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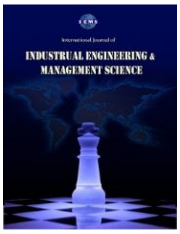

Supply chain analysis and improvement by using the SCOR model and Fuzzy AHP: A Case Study

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1 Analysis
2 Improvement
3 Supply Chain
4 SCOR
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A B S T R A C T

Due to the growing competition in supply chains, continuous updates of the supply chain structure are necessary for companies' durability and competitiveness. Therefore, Successful companies, regardless of their current position, are constantly striving to improve and upgrade their supply chain. A lot of research has been conducted so far to achieve the above goals. Hence, the present study aimed to use an appropriate method based on the standard framework of criteria and processes to improve the supply chain capabilities. This standard framework is the supply chain operations reference model (SCOR). Along with this, Fuzzy AHP has been used for valuation plans. The plans provided based on the best practices of the SCOR model. After analyzing the processes and mapping existing supply chain, the pairwise comparisons data obtained from the questionnaire that was completed by the expert of this field, by the use of Fuzzy AHP technique and based on the criteria of the SCOR model, the plan with the maximum weight, was selected and according to it, changes were made in the supply chain. Given to illustrate the theory.

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1 Introduction

A supply chain is a network of participants (e.g., suppliers, manufacturers, warehouses, distributors, and retailers) who, through coordinated plans and activities, develop products by converting raw materials into finished products (Chiadamrong and Piyathanavong, 2017). Supply chains are facing numerous changes that are contributing to increasing their complexity and vulnerability to disturbances (Carvalho et al., 2012). The necessity to coordinate several business partners, internal corporate departments, business processes and diverse customers across the supply chain gave rise to the field of supply chain management (SCM) (Turban et al., 2011). Supply chain management includes coordination and motivation of independently operating partners. Therefore, it is important to align logistics structures, processes and incentives, especially when making major changes involving those components (Lundin, 2012). Supply chain management means managing flow of product, information, and financial resources between different stages of the supply chain to maximize profit and value for the entire supply chain. Also Supply Chain Management is defined by Agarwal et al. (2006) as the integration of key business processes from end user through to the original suppliers that provides products, services and information and hence adds value for customers and other stakeholders. Given that the complexity of supply chains is growing in a competitive environment, SCM needs to constantly perform redesigning and renovation their supply chain to improve value and performance. Villarreal et al. (2004) argue supply Chain continuous improvement has become a necessary strategy for businesses to attain the required performance level to compete worldwide. Unlike the supply chain (SC) design problem which deals with the configuration of a new SC, the redesign problem assumes that a SC already exists and focuses on its reconfiguration in order to take profit of the changing logistics, financial, and fiscal advantages offered by each country (Hammami and Frein, 2014). Supply chain redesign involves decisions on facility location, relocation, investment, disinvestment, technology upgrade, production-allocation, distribution, supply contracts, capital generation, etc (Naraharisetti et al., 2008). Although a number of methodologies exist for business process redesign (BPR), supply chain re-design (SCR), and e-business process design, there is a lack of an integrated BPR methodological framework to support supply chain integration (SCI) (Palma-Mendoza et al., 2014). A supply chain re-design can achieve radical improvement but can also be risky if it is not focused on the appropriate process; thus, if supply chain process re-design is going to take place, it is better to focus on a target process (Ashayeri et al., 1998). So According to this, identification of relevant supply chain processes and selection of a target process for re-design is One of the critical steps that Palma-Mendoza (2014) and Huan et al. (2004) have provided a solution based on the combination of the SCOR model and the analytical hierarchy process. Palma-Mendoza (2014) has proposed a solution to using the Supply Chain Operations Reference (SCOR) model for the identification of relevant supply chain processes and Analytical Hierarchy Process (AHP) for the selection of a target for the redesign. Redesigning the supply chain if properly implemented, can dramatically improve performance of supply chain.

The rest of the paper is organised as follows. In section 2, the SCOR model, fuzzy AHP and The benefits of combining them are discussed. Section 3, introduces the studied case. In Section

4, the research methodology is described. In Section 5, the studied case is analyzed according to the proposed method and the results are reported. Finally, the conclusions and suggestions for future research are presented in Section 6.

2 Literature review

2.1 Overview of the SCOR model

The SCOR model is a supply chain performance evaluation model. It provides a consistent supply chain management framework, including business process, performance evaluation, and the best practice. It can help all participants of a supply chain, including manufacturers, first-tier and second-tier suppliers, downstream retailers/distributors/logistics service providers and customers, to improve the efficiency of supply chain management thereafter by communicating effectively via the reference model (Hwang et al., 2008). The SCOR is a cross-industry, standard supply chain model that forms analytical tools for the supply chain on the basis of process, performance evaluation and best practice (Hwang et al., 2008). SCOR provides a standard description of supply chain processes, performance metrics, best practice and enabling technologies. It offers a comprehensive methodology to improve supply chain operations (Georgise et al., 2012). This process reference model designed to facilitate communication among supply chain members. It provides a common language for communication and is used to describe a measure and evaluate the supply chain configuration (Georgise et al., 2012). One of the applications of the SCOR model is to aid the understanding of a particular supply chain by means of mapping it in business process terms using SCOR model terminology (Wang et al., 2010). Thus, mapping with SCOR model will show the relevant SC processes present in the particular supply chain under study (Palma-Mendoza, 2014). The performance section of the SCOR consists of two types of elements: Performance Attributes and Metrics Shown in Table

Table 1 The SCOR Performance Attributes and Level 1 Metrics Source: (SCC, 2012)

Performance Attribute	*Level-1 Strategic Metric*
Reliability	Perfect Order Fulfillment
Responsiveness	Order Fulfillment Cycle Time
Agility	Upside Supply Chain Flexibility Upside Supply Chain Adaptability Downside Supply Chain Adaptability Overall Value At Risk
Cost	Total Cost to Serve
Asset Management Efficiency	Cash-to-Cash Cycle Time Return on Supply Chain Fixed Assets Return on Working Capital

