ₁₀
C ₁	(0.25, 0.24, 1)	(.16, 0.25, 0.5)	(.2, 0.27, 0.2)	(0.12, 0.2, 0.5)	(0.14, 0.18, 0.33)	(0.12, 0.21, 1)	(0.14, 0.18, 0.5)	(0.12, 0.16, 0.25)	(0.12, 0.18, 0.50)	(0.11, 0.15, 0.25)
C ₂	(0.14, 0.25, 0.5)	(0.11, 0.13, 0.16)	(0.2, 0.17, 0.33)	(0.11, 0.13, 0.16)	(0.11, 0.13, 0.2)	(0.11, 0.12, 0.16)	(0.14, 0.18, 0.25)	(0.14, 0.21, 0.33)	(0.14, 0.23, 1)	(0.14, 0.2, 0.33)
C ₃	(0.11, 0.33, 0.44)	(0.77, 0.88, 1)	(0.33, 0.55, 0.77)	(0.44, 0.62, 0.77)	(0.33, 0.55, 0.77)	(0.77, 0.88, 1)	(0.55, 0.77, 0.88)	(0.33, 0.51, 0.88)	(0.25, 0.59, 0.77)	(0.33, 0.59, 0.88)

Step 4: Compute the weighted normalized matrix (Table 12- Table14)

Table 12. Compute the weighted normalized matrix (a)

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈	P ₉	P ₁₀	w _i
C ₁	(0.25, 0.24, 1)	(0.16, 0.25, 0.5)	(0.2, 0.27, 0.2)	(0.12, 0.2, 0.5)	(0.14, 0.18, 0.33)	(0.12, 0.21, 1)	(0.14, 0.18, 0.5)	(0.12, 0.16, 0.25)	(0.12, 0.18, 0.50)	(0.11, 0.15, 0.25)	.3
C ₂	(0.14, 0.25, 0.5)	(0.11, 0.13, 0.16)	(0.2, 0.17, 0.33)	(0.11, 0.13, 0.16)	(0.11, 0.13, 0.2)	(0.11, 0.12, 0.16)	(0.14, 0.18, 0.25)	(0.14, 0.21, 0.33)	(0.14, 0.23, 1)	(0.14, 0.2, 0.33)	.3
C ₃	(0.11, 0.33, 0.44)	(0.77, 0.88, 1)	(0.33, 0.55, 0.77)	(0.44, 0.62, 0.77)	(0.33, 0.55, 0.77)	(0.77, 0.88, 1)	(0.55, 0.77, 0.88)	(0.33, 0.51, 0.88)	(0.25, 0.59, 0.77)	(0.33, 0.59, 0.88)	.4

Table 13. Compute the weighted normalized matrix (b)

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
C_1	0.075, 0.126, 0.3	0.048, 0.075, 0.15	0.06, 0.081, 0.06	0.036, 0.06, 0.15	0.042, 0.054, 0.099	0.036, 0.063, 0.03	0.042, 0.054, 0.015	0.036, 0.048, 0.075	0.036, 0.054, 0.15	0.033, 0.045, 0.075
C_2	0.042, 0.075, 0.015	0.033, 0.039, 0.048	0.06, 0.051, 0.099	0.033, 0.039, 0.048	0.099, 0.039, 0.06	0.033, 0.036, 0.0841	0.042, 0.054, 0.075	0.042, 0.063, 0.099	0.042, 0.069, 0.3	0.042, 0.06, 0.099
C_3	0.044, 0.132, 0.176	0.308, 0.352, 0.4	0.132, 0.22, 0.308	0.176, 0.248, 0.308	0.132, 0.22, 0.308	0.132, 0.352, 0.4	0.22, 0.28, 0.352	0.132, 0.204, 0.308	0.1, 0.236, 0.308	0.132, 0.236, 0.352

Step-5: Identify the FUZZY positive ideal solution (FPIS) and FUZZY negative ideal solution (FNIS), and compute the distance of each problem from FPIS and FNIS. The closeness coefficient (CC_i) of each problem is calculated.

