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# Presentation a New Algorithm for Performance Measurement of Supply Chain by Using FMADM Approach

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**Abstract:** Supply chain management has become such a popular topic in modern business management and researches. It brings the revolutionary philosophy and approach to manage the business with the sustained competitiveness. However, the existing performance measurement theory fails to provide its necessary support in strategy development, decision making and performance improvement. The main goal of this paper is presentation of a new approach to supply chain performance measurement by use of FMADM (Fuzzy Multi Attribute Decision Making) method. For this goal, we extract the performance metrics based-on balanced scorecard (BSC) model. Afterward we present a three-step approach to measure the performance of the supply chain by FMADM method. In the process of supply chain performance measurement, many of our data are qualitative. Since the qualitative data are ambiguous we transform the qualitative terms into quantities terms by using the fuzzy collections. This includes identifying and prioritization the key factors in increasing competitiveness. The main framework of this method is outlined with some suggestions and a simple example

**Key word:** Performance measurement . BSC model food supply chain . FMADM . fuzzy approach

## INTRODUCTION

In modern business environments characterized by ever-increasing competition and economy globalization, manufacturers have been exploiting innovative technologies and strategies to achieve and sustain competitive advantage. As an effective business philosophy, Supply Chain Management (SCM) has gained a tremendous amount of attention from both the academics and practitioners community in the recent years. Nowadays, more than ever, manufacturers face an increasing pressure of customers' requirements in product customization, quality improvement and demand responsiveness. On the other hand, they need to reduce production cost, shorten lead time and lower inventory level to ensure profitability. In order to survive under these pressures, more and more enterprises are striving to develop long-term strategic partnerships with a few competent suppliers and collaborate with them in product development, inventory control and non-core process outsourcing. Moreover, various value-adding processes from material purchasing, production and assembly, to distribution and customer order delivery are integrated and synchronized to achieve the common goal of enhancing customer satisfaction. In this connection, the paradigm of modern business management has witnessed a significant change from competing as solely autonomous entities to competing as integrated supply chains [1]. Over the last decade of evolution of SCM, a steady stream of articles dealing with the theory and practice of SCM have been published, but the topic of performance measurement does not receive adequate consideration in SCM [2].

As an indispensable management tool, performance measurement provides the necessary assistance for performance improvement in pursuit of supply chain excellence. However, many critical drawbacks pervert the existing Performance Measurement Systems (PMSs) from making a significant contribution to the development and improvement of SCM. With the aim to fill this gap, this paper attempts to propose a model. Because of linguistic terms are ambiguous, in this paper we use fuzzy logic. On the other hand we will use SCOR model to select the criteria of SCMs performance.

The paper is organized as follows. Next section introduces the basic definitions and notations of the SCM nature, BSC model and fuzzy numbers and linguistic variables. Finally, we present our model to rating the SCMs in according to criteria.

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## PERFORMANCE MEASURMENT IN SCM

Traditionally, performance measurement is defined as the process of quantifying effectiveness and efficiency of action [3]. In other words, measuring performance means transferring the complex reality of performance into a sequence of limited symbols that can be communicated and reported under similar circumstances [4]. In modern business management, performance measurement assumes a far more significant role than quantification and accounting

Performance measurement can provide important feedback information to enable managers to monitor performance, reveal progress, enhance motivation and communication and diagnose problems [5]. In SCM, performance measurement can facilitate inter-understanding and integration among the supply chain members. It also provides insight to reveal the effectiveness of strategies and to identify success and potential opportunities. It makes an indispensable contribution to decision making in SCM, particularly in re-designing business goals and strategies and re-engineering processes.

Some researchers have addressed performance measurement in SCM. Beamon [6] categorizes performance measures in existing literature into two groups: qualitative and quantitative, where customer satisfaction and responsiveness, flexibility, supplier performance, costs and others for supply chain modeling are discussed. Beamon [6] identifies three types of measures: resources, output and flexibility. Gunasekaran *et al*. [7] develop a framework for respectively measuring the performances from strategic, tactical and operational levels in supply chains; this framework mainly deals with supplier, delivery, customer service and inventory and logistics costs. However, there is very little literature available on performance measurement in SCM, especially dealing with system design and measures selection, though various theories and practices have been addressed in the past articles. Moreover, in SCM context, the contributions of the PMSs in use are discounted by the existence of too many flaws. Traditional PMSs that are financially focused have already received wide criticism on short-term and profit orientation, encouraging local optimization, failing to support continuous improvement and uni-dimensional measures [8]. Besides, PMSs in SCM context are also accompanied by many problems as stated below [7].: Being not connected with strategy; lack of a balanced approach to integrate financial and non-financial measures; lack of system thinking, in which a supply chain must be viewed as one whole entity and measured widely across the whole and loss of supply chain context and thus encouraging local optimization. It is much easier to write a definition of SCM than to implement it [1]. With these defects aforementioned, performance measurement fails to assist in facilitating SCM development. An effective performance measurement method has always been under considerable debate and requires further research exploration [6, 8].