2.2 Fuzzy analytic hierarchy process

Fuzzy Analytic Hierarchy Process (F-AHP) embeds the fuzzy theory to basic Analytic Hierarchy Process (AHP), which was developed by Saaty (1980). AHP is a widely used decision-making tool in various multi-criteria decision-making problems. It takes the pair-wise comparisons of different alternatives with respect to various criteria and provides a decision support tool for multi-criteria decision problems (Ayhan, 2013). (Van Laarhoven and Pedrycz, 1983) for the first time extended the analytical hierarchy process to fuzzy analytical hierarchy process replacing triangular fuzzy numbers in the pairwise comparison matrix and using the fuzzy logarithmic least squares method. They did this based on the expanded method of the Saaty analysis developed by De Graan (1980) And Lootsma (1980) using logarithmic least squares. Later, Buckley (1985) proposed the use of Trapezoidal numbers, since he believes that these numbers are better understood by the experts. He calculated priorities using geometric mean and then, calculated the final fuzzy weights by combining them with the Saaty's hierarchy and eventually, prioritized them using a fuzzy ranking. Chang (1996) proposed another approach called the "extent analysis method", considering the fuzzy triangular numbers in the pairwise comparison matrix. He first combined the elements of each row and then normalized it; finally, he calculated the probability degree of any number being larger than others, introduced it as the weight of the alternatives after normalization. This method provides crisp weights for the pairwise comparison matrix. However, it should be noted that, as Saaty showed, although very simple and applied, this method can only be used in cases where matrices are fully compatible. Gogus and Boucher (1997) claimed that the reason for the generation of irrational weights lies in the fuzzy triangular pairwise comparisons provided by the decision makers, rather the methods presented by the researchers. One year later, Gogus and Boucher (1998) developed the evolved method based on strong transmissibility with any number of decision makers. The analytical hierarchy process is widely used to make decisions in a real situation. However, despite its simplicity and efficiency, it has often been criticized because of not considering the carelessness and inherent uncertainty of decision makers' perceptions and the reflection of their views as a crisp number. In normal AHP, decision makers' views are expressed as a crisp number, however, it may not be accurate because of the ambiguity and uncertainty in the evaluation, since many criteria are intrinsically qualitative and subjective, and it is impossible for the decision-maker to assign an absolute and crisp number for evaluating them. Hence, the use of fuzzy numbers is more consistent with verbal and sometimes ambiguous human statements. Therefore, it is better to make real decisions based on fuzzy numbers.

2.3 The change extended analysis method

Chang (1992) presented a very simple method to extend the analytical hierarchy process to fuzzy space. The method, which is developed based on arithmetic mean of expert opinion and Saaty's normalized method using triangular fuzzy numbers, was considered by the researchers.

2.3.1 The method implementation phases

Step 1: Drawing a hierarchical tree: At this stage, the decision-making hierarchy structure is drawn using the criteria and alternative target levels.

Step 2: forming the pairwise comparison matrix: the concordance matrices are composed according to the decision tree and using expert opinions by triangular fuzzy numbers as shown in table 2 .

Table 2 Linguistic terms and the corresponding triangular fuzzy numbers

Saaty's scale relative importance	*Linguistic scales*	*Fuzzy Triangular Scale*
1	Equally important	(1, 1, 1)
3	Weakly important	(2, 3, 4)
5	Fairly important	(4, 5, 6)
7	Strongly important	(6, 7, 8)
9	Absolutely important	(8, 9,10)
2	The intermittent values between two adjacent scales	(1, 2, 3)
4		(3, 4, 5)
6		(5, 6, 7)
8		(7, 8, 9)

Step 3: Fuzzy comparison inconsistency ratio: One of the important steps in the fuzzy AHP method is to calculate the inconsistency ratio. This ratio should always be less than 0.1 for comparisons to be appropriate and if this rate is greater than 0.1, then the comparison should be revised. The rate of inconsistency states whether this paired comparison was performed correctly or not. In this paper, the Gogus and Boucher (1998) method is used to calculate the inconsistency ratio.

Step 4: arithmetic mean of views: the arithmetic mean of decision-makers' views are calculated to obtain the following matrix.

$$\tilde{A} = \begin{bmatrix} (1.1.1) & \tilde{a}_{12} & \tilde{a}_{1n} \\ \tilde{a}_{21} & (1.1.1) & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & (1.1.1) \end{bmatrix} \quad (1)$$

$$\tilde{a}_{ij} = \frac{\sum_{K=1}^{P_{ij}} a_{ijk}}{P_{ij}} \qquad i,j=1,2,\ldots,n \quad (2)$$

Step 5: Calculating the sum of the row elements: the sum of the row elements should be calculated.

$$\tilde{S}_i = \sum_{j=1}^{n} \tilde{a}_{ij} \quad (3)$$

Step 6: Normalizing: the sum of the rows should be normalized in this stage.

$$\tilde{M}_i = \tilde{S}_i \otimes \left[\sum_{i=1}^{n} \tilde{S}_i\right]^{-1} \quad (4)$$

If $\tilde{S}_i$ is shown as $(l_i . m_i . u_i)$ then above relationship is calculated as follows.

$$\tilde{M}_i = \left(\frac{l_i}{\sum_{i=1}^{n} u_i} . \frac{m_i}{\sum_{i=1}^{n} m_i} . \frac{u_i}{\sum_{i=1}^{n} l_i}\right) \quad (5)$$

Step 7: Determining the degree possibility of being greater: the probability of being greater should be calculated for each μ_i than the other μ_i and called as $d'(A_i)$.

$$d'(A_i) = \text{Min V} (M_i \geq M_k) \qquad k=1,2,\ldots,n \;\; k \neq 1 \quad (6)$$

Then, the matrix weight vector is obtained as follows:

$$W' = \left(d'(A_1)\right).\left(d'(A_2)\right).\dots.\left(d'(A_n)\right)\mathrm{T} \quad (7)$$

Step 8: normalizing: the normalized weights should be obtained by normalizing the weights vector(W').

$$\mathrm{W}=\left[\frac{d'(A_1)}{\sum_{i=1}^{n} d'(A_i)}.\frac{d^1(A_2)}{\sum_{i=1}^{n} d'(A_i)}.\dots.\frac{d'(A_n)}{\sum_{i=1}^{n} d'(A_n)}\right] \quad (8)$$

The above weights are crisp (non-fuzzy) weights. The rotation of all matrices is obtained by repeating this process.

Step 9: Combining weights: the final weight of the alternative is obtained by combining the alternative and criteria weights.

$$\widetilde{U}_i = \sum_{j=1}^{n} \widetilde{w}_i.\tilde{r}_{ij} \quad (9)$$

2.4 Combining AHP and SCOR

A number of authors propose to use AHP to identify and select target processes (Korpela et al., 2001; Palma-Mendoza, 2014). In summary, it is clear that for the selection of a target for the redesign, it is necessary to define a set of criteria, and then perform a comparison among the processes identified against the criteria. Multi-criteria decision analysis appears the most adequate in particular when it can be combined with the SCOR model to establish standard criteria for comparison (Palma-Mendoza, 2014). Some processes in a supply chain are more critical than others. Thus, in order to differentiate the degree of importance among several supply chain processes, it is proposed to use multi-criteria decision analysis such as AHP as a decision support tool for process selection. Results provided by the AHP analysis go beyond target process selection. From the AHP analysis, it is possible to calculate a priority rank for the metric criteria used; thus, making it possible to identify the most important SCOR metrics associated with the target for re-design. Identification of these relevant metrics will be the starting point for the definition of objectives for improvement (Palma-Mendoza, 2014). This structured approach facilitates decision making. The SCOR model is a hierarchical model that consists of different process and metric levels; thus, it seems natural to combine the AHP with the SCOR model (Li et al., 2011). Figure 1, presents the performance attributes of the SCOR model in the form of analytical hierarchy process structure.