Table 14. Ranking the existing SCM problems

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
D^+	1.57	1.42	1.53	1.47	1.5	1.433	1.55	1.49	1.54	1.54
D^-	0.37	0.36	0.26	0.27	0.3	0.25	0.24	0.31	0.24	0.27
$\frac{D^-}{D^+ + D^-}$	0.19	0.202	0.145	0.155	0.167	0.149	0.134	0.172	0.134	0.149
Rank	2	1	8	5	4	6	10	3	9	7

4. Results and Discussion

4.1 Result Analysis

Based on the AHP technique, Table 8 shows ranking operations. (P2) has the maximum weightage value (0.2392) and got 1st rank. The problem (P1) has a 2nd rank, with a weightage value of 0.1706. P8 has got the 3rd rank, having the weightage value (0.1427) and gradually problems P5, P7, P4, P3, P6, P9, P10 have got the rank 4th, 5th, 6th, 7th, 8th, 9th, 10th with the weightage value (0.1062, 0.0758, 0.0655, 0.0601, 0.0580, 0.0485, 0.0296).

Again, based on the Fuzzy TOPSIS technique, Table 14 shows the ranking operations. The (P2) problem has a maximum weightage value (0.202) and got 1st rank. Problem (P1) has got 2nd rank having weightage value (0.19). Problem (P8) has got the 3rd rank having the weightage value (0.172) and gradually problems P5, P4, P6, P10, P3, P9, P7 have got the rank 4th, 5th, 6th, 7th, 8th, 9th, 10th with having the weightage value (0.167, 0.155, 0.149, 0.149, 0.145, 0.134, 0.134).

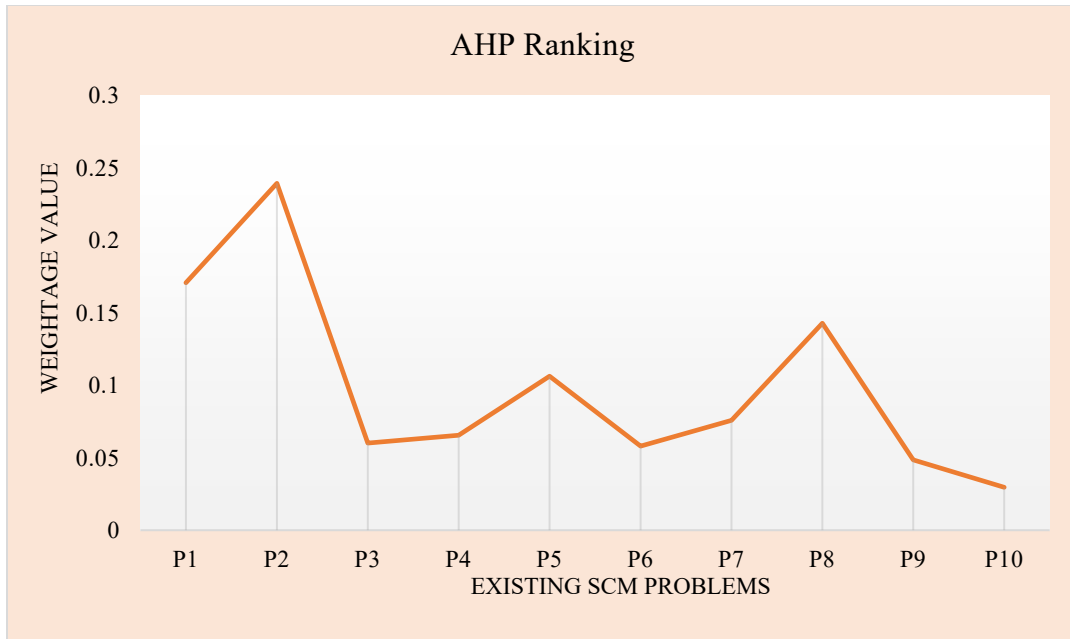


Figure 4. Rating result of AHP.