## SELECTION OF A FUNDAMENTAL SUPPLY CHAIN PERFORMANCE MEASURES MODEL

In regard to fundamental framework selection, the major criteria for framework selecting were examined by [9], Beamon [6], Singh and Shah [10] and Merz [11]. These criteria included the scope of measurement and the reliability of the model. The initial model should be able to assess the whole supply chain system as well as achieving satisfaction from model users.

The four perspectives of BSC-learning & growth perspective, business process perspective, customer perspective and financial perspective-are not parallel, but financial index is the core content; essentially, business process and customer are connotative revenue or cost and learning & growth is for future profit opportunities. As a strategic performance management framework, BSC links supply chain performance indexes with the alliance's strategic planning; but the process oriented approach of SCM makes that BSC can't be used in the traditional way, which is suitable for functional department performance measuring. Processes measuring are the basal components of supply chain performance management and linkage between BSC and processes measure is the process performance indicators. The design of indicators system is a difficult task. Kaplan & Norton didn't point out that each dimensionality concretely includes which index and that the indicator system for functional department measuring is not suitable for process measuring. Many researches have been done on them and different supply chain performance indicators system has been delivered. Thus integrating them may be a feasible choice. Figure 1 indicates a hierarchy model for using BSC in SCM. By the causality chain of BSC, supply chain strategic performance indexes are linked with supply chain economic value added. There have been many criticisms for BSC using traditional financial indexes already. EVA not only complements BSC in the financial perspective, but provides performance measuring a consistent yardstick, which harmonizes conflicts among the four perspectives of BSC. AHP (Analytic Hierarchy Process) is usually utilized to apportion weights of indexes in implementing BSC. The effective indicator system doesn't predicate success

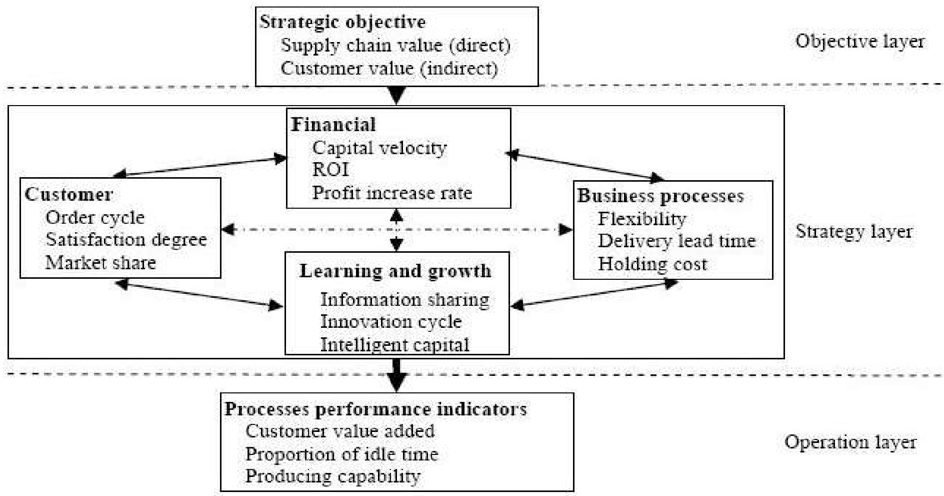


Fig. 1: BSC model of SCM

of BSC; the strategic measuring is required to be analyzed into activity analysis, thus implementing BSC needs the support of activity measuring technique.

## FUZZY NUMBERS AND LINGUISTIC VARIABLES

In this section, some basic definitions of fuzzy sets, fuzzy numbers and linguistic variables are reviewed from Buckley [12], Negi [13] and Zadeh [14]. The basic definitions and notations below will be used throughout this paper until otherwise stated.

**Definition 1:** A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{A}}(x)$ which associates with each element x in X a real number in the interval [0, 1]. The function value $\mu_{\tilde{A}}(x)$ is termed the grade of membership of x in $\tilde{A}$.

**Definition 2:** A fuzzy set $\tilde{A}$ in the universe of discourse X is convex if and only if

$$\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min(\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2))$$

For all x1; x2 in X and all $\lambda \in [0,1]$
Where min denotes the minimum operator

**Definition 3:** The height of a fuzzy set is the largest membership grade attained by any element in that set. A fuzzy set $\tilde{A}$ in the universe of discourse X is called normalized when the height of $\tilde{A}$ is equal to 1 [12]

**Definition 4:** A fuzzy number is a fuzzy subset in the universe of discourse X that is both convex and normal.

Figure 2 shows a fuzzy number ñ in the universe of discourse X that conforms to this definition.

**Definition 5:** The $\alpha'$-cut of fuzzy number ñ is defined as

$$\tilde{n}^{\alpha} = \{x_i : \mu_{\tilde{n}}(x_i) \geq \alpha, x_i \in X\}$$

Where $\alpha \in [0,1]$.

The symbol $\tilde{n}^0$ represents a non-empty bounded interval contained in X, which can be denoted by $\tilde{n}^{\alpha} = [n_l^{\alpha}, n_u^{\alpha}]$, $n_l^{\alpha}$ and $n_u^{\alpha}$ are the lower and upper bounds of the closed interval, respectively (Kaufmann and Gupta, 1991; Zimmermann, 1991). For a fuzzy number ñ, if $n_l^{\alpha} > 0$ and $n_u^{\alpha} \leq 1$ for all $\alpha \in [0,1]$, then ñ is called a standardized (normalized) positive fuzzy number [13].