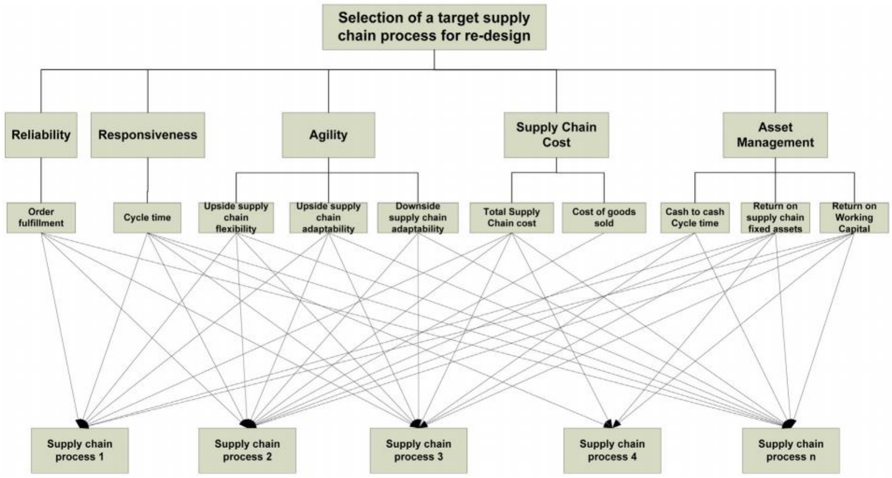


Figure 1 AHP structure for selection of a target supply chain process for re-design.

Source: Palma-Mendoza (2014)

3 Overview of pakshima company

Pakshima is a detergent manufacturer company in one of the northwestern cities of Iran. The products of the company are distributed at local and foreign markets. The countries where the company's products are distributed are most of the neighboring countries. Due to the increasing number of detergent manufacturers and product diversity, the company needs to reform its supply chain to maintain its competitive strategy. To achieve this, we use the method outlined in this article. It should be mentioned that the inputs of the company include chemicals and detergent containers. As well as, transporting, storing and distributing is conducted by the company itself after the production of detergents.

4 Research methodology

Improvement in the company's current supply chain is our goal which will be realized through identifying processes, identifying existing opportunities and providing plans for change Based on SCOR metrics, processes, and best practices. Therefore, a decision-making group was formed including experts from different decision-making units. For each of the relevant criteria and attributes of the SCOR model, detailed discussions were conducted and, finally, the work was started to select the best alternative considering three improvement plans. The hierarchical structure designed for this purpose consists of the general objective at first level, the performance attributes of the SCOR model in the second level, the level-1 strategic metric of the SCOR model in the third level, and finally, the improvement plans at the final level (figure 4). In the present study, for easier understanding, we define the performance attributes as criteria, the level-1 strategic metric as sub-criteria, and improvement plans as alternatives in the hierarchical structure. Comparison of the importance of criteria, sub-criteria, and alternatives was conducted using a questionnaire. The questionnaire facilitates answering the pairwise comparison questions. The preference of a criterion to the other was determined using experts' knowledge and experience. Firstly, experts pairwise compared the criteria; then, compared the sub-criteria with respect to the criteria; finally, they compared improvement plans with respect to each of sub-criteria. Thereafter, priority weights were calculated for each of the criteria, sub-criteria and alternatives using the fuzzy AHP approach. Finally, Alternative with the highest weight selected to improve supply chain.

5 Case analysis

5.1 mapping existing supply chain

The SCOR model uses four separate charts and maps to model each supply chain. Each of these models may pursue different goals which are as follows:

1. Business Scope Diagram: This graph specifies the scope of a project or organization.
2. The geographic map: shows the material flows on the surface of a geographic map, and the complexity or redundancy of the nodes (each node in this map represents a logical or geographic entity in a supply chain; such as warehouse, factory, store, and so forth).
3. Thread diagram: This diagram is the same material flow diagram for level 2 processes. In this diagram, the complexity or redundancy of high - level processes is known.
4. Process flow diagram or process models: It deals with the analysis of workflows, materials, and information on level 3.

5.2 Level 2 Processes of Studied case

Recognizing the type and form of inter-organizational processes is another important factor in understanding the supply chain. Hence, a study was conducted on the second-level processes of the SCOR model along with the identification and allocation of each of these processes to the relevant departments. In this regard, the SCOR processes map is utilized as the basis for evaluating and understanding the supply chain.

5.2.1 AS IS process thread diagram

level-2 process diagrams help identify structural issues in the supply chain. Thread diagram shows the flow of products (including tangible goods and services) as a chain of linked activities. Product flow represents the transfer of a product from one process to another (Leukel and Sugumaran, 2013). Bolstorff and Rosenbaum (2012) propose to use the SCOR model to capture the AS-IS (current status) of a supply chain under study. The use of the AS IS and TO BE charts is also an effective way to turn the perspective into the results. The AS IS chart indicates the status quo and current capabilities of the organization's processes. The main purpose of this chart should be towards the way that improvements are needed and the starting point for the changes. Figure 2 represents the SCOR Thread diagram for the Pakshima Company based on the companies' current processes. The SCOR processes, related to each step of the supply chain, were described below:

Supplier's delivery processes: As can be seen in the figure 2, after the delivery planing (P4) supplier delivery planning to meet delivery requirements. Since chemicals are produced and stored on the supplier's site without receiving the order, and they are only produced and stored based on sales forecasts, then, the relevant delivery activity is (D1), which is performed for the delivery of the Stocked Product. Since the containers of the materials are ordered to the supplier according to the needs and the amount of production, then, the supplier attempts to produce and deliver upon receipt an order. Therefore, the act of their delivery (D2) is related to the delivery of production products based on order or in other words, deliver Make-to-Order Product (MTO).

Sourcing, Making and Delivery processes of studied case: The level 2 process of Pakshima Company include the supply chain planning (P1), Plan Source or planning for raw material requirements including chemicals and containers (P2), Plan Make or production planning to meet production requirements (P3), delivery planning to meet delivery requirements (P4), Source Stocked Product or sourcing raw materials with persistent storage in which no customer reference or customer order detail is exchanged with the supplier (S1), Source Make-to-Order Product or ordering and receiving raw materials based on customer order (S2), manufacturing activities for a specific customer order (M2), and products delivery activities (D2).

Warehousing processes : Also in storage, the planning activities (P1), (P2), (P4) and sourcing activities (S2) and delivery activities (D1) are underway by pakshima.

Customer Sourcing processes: The customers are also planning to source products (P2), retailers order their products from the warehouse, where the company's products are stored for the local market (S1), and foreign customers receive their products on demand by direct order to the company (S2).