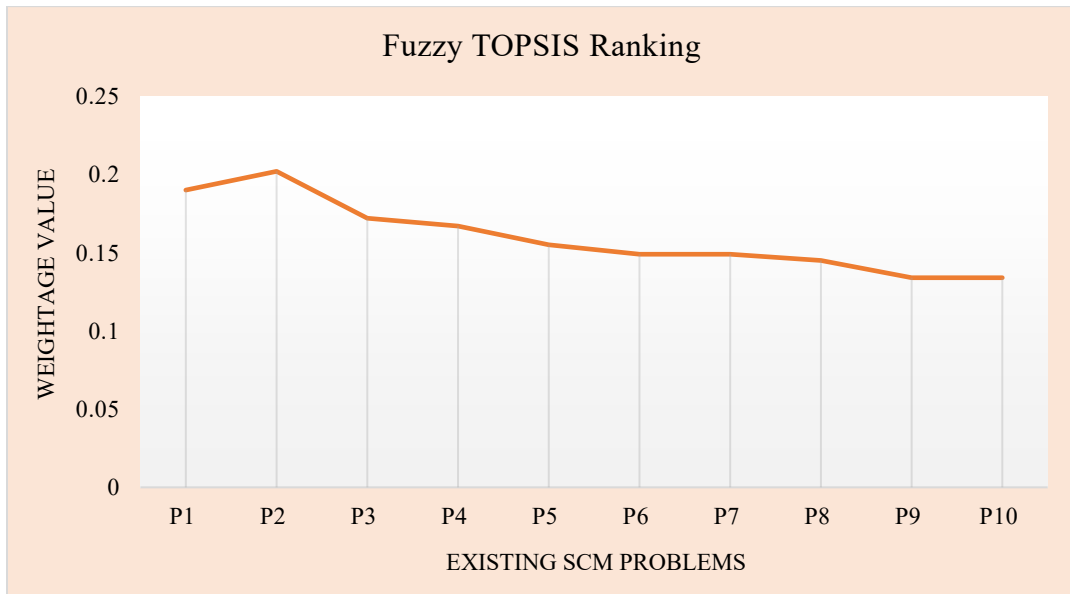


Figure 5. Rating result of Fuzzy TOPSIS.

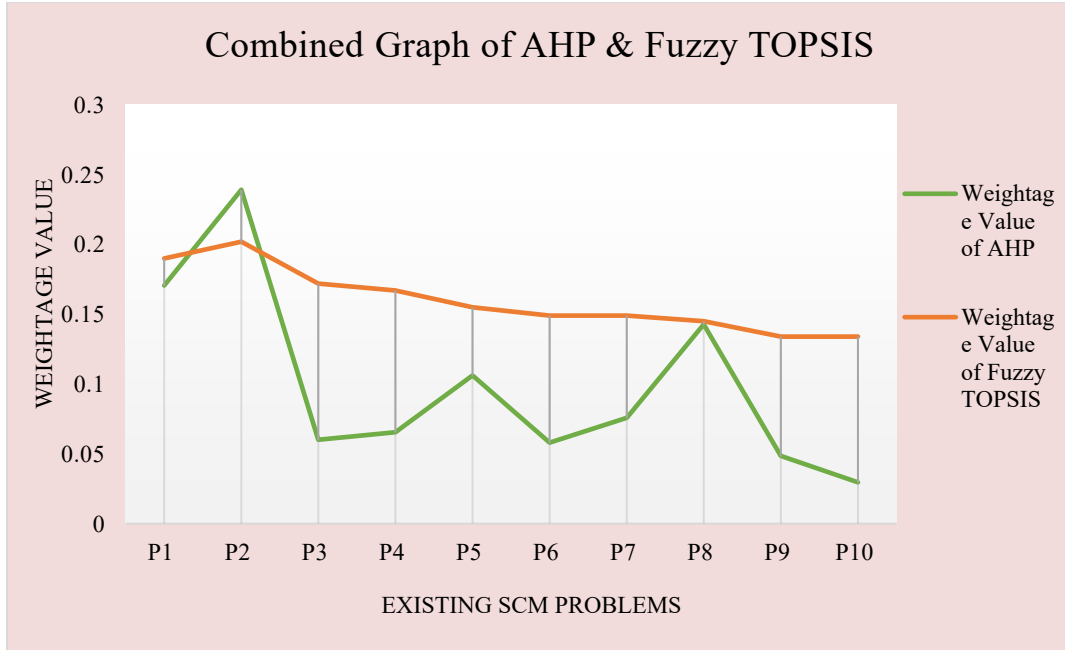


Figure 6. Combined rating result of AHP & Fuzzy TOPSIS.