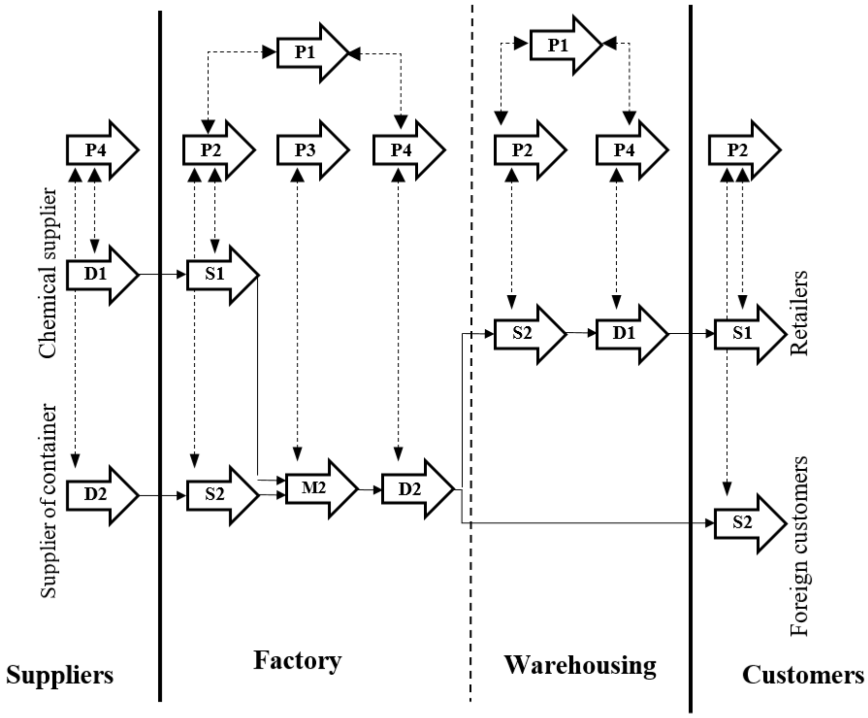


Figure 2 AS IS Process Thread Diagram of Pakshima

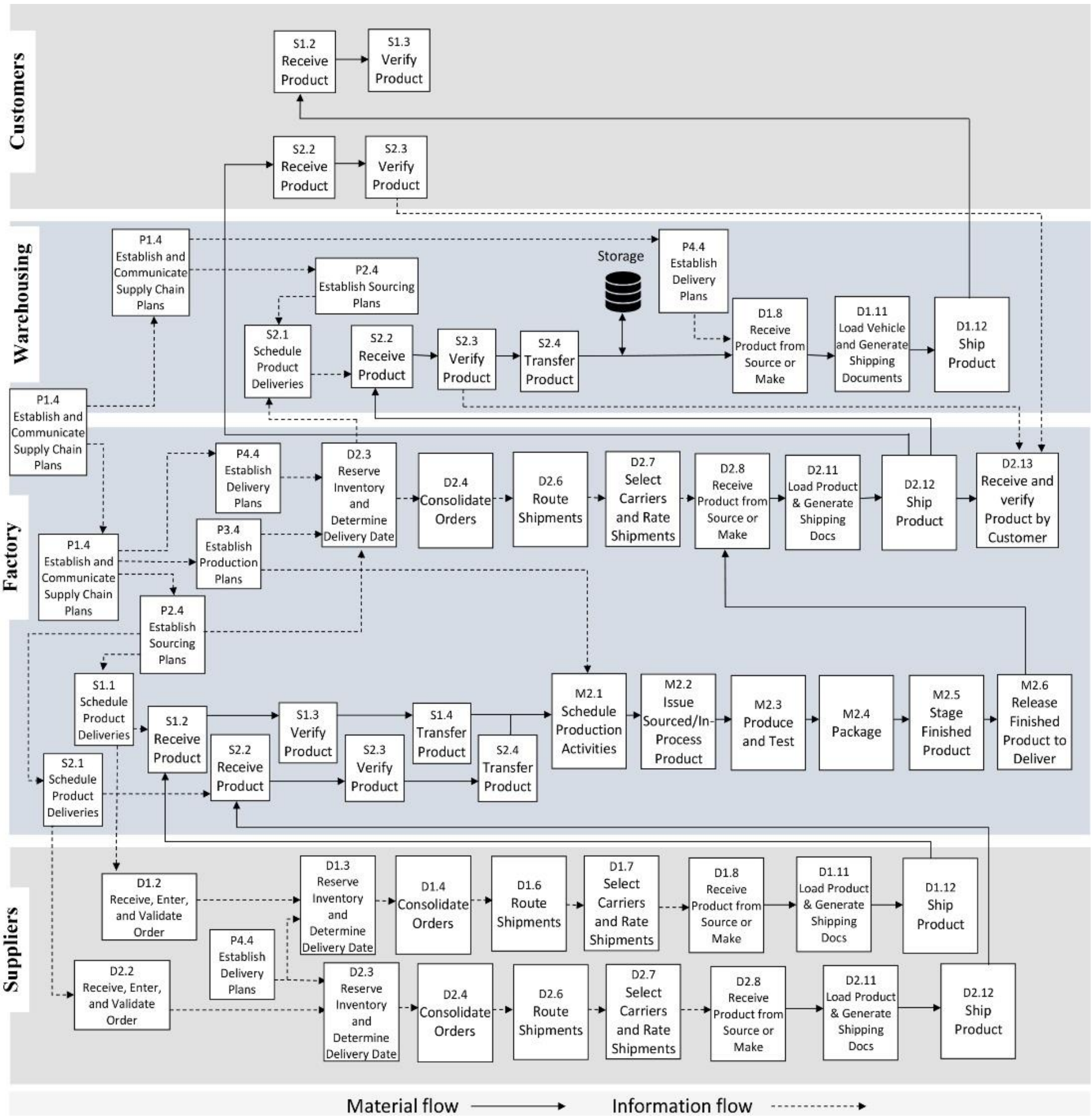
5.3 Study of level 3 processes

Understanding the inputs of processes and predicting outcomes is a factor affecting the correct planning and defining appropriate goals. Therefore, identifying related third-level supply chain processes and examining the criteria associated with these processes will help the organization to plan and make the right decisions.

5.3.1 Workflow diagrams or process models

In this diagram, workflow, materials, and information are displayed at level 3 of the processes. It deals with the interactions between the system, man and information. Figure 3 indicates the corresponding level 3 processes.

Figure 3 SCOR Level 3 process model of Pakshima Supply chain



5.4 Identifying improvement opportunities based on the best practices of the SCOR model

SCOR is the ideal supply chain analysis tool and offers an efficient way to identify improvement opportunities. The activities associated with developing the roadmap for change. This includes identifying the steps required to implement changes to facilities, contracted parties, staffing, automation, and process. Specific changes are assigned to unique owners. This includes reviewing the specific change/projects with key stakeholders. The objective of this process is to obtain approval to launch change projects (SCC, 2012). With the analysis of the level 3 processes of the supply chain, and based on the best practices of the supply chain operations reference model as well as existing opportunities, three programs have been proposed to improve supply chain performance. Plans titles; related level 3 processes and expected Advantages for projects are explained below.

5.4.1 Case 1: ERP implementation in the company (ERP software)

Using ERP software in organizations is inevitable in today's competitive world. This is because integrated management of the organization's processes requires a comprehensive and complete ERP system, which will direct managers to make accurate, and timely decisions, and increase the efficiency of the organization's activities and processes by collecting information from different units. One of the most important uses of the ERP system is the ability to create integrity in the various organization's departments and processes. The ERP software will create this communication and coordination by collecting information from different organizational units. ERP resource planning is a set of various modules, including human resources, finance and accounting, warehouse, properties, etc., which have the ability to change and compliance with organizational conditions according to the needs of organizations. Creating a database, ERP software makes it possible for managers to quickly and timely use information for accurate decision making.