Here, it is observed that the above two methods (Figure 4- Figure 6), problem P₂, are selected as the most critical problem of the current SCM model. But the other rank is not the same for other existing SCM problems. So, for the actual ranking, we must calculate the average rating scores of the two methods. That calculation is shown below.

$$C_{AVG} = \frac{(C_{AHP} + C_{Fuzzy\ TOPSIS})}{2}$$

Table 15. Average rating result of the two methods

Problems	Weightage Value of AHP	Weightage Value of Fuzzy TOPSIS	Average	Rank
P ₁	0.17	0.19	0.18	2
P ₂	0.24	0.202	0.22	1
P ₃	0.06	0.172	0.12	6
P ₄	0.07	0.167	0.12	5
P ₅	0.11	0.155	0.13	4
P ₆	0.06	0.149	0.10	8
P ₇	0.08	0.149	0.11	7
P ₈	0.14	0.145	0.14	3
P ₉	0.05	0.134	0.09	9
P ₁₀	0.03	0.134	0.08	10

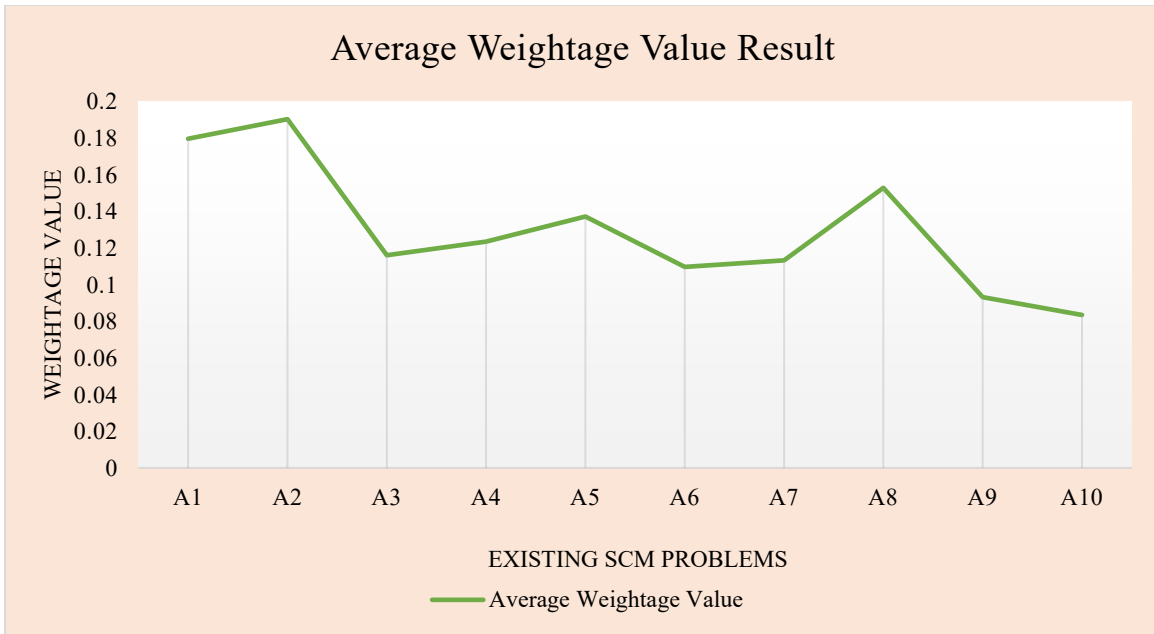


Figure 7. Average weightage value result of the two methods.

The final ranking of the critical problems is arranged as $P2 > P1 > P8 > P5 > P4 > P3 > P7 > P6 > P9 > P10$ in the above Table 15. The result shows that P2 is the most critical problem and P10 is the least critical problem among the ten critical problems that exist in the current SCM model of ABC Pharmaceutical Industry Ltd., Bangladesh (Figure 7). To achieve an effective SCM model, these problems need to be solved.

4.2 Suggestion regarding Current Problems

From the above calculation, it is ensured that the major difficulty the current SCM model of the ABC pharmaceutical industry is facing is high transportation costs from the warehouse to retailers. Then the problem is that the information is not flowing quickly and accurately from the root level to the top management. The company has only one finished good inventory warehouse, which is located at Pabna, from where the products are supplied to a number of regional depots. It is a time-consuming matter, as well as the supply facing much more complexity. And the company has to keep a large amount of finished goods inventory there, for this, the warehouse needs a high maintenance cost. These activities create a number of non-value-added situations for the company and create a huge amount of waste.

These problems need to be solved. In this case, our recommendation is that the company should increase its finished goods inventory warehouse. The only warehouse is located in the Southeast part of Bangladesh. From there, the regional departments of Sylhet zone, Chittagong zone, Barisal zone, and Khulna zone are a long distance apart. The transportation cost, lead time, complexity of transportation, and so on are creating many more difficulties for the company to supply products from the warehouse to these long-distance regional depots (Figure 8).

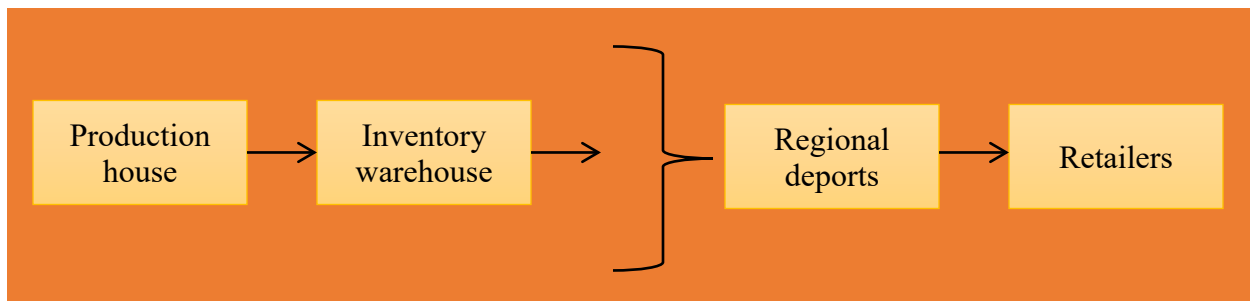


Figure 8. Current Distribution System.

So, our recommendation is that the company may establish three or four more finished goods inventory warehouses at Sylhet, Chittagong, Barisal, and perhaps at Khulna zone to ensure smooth supply of their products even in case of any kind of emergency. The proposed distribution model is shown in Figure 9.

There are some other proposals for reducing those difficulties, which are described below-

- i. Companies may increase their regional departments. Currently, the company has twenty departments all over the country. The company may establish its depot in every district of the country. It will help to eliminate the information gap between the customers and the company. Besides, it will help to reduce transportation costs and the lead time of transportation. It will also help the company to reduce the sudden stockout problem in the market.
- ii. The company may increase the use of small transportation vehicles. It may help the company to reach the rural markets, which will help the company to satisfy its customers. Besides, it may help the company to increase its sales in the rural areas of Bangladesh.
- iii. Cross-docking may be applied to increase quick response. In a traditional warehouse, goods are received from vendors and stored in devices like racks or shelves. When a customer requests an item or items, workers pick them from the shelves and send them to their destination. In cross-docking, goods arrive from the vendor and already have a customer order. So, the workers need only to move the shipment.
- iv. The concept of reverse logistics is the process of moving goods from their typical destination for the purpose of capturing value or proper disposal. Usually, logistics deals with events that bring the product to the customers. In this case, the resource goes at least one step back in the supply chain. Thus, the company may also apply this process.
- v. The company should be assured of being free from political problems. The Government should provide proper marketing rights for pharmaceutical products that are fully consistent with flexibility.
- vi. Employee turnover may be reduced if the company ensures proper benefits and facilities.
- vii. The Government should make appropriate measures to mend inappropriate roads, traffic snarls, and extortion issues, etc, so that the delivery of the medicines is not delayed.