Table 3 The related processes and expected advantages.

Related SCOR processes		*Advantages*
S1.2, S1.4, S2.2, S2.4, S2.5, S3.4, S3.6, S3.7, M1.5, M1.6, M2.4, M2.5, M2.6, M3.2, M3.3, M3.5, M3.6, M3.7, SR1.5, DR1.1, DR1.4, SR2.2, SR2.3, SR2.5, SR3.5, E3	a	Reducing the costs of marketing and selling
	b	Integrated Management of Financial and Human Resources
	c	Increasing the rate of efficiency and productivity

5.4.2 Case 2: Transportation Management Outsourcing to third-party logistics (3PL) providers

Outsourcing is a way of improving productivity that has been considered in the last two decades. According to the research, increased outsourcing can reduce costs and reduce the need for investment in facilities, equipment, and manpower. Cost and service criteria are considered as the main drivers of corporate desire to outsourcing logistics services. The next factor, proposed by managers, is their desire to focus on the competitive advantages of their company; so that the organization will increase its ability to address its main goals and tasks by outsourcing these affairs. The collaboration between different industries and 3PL logistics companies will results in reduced inventory, reduced fixed assets, reduced logistics costs, increased order completion accuracy, and increased order completion rate.

Table 4 The related processes and expected advantages.

Related SCOR processes		*Advantages*
P4, p4.1, p4.2, p4.3, p4.4, p5	a	Reduce overall costs (transportation costs)
	b	speeding up delivery to the end customer
	c	Save Time & Money
	d	**Better Productivity**
	e	**Better Results**

5.4.3 Case 3: Outsourcing distribution and Warehousing to third-party logistics (3PL) providers

Sending goods at the right time and place, with optimal quality for the customer, is one of the issues that are the focus of attention in distributor companies and centers. This is within the external logistics scope and like any systematic action requires the correct planning based on the number of distribution vehicles, the product layout in the vehicle, determining the distribution paths (distribution grid) and the optimal sequence of distribution operations. Considering the fact that the mentioned process is in the downstream loop of the chain and is directly related to the customer or final consumer, it will be of special importance in terms of timely delivery of goods and direct impact on customer satisfaction and is an applied way to reduce the costs of external logistics.

Table 5 The related processes and expected advantages.

Related SCOR processes		*Advantages*
P4 (p4.4), P5	a	Increasing delivery performance
	b	Help to Information and Inventory Management
	c	balance customer service levels and logistics costs
	d	A sharp decrease in direct and variable costs
	e	Managing distribution costs and avoiding the cost of unused capacity

5.5 Prioritization improvement plans using Fuzzy AHP

Fuzzy AHP is a method for calculating the weight of the criteria and selecting the alternative with the highest weight. The decision makers (experts), in this method, use linguistic evaluations in fuzzy forms to perform pairwise comparisons. The triangular fuzzy numbers are used in all pairwise comparison matrices in the proposed method. Hence, the weight of the criteria is calculated as triangular fuzzy numbers, and then, these weights are included in the fuzzy AHP methodology for ranking the alternatives. The experts' opinions were used to determine the priority of the plans and finally selecting the plan with the highest priority. To achieve this, the Fuzzy Pairwise Comparison Questionnaire was developed based on the hierarchical tree (Figure 4) and ten experts and practitioners of the related field completed the questionnaires. Then, the results were analyzed using Fuzzy AHP. Below, Solving the hierarchical model using AHP fuzzy chang are described.

5.5.1 Creating a hierarchy tree

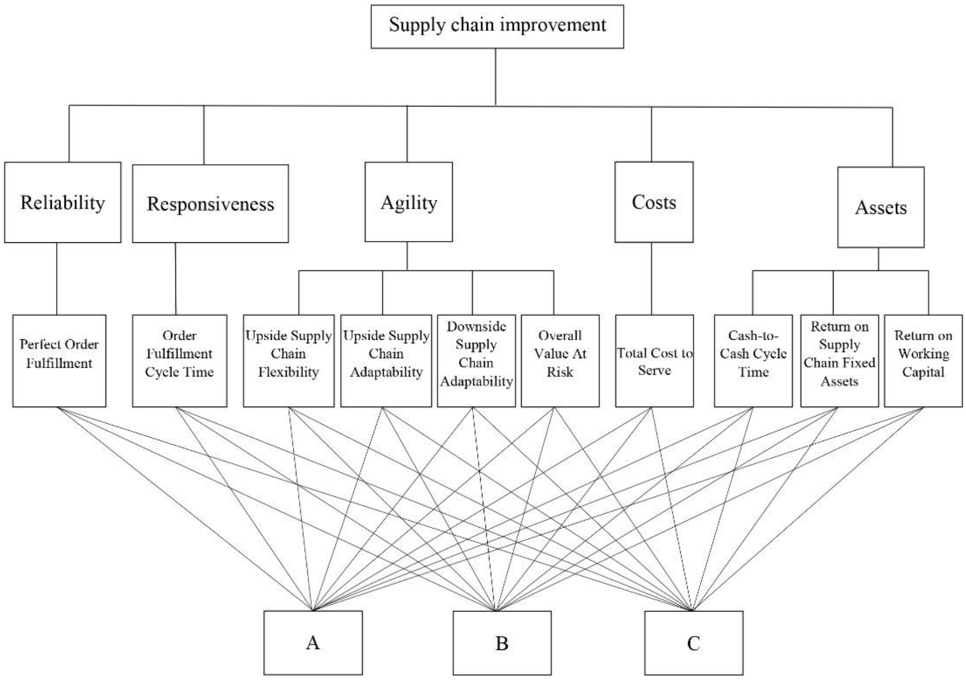
1 Define objective

2 Placing the criteria

3 Placing the Sub-criteria

4 Define Alternatives

Figure 4 Hierarchical tree structure created for pairwise comparisons based on SCOR model 11



After the formation of the hierarchy figure 4, the weight of each criterion, sub-criteria, and alternatives are calculated by the Chang Fuzzy AHP approach. The importance or priority of a criterion, attribute or alternative has compared to the other through the questionnaire. To this end, the experts and practitioners of the studied organization evaluated and weighed criteria and alternatives using their experience and knowledge and according to the specific characteristics of the industry and the company.

5.5.2 Determining the relative weights of criteria, sub-criteria, and Alternatives (plans)

Using the results of the questionnaire, first, the fuzzy assessment matrix of the criteria, Sub-criteria, and Alternatives formed using fuzzy triangular numbers. The fuzzy values are calculated according to each of the criteria using the formula for calculating the algebraic calculations of the fuzzy sets.

In determination the weight of the criteria, using the results obtained from the questionnaire, first, the fuzzy evaluation matrix is formed using fuzzy triangular numbers (table 6). at this stage, the criteria are pairwise compared.

Table 6 integrated fuzzy comparison matrix (with arithmetic mean) for criteria

overall objective	*Reliability*			*Responsiveness*			*Agility*			*Cost*			*Assets*		
Reliability	1	1	1	0.8513	1.0718	1.3110	0.5119	0.6598	0.9603	0.4158	0.5781	0.8706	0.6335	0.9883	1.4479
Responsiveness	0.7628	0.9330	1.1746	1	1	1	0.5991	0.7995	1.0118	0.4557	0.6143	0.8663	0.7034	0.9936	1.4727
Agility	1.0414	1.5157	1.9537	0.9883	1.2508	1.6693	1	1	1	0.6012	0.7579	1.0718	1.1031	1.6438	2.3618
Cost	1.1487	1.7299	2.4052	1.1543	1.6279	2.1946	0.9330	1.3195	1.6632	1	1	1	1.6917	2.3733	3.1853
Assets	0.6906	1.0118	1.5784	0.6790	1.0065	1.4218	0.4234	0.6084	0.9066	0.3139	0.4213	0.5911	1	1	1

Table 7 Consistency state of Pairwise comparison matrix of criteria with respect to "overall objective"

inconsistency ratio

CR_m= 0.004315	CR_g = 0.011642
The matrix is consistent	

Notes: *Determination of inconsistency ratio based on Gogus and Boucher (1998) method.

Table 8 Calculation of criteria weight

	fuzzy sum of each row	*Fuzzy compound extension*	*degree of preference of S_i on S_k*	*Degree of preference*	*Normalizing of preferences*
	3.4125 4.2979 5.5898	0.0972 0.1597 0.2700	0.991 0.660 0.421 1.000	0.421	0.1407
	3.5208 4.3404 5.5255	0.1003 0.1613 0.2669	1.000 0.660 0.416 1.000	0.416	0.1391
	4.7340 6.1682 8.0565	0.1348 0.2293 0.3892	1.000 1.000 0.759 1.000	0.759	0.2539
	5.9278 8.0506 10.4484	0.1688 0.2992 0.5047	1.000 1.000 1.000 1.000	1.000	0.3345
	3.1070 4.0480 5.4979	0.0885 0.1505 0.2656	0.948 0.938 0.624 0.394	0.394	0.1318
sum	20.7021 26.9050 35.1180			2.989	1.000
Reverse	0.0483 0.0372 0.0285			*sum*	

Based on the results of the above table, the prioritization of Sub-criteria with respect to "Goal" is:

1 Cost
2 Agility
3 Reliability
4 Responsiveness
5 Assets

After achieving the normalized non-fuzzy relative weights for criteria, the same methodology is applied to find the respective values for Sub-criteria. But now, the Sub-criteria should be pairwise compared with respect to each criterion particularly. That means this analysis should be repeated for 2 more times for 2 of criterion. However, it will be burdensome to explain for each 2 of them; only "Agility" criterion will be handled. Pairwise comparison of Sub-criteria with respect to "Agility" criterion is interviewed and the following Table 9 is achieved.

Table 9 integrated Comparison matrix (with arithmetic mean) of Sub-criteria with respect to "Agility" criterion

Agility	*Upside Supply Chain Flexibility*	*Upside Supply Chain Adaptability*	*Downside Supply Chain Adaptability*	*Overall Value At Risk*
Upside Supply Chain Flexibility	1 1 1	1.0000 1.3741 1.8015	1.1822 2.0477 3.0157	0.4375 0.6084 0.9716
Upside Supply Chain Adaptability	0.5551 0.7277 1.0000	1 1 1	0.7850 1.0537 1.4555	0.3925 0.5610 0.8459
Downside Supply Chain Adaptability	0.3316 0.4884 0.8459	0.6871 0.9490 1.2738	1 1 1	0.3577 0.5394 0.9066
Overall Value At Risk	1.0292 1.6438 2.2855	1.1822 1.7826 2.5477	1.1031 1.8541 2.7956	1 1 1

Table 10 Consistency state of Pair wise comparison matrix of Sub-criteria with respect to "Agility" criterion:

inconsistency ratio

CR_m= 0.014053	CR_g = 0.028505
The matrix is consistent	

Table 11 Calculation of Sub-criteria weight

	fuzzy sum of each row			*Fuzzy compound extension*			*degree of preference of S_i on S_k*			*Degree of preference*	*Normalizing of preferences*
	3.6198	5.0301	6.7888	0.1524	0.2853	0.5205	1.000	1.000	0.827	0.827	0.3061
	2.7326	3.3424	4.3014	0.1151	0.1896	0.3298	0.649	1.000	0.470	0.470	0.1742
	2.3764	2.9767	4.0263	0.1001	0.1688	0.3087	0.573	0.903	0.404	0.404	0.1495
	4.3145	6.2804	8.6288	0.1817	0.3562	0.6616	1.000	1.000	1.000	1.000	0.3702
sum	13.0432	17.6297	23.7452							2.701	1.000
Reverse	0.0767	0.0567	0.0421							*sum*	

Based on the results of the above table, the prioritization of Sub-criteria with respect to "Agility" is:

1 Overall Value at Risk
2 Upside Supply Chain Flexibility
3 Upside Supply Chain Adaptability
4 Downside Supply Chain Adaptability

After determining the weight of criteria and Sub-criteria in the next step, Alternatives should be pairwise compared with respect to Sub-criteria. That means this analysis should be repeated for 10 more times to the number of sub-criteria. Because of the difficulty of explaining to all of them, only Perfect Order Fulfillment will be explained. Table 12 indicates alternatives Pairwise comparison matrix with respect to Perfect Order Fulfillment.

Table 12 integrated comparison matrix (with arithmetic mean) of Alternatives with respect to Perfect Order Fulfillment

Perfect Order Fulfillment	*A*			*B*			*C*		
A	1	1	1	1.2457	1.8131	2.3618	0.8960	1.1698	1.3904
B	0.4234	0.5515	0.8027	1	1	1	0.4169	0.5515	0.7850
C	0.7192	0.8548	1.1161	1.2738	1.8131	2.3985	1	1	1

Table 13 Consistency state of Pairwise comparison matrix of Alternatives with respect to Perfect Order Fulfillment

inconsistency ratio	
CR_m= 0.002796	CR_g = 0.005127
The matrix is consistent	

Table 14 Calculation of Sub-criteria weight

	fuzzy sum of each row	*Fuzzy compound extension*	*degree of preference of S_i on S_k*	*Degree of preference*	*Normalizing of preferences*
	3.1417 3.9830 4.7522	0.2650 0.4083 0.5959	1.000 1.000	1.000	0.468
	1.8403 2.1031 2.5878	0.1552 0.2156 0.3245	0.236 0.310	0.236	0.110
	2.9931 3.6680 4.5146	0.2525 0.3760 0.5661	0.903 1.000	0.903	0.422
sum	7.9751 9.7540 11.8545			2.139	1.000
Reverse	0.1254 0.1025 0.0844			*Sum*	

Based on the results of the above table, the prioritization of Sub-criteria with respect to "Agility" is:

1 A
2 C
3 B

5.6 prioritization and calculation the final weight of criteria, sub-criteria, and alternatives

The final weight of criteria, sub-criteria, and alternatives is obtained according to the relative weights calculated in the previous step.