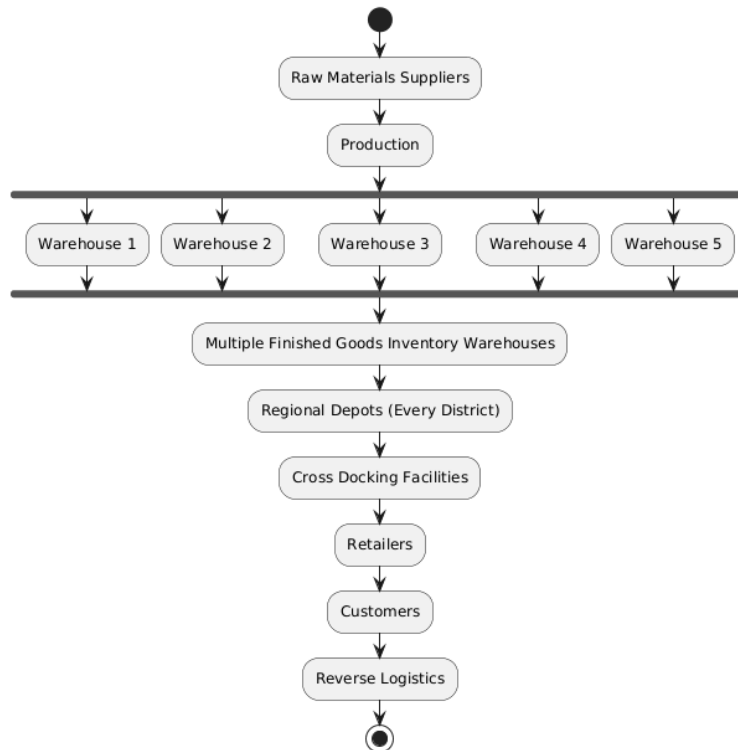


Figure 9. Proposed Distribution System.

The suggestions in this study address the significant concerns observed in the current supply chain model. It can be argued that at the onset of implementation of these recommendations, it will seem that the operations may become costlier, but it is hoped that in the long term, the impact will be highly positive to the company. The new model will experience an increase in overall efficiency, which will translate to more product sales and hence will translate to customer satisfaction.

The proposed structure will ensure that the firm relies on a small number of medical representatives thereby limiting the number of personnel costs. Another estimated outcome of the redesigned system is the lowering of the transportation cost and order lead time which will in turn enable the company to reduce the price of the products and compete favorably in the market. The most important resource of any business is that of the customers and these strategic additions should improve customer loyalty and service quality and long-term viable growth and profitability.

4.3 Description of Suggested Improved Model

Raw Materials Suppliers: Continue supplying raw materials to the manufacturing units to keep smooth operations.

Manufacturing: The process of turning raw materials into finished goods is the same procedure as before.

Multiple Finished Goods Inventory Warehouses: Establish multiple warehouses in Sylhet, Chattogram, Barisal, and Khulna to reduce lead times and transportation costs.

Increase Regional Depots: Establish depots in every district to increase distribution efficiency and reduce stockouts.

Cross-Docking Facilities: Implement cross-docking to speed up the supply chain, moving goods straight from inbound to outbound shipment.

Retailers: Deliver products more efficiently and quickly to retailers.

Customers: The retailers provide the final products to the customers more promptly.

Reverse Logistics: Implement reverse logistics to better manage returns and recycling while maximizing resource efficiency and value recovery.

4.4 Benefits of the Suggested Model

Reduced Transportation Cost: The transportation costs are significantly reduced by having multiple warehouses.

Improved Information Flow: Better and quicker information flows from lower management to upper management.

Reduced Lead Times and Complexity: Shorter distances to regional depots simplify transportation and decrease lead times.

Lower Maintenance Costs: Spreading inventory across multiple warehouses reduces the burden on any single facility.

Increase Customer Satisfaction: Quicker and more dependable deliveries improve customer satisfaction.

Increased Sales in Rural Areas: More regional depots and smaller transportation vehicles enhance reach and market penetration.

Better Handling of Emergencies: Multiple warehouses ensure supply stability in risky circumstances.

Cost Savings: Reduced need for medical representatives, lower transportation costs, and faster responses reduce overall expenses.

Improved Product Pricing: Reduced overall expenses enable the company to offer more affordable prices.

This proposed model addresses the existing problems and improves overall efficiency, leading to a more resilient and adaptable supply chain.

5. Conclusion

This research study presents an analysis of the existing supply chain management (SCM) model of a national pharmaceutical company in Bangladesh to enable more competitive and efficient operations. Its aims were to find out the limitations of the current SCM system, to define which of the issues are the most severe, to measure and rank these issues, and to suggest effective directions of improvement. A fishbone (cause-effect) diagram was used to identify ten priority SCM problems, after which hybrid Multi-Criteria Decision-Making (MCDM) framework based on AHP and Fuzzy TOPSIS was used to prioritize the ten problems. Quantitatively, high transportation cost between warehouse and retailers (P2) is the highest-priority problem, thus being ranked 1st (AHP = 0.24, Fuzzy-TOPSIS = 0.202, Average = 0.22), then there is slow/inaccurate flow of information (P1) that is ranked 2nd (AHP = 0.17, Fuzzy-TOPSIS = 0.19, Average = 0.18). Supply complexity/insufficient supply (P8) is the next significant issue with a 3rd position (AHP = 0.14, Fuzzy-TOPSIS = 0.145, Average = 0.14). These findings give a precise quantitative background to targeted

interventions and directly inspire the suggested to-be SCM design, such as regional warehousing and depot restructure to lessen transportation load (solving P2), cross-docking and enhanced coordination to elevate responsiveness and reduce delays (solving P1/P8), and reverse logistics to enhance overall robustness.

The suggested diagnostic-and-redesign model may be implemented into other pharmaceutical companies in Bangladesh and could be further applied to other industrialization industries (i.e., RMG, leather, electronics, shipbuilding). Future research can enhance resilience through the inclusion of a more comprehensive array of quantitative and qualitative indicators, complementary validation of the priority setting with other MCDM tools (e.g., ANP, ELECTRE, Fuzzy-AHP, MOORA, ORESTE), and development of new digital enablers including AI-based forecasting and blockchain-based traceability to provide support to pharmaceutical SCM operations and stability.

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Biographies

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Md. Mahafuj Anam Murad is an undergraduate student of the Department of Industrial and Production Engineering, Jashore University of Science and Technology (JUST), Bangladesh. His area of research interest is Supply Chain Management, Process Optimization, Virtual Reality (VR), Digital Twin & Sensor-Based Modelling for Industrial Applications. He has worked on several ergonomics, supply chain optimization and human-machine interaction related research projects. Murad has presented and published his work at national and international conferences. He also went through industrial training institutions of the Bangladesh Industrial Technical Assistance Centre (BITAC) and the Bangladesh Knitwear Manufacturers and Exporters Association (BKMEA), where he learned about practical knowledge of production systems and industrial operations.

Sifat Ajmeer Haque has completed his Bachelor from the Department of Industrial and Production Engineering, Jashore University of Science and Technology (JUST), Bangladesh. He is passionate about solving problems in the manufacturing industry, especially in plastic production. His research focuses on improving quality management in small businesses and exploring how Industry 4.0 can be better applied in industries. Currently, he is working on making processes more efficient in plastic manufacturing by using methods like SMED to save time and energy.

Sarojit Kumar Biswas is currently working as an Assistant Professor in the Department of Industrial and Production Engineering at Jassore University of Science and Technology (JUST), Bangladesh. He received his B.Sc. in Industrial and Production Engineering from Rajshahi University of Engineering and Technology (RUET) in 2012. His research interests focus on Supply Chain Optimization, System Dynamics, Production Scheduling and Ergonomics. He published his research in several international conferences and journals.

Dr. Tzu-Liang (Bill) Tseng is a professor and Chair of Department of Industrial, Manufacturing and System Engineering at the University of Texas at El Paso (UTEP). He received his M.S. degree in Industrial Engineering (concentration on manufacturing systems and operation research/decision sciences) from the University of Wisconsin at Madison in 1993 and 1995 respectively and Ph.D. in Industrial Engineering from the University of Iowa in 1999. Dr. Tseng is also a Certified Manufacturing Engineer from Society of Manufacturing Engineers since 2002. Dr. Tseng specializes in remote collaborative product design, manufacturing process, data mining, knowledge management, specifically in the area of Internet Based Decision Support System (IBDSS). Over the years, he has served as principal investigators of IBDSS and Knowledge Management System (KMS) sponsored by NSF, KSEF and industry. Before joining UTEP in 2004, he served as a faculty at the Department of Manufacturing Sciences at Western Kentucky University and as a senior research fellow at the Institute of Manufacturing Technology. He has been serving as PI and Co-PI of several research projects funded by NSF, NSF-EPSCoR, KSEF, DoEd and Tyco Inc. Dr. Tseng delivered research results to many refereed journal and conference publications such as IEEE Transactions, IIE Proceedings, International Journal of Product Research, Expert Systems with Applications and Computer Standards & Interfaces (over 200 publications). He has given many technical presentations in research conferences like INFORMS, Industrial Engineering Research Conference (IERC), International Conference on Industrial Engineering Theory, Applications and Practice and World Multiconference on Systemics, Cybernetics and Informatics (SCI) Conference. Dr. Tseng is also awarded the 'Who's Who in America?' in 2005-2006. He is a Senior Member of Institute of Industrial Engineers, American Association for Artificial Intelligence and is actively involved in several consortia activities.