Table 15 The final weight of the criteria

criteria	***weight***
Reliability	*0.1407*
Responsiveness	*0.1391*
Agility	*0.2539*
Cost	*0.3345*
Assets	*0.1318*

Figure 5 Criteria Final Weight diagram

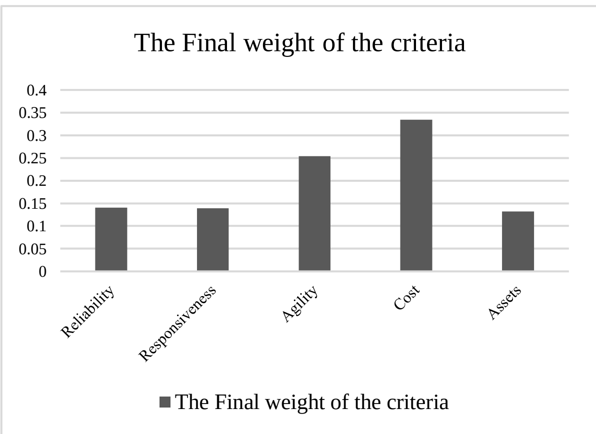


Table 16 Sub-criteria Final weight

Sub-criteria	*weight*
Perfect Order Fulfillment	0.1407
Order Fulfillment Cycle Time	0.1391
Upside Supply Chain Flexibility	0.077721
Upside Supply Chain Adaptability	0.044222
Downside Supply Chain Adaptability	0.037966
Overall Value At Risk	0.093991
Total Cost to Serve	0.3345
Cash-to-Cash Cycle Time	0.06107
Return on Supply Chain Fixed Assets	0.022984
Return on Working Capital	0.047746

Figure 6 Sub-criteria Final Weight diagram

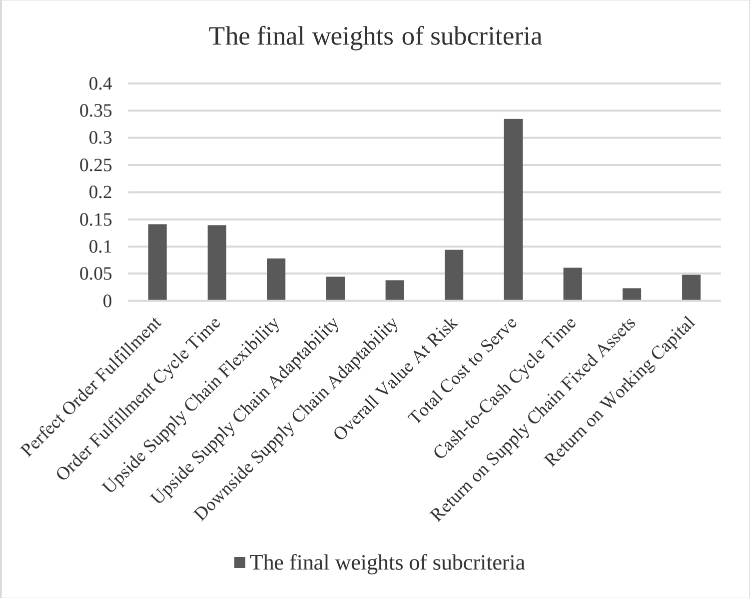
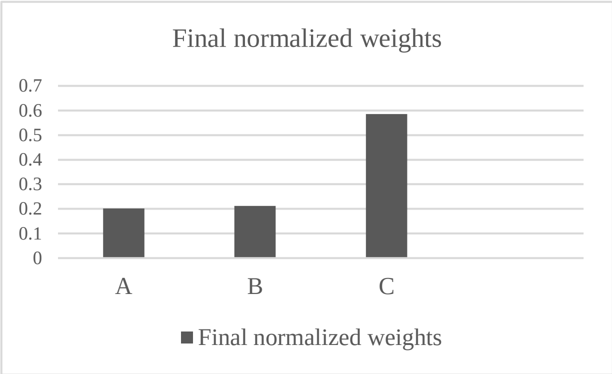


Table 17 Alternatives Final normalized weight

alternative	*Final normalized weights*	*Prioritization based on the final weight*
A	0.202	3
B	0.212	2

C	0.586	1

Figure 7 Alternatives Final Weight diagram



5.7 Company's Supply Chain after Improvement

5.7.1 To-Be process thread diagram

This diagram defines the status of the future process in an organization. In other words, how the processes of organizations and their capabilities will emerge in the future. in fact, It is the result of the process improvement (AS IS) and describes the concept of what existing processes should be. Figure 8 shows the new level 2 processes of Pakshima ,which include the improvement plan selected through the fuzzy analytic hierarchy process. After performing the fuzzy pairwise comparisons and selecting the third Alternative, which is the outsourcing distribution and warehousing to third-party logistics (3PL) providers, Company after production of goods, it will put them at the discretion of the third - party logistics company for distribution and storage. As shown in Fig. 8, the solid blue line indicates the outsourcing and separation of the distribution sector.

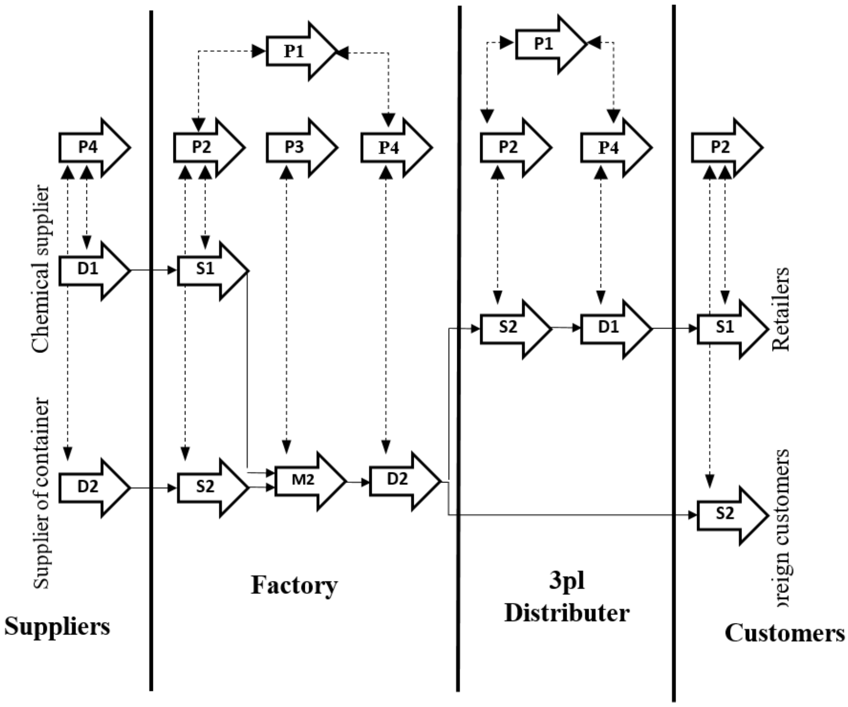


Figure 8 TO BE Process Thread Diagram

Conclusion

Usually, in defining improvement plans to make constructive changes in the supply chain, the focus is on reality-based ideas which are applicable in real conditions Because of implementation of strategic decisions costs a lot. Considering the way of selecting improvement plans based on the best practices of the SCOR model, and through the formation of the expert group and their accurate feasibility study, we can conclude that all the mentioned ideas have the potential to be executed at the company level as the final project if selected by the Fuzzy AHP approach. The SCOR model and the Fuzzy Analytical Hierarchy Process have an aligned and similar structure to use and integrate them in selecting the best supply chain improvement plans. Therefore, the combination of the Analytical Hierarchy Process and the SCOR model is one of the best available options. Also, the structural shortcomings of this model have been also resolved using the AHP method and the supply chain analyzability is increased based on the SCOR model by combining the experimental structure of this model and the hierarchical structure of the AHP method. In the present study, correct changes occurred in the supply chain using the mentioned method which has been effective in increasing the competitiveness and reducing the costs of the company. For future research, other decision techniques or an integrated multi-criteria decision-making methodology can be used to prioritize criteria and alternatives. This method can also be used for other aspects of improvement and decision-making in supply chain and organizations.

References

Agarwal, A., Shankar, R. and Mandal, P. (2006) 'Effectiveness of information systems in supply chain performance: a system dynamics study', *International Journal of Information Systems and Change Management*, Vol. 10, No. 2, pp.101 – 122.

Ashayeri, J., Keij, R. and Broker, A. (1998) 'Global business process re-engineering: a system dynamics-based approach', *International Journal of Operations and Production Management*, Vol. 18, No. 9/10, pp.817-831.

Ayhan, M.B. (2013) 'A fuzzy AHP approach for supplier selection problem: a case study in a Gearmotor company', *International Journal of Managing Value and Supply Chains (IJMVSC)*, Vol. 4, No. 3, pp.11-23.

Bolstorff, P. and Rosenbaum, R. (2011) *Supply chain excellence: a handbook for dramatic improvement using the SCOR model*, 2nd ed., AMACOM, New York.

Buckley, J.J. (1985) 'Fuzzy hierarchical analysis', *Fuzzy Sets and Systems*, Vol. 17, No. 3, pp.233-247.

Carvalho, H., Barroso, A.P., Machado, V.H., Azevedo, S. and Cruz-Machado, V. (2012) 'Supply chain redesign for resilience using simulation', *Computers & Industrial Engineering*, Vol. 62, No. 1, pp.329-341.

Chang, D.Y. (1996) 'Application of the extent analysis method on fuzzy AHP', *European Journal of Operational Research*, Vol. 95, No. 3, pp.649-655.

Chang, D.Y. (1992) 'Extent Analysis and Synthetic Decision', *Optimization Techniques and Applications*, Vol. 1, pp.352-355.

Chiadamrong, N. and Piyathanavong, V. (2017) 'Optimal design of supply chain network under uncertainty environment using hybrid analytical and simulation modeling approach', *Journal of Industrial Engineering International*, Vol. 13, No. 4, pp.465-478.

De Graan, J.G. (1980) *Extensions to the multiple criteria analysis of T.L.Saaty*, national institute for water supply, The Netherlands, m.f.a. 80-3/REP.

Georgise, F.B., Thoben, K.B. and Seifert, M. (2012) ' Adapting the SCOR Model to Suit the Different Scenarios: A Literature Review & Research Agenda', *International Journal of Business and Management*, Vol. 7, No. 6, pp.2-17.

Gogus, O. and Boucher, T.O. (1997) 'A consistency test for rational weights in multi-criterion decision analysis with fuzzy pairwise comparisons', *Fuzzy Sets and Systems*, Vol. 86, No. 2, pp.129-138.

Gogus, O. and Boucher, T.O. (1998) 'Strong transitivity, rationality and weak monotonicity in fuzzy pairwise comparisons', Fuzzy Sets and Systems, Vol. 94, No 1, pp.133-144.

Hammami, R. and Frein, Y. (2014) 'Redesign of global supply chains with integration of transfer pricing:Mathematical modeling and managerial insights', *International Journal of Production Economics*, Vol. 158, No. 1, pp.267-277.

Huan, S. H., Sheoran, S. K. and Wang, G. (2004) 'A review and analysis of supply chain operations reference (SCOR) model', *Supply Chain Management: An International j*ournal, Vol. 9, No. 1, pp.23-29.

Hwang, Y.D., Lin, Y.C. and Lyu Jr, J. (2008). 'The performance evaluation of SCOR sourcing process—The case study of Taiwan's TFT-LCD industry', *International Journal of Production Economics*, Vol, 115, No. 2, pp.411–423.

Korpela, J., Lehmusvaara, A. and Tuominen, M. (2001) ‘An analytic approach to supply chain development’, *International Journal of Production Economics*, Vol. 71, No 1–3, pp 145-155.

Leukel, J. and Sugumaran, V. (2013) ‘Formal correctness of supply chain design’, *Decision Support Systems*, vol. 56, No. 1, pp.288-299.

Lootsma, F. A. (1980) ‘Saaty's priority theory and the nomination of a senior professor in operations research’, *European Journal of Operations research*, Vol. 4, No. 6, pp.380-388.

Lundin, J. F. (2012) ‘Redesigning a closed-loop supply chain exposed to risks’, *International Journal of Production Economics*, Vol. 140, No. 2, pp.596–603.

Naraharisetti, P.K., Karimi, I.A. and Srinivasan, R. (2008) ‘Supply chain redesign through optimal asset management and capital budgeting’, *Computers and Chemical Engineering*, Vol. 32, No. 12, pp.3153–3169.

Palma-Mendoza, J.A., Neailey, K. and Roy, R. (2014) ‘Business process re-design methodology to support supply’, *International Journal of Information Management*, Vol. 34, No. 2, pp.167-176.

Palma-Mendoza, J. A. (2014) ‘Analytical hierarchy process and SCOR model to support supply chain re-design’, *International Journal of Information Management*, Vol. 34, No. 5, pp.634-638.

Saaty, T.L. (1980) The Analytic Hierarchy Process, McGraw-Hill, New York.

Supply Chain Council (2012) SCOR: *Supply chain operations reference model*. Chicago, APICS.

Turban, E., King, D., Lee, J., Liang, T.P. and Turban, D. (2011) ‘Electronic Commerce 2012: A managerial and social networks perspective’, New Jersey: Pearson-Prentice Hall.

Van Laarhoven, P.J.M., Pedrycz, W. (1983) ‘Fuzzy extension for Saaty's priority theory’, *Fuzzy Sets and Systems*, Vol. 11, No. 1-3, pp.229-241.

Villarreal, B., Gonzalez, D. and Madero, P. (2004) ‘A Diagnostic Analysis Tool for Supply Chain Improvement’. Paper Presented at the *Second World Conference on POM and 15th Annual POM Conference*. *Production and Operations Management Society*. April 30 – May 3 2004. Cancun, Mexico.

Wang, W. Y. C., Chan, H. K. and Pauleen, D. J. (2010) ‘Aligning business process reengineering in implementing global supply chain systems by the SCOR model’, *International Journal of Production Research*, Vol. 48, No. 19, pp.5647–5669.