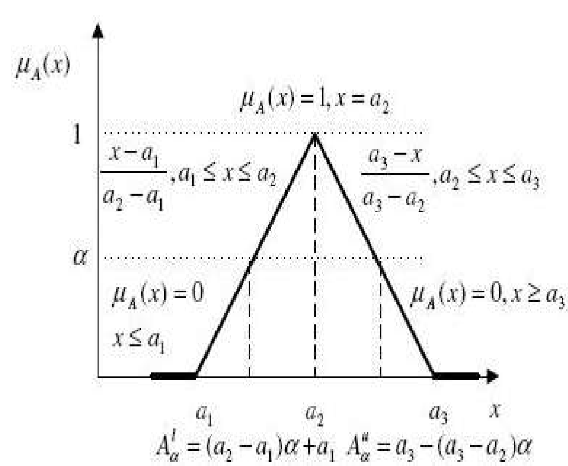


Fig. 2: A positive triangular fuzzy number, its membership function and a-cut

**Definition 6:** A positive Triangular Fuzzy Number (TFN) $\tilde{A}$ can be defined by a triplet $\tilde{A} = (a_1, a_2, a_3)$ that Shown in Fig. 4. The membership function is defined as:

$$\mu_A(x) = \begin{cases} 0, & x \prec a_1 \\ \dfrac{x - a_1}{a_2 - a_1}, & a_1 \le x \le a_2 \\ 1, & x = a_2 \\ \dfrac{x - a_3}{a_2 - a_3}, & a_2 \le x \le a_3 \\ 0, & x \succ a_3 \end{cases}$$

A non-fuzzy number r can be expressed as (r, r, r). The a-cut of the fuzzy number $\tilde{A}$ which can be denoted by $A_\alpha = [A_\alpha^l, A_\alpha^u]$, is shown in the Fig. 4.

Given any two positive TFNs, $\tilde{m} = (m_1, m_2, m_3)$ and $\tilde{n} = (n_1, n_2, n_3)$, some main operations of fuzzy numbers $\tilde{m}$ and $\tilde{n}$ can be expressed as follows:

$$\tilde{m}(+)\tilde{n} = (m_1 + n_1, m_2 + n_2, m_3 + n_3)$$
$$\tilde{m}(-)\tilde{n} = (m_1 - n_3, m_2 - n_2, m_3 - n_1)$$
$$\tilde{m} \otimes \tilde{n} \cong (m_1 n_1, m_2 n_2, m_3 n_3)$$
$$\tilde{m}(\div)\tilde{n} \cong \left(\frac{m_1}{n_3}, \frac{m_2}{n_2}, \frac{m_3}{n_1}\right)$$

**Definition 7:** A matrix $\tilde{D}$ is called a fuzzy matrix if at least one element is a fuzzy umber [12-15].

**Definition 8:** A linguistic variable is a variable whose values are expressed in linguistic terms [15]. The concept of a linguistic variable is very useful in dealing with situations, which are too complex or not well defined to be reasonably described in conventional quantitative expressions [15]. For example, ''weight'' is a linguistic variable whose values are very low, low, medium, high, very high, etc. Fuzzy numbers can also represent these linguistic values.

## PROPOSED MODEL

In this part, our model which consists of following steps is represented for competitiveness measurement of supply chain management.

Our model has five steps:

**Step1:** Select the best criteria for SCMs performance appraisal. In this step we were choosing more important and effective criteria in specifying competitiveness of supply chain and doing more accurate examination on them. In the other word, effective and non-effective criteria in competitiveness of supply chain can be distinguished from each other. For these selection, we used experts point of views which that a group of expert persons (or panel group) that their opinions are involved.

Each expert person should represent its opinion for each choice, which is an accomplished person should state to what extent will satisfy different criteria. This evaluation for satisfying criteria by choices is done in the from of following scale elements(s).

| | |
|---|---|
| $S_7$ | Outstanding (OU) |
| $S_6$ | Very high (vh) |
| $S_5$ | High (h) |
| $S_4$ | Medium (m) |
| $S_3$ | Low (l) |
| $S_2$ | Very low (vl) |
| $S_1$ | Non (n) |

Additionally, each expert person should represent importance degree of different criteria in its view in the form of "S" scale. Next step in this process is unit evaluation of each expert person for its choice.

**Step 2:** Determining relative importance (weight-giving) of chosen criteria of first step, using fuzzy AHP technique.

The traditional AHP needs exact judgments. In addition, due to the complexity and uncertainty involved in real world decision problems, it is sometimes unrealistic or even impossible to perform exact comparisons. Since fuzziness and vagueness are common characteristics in many decision-making problems, a good decision-making model needs to tolerate ambiguity or vagueness. Decision makers often provide uncertain responses rather than precise judgments and the transformation of qualitative preferences to point estimates may not be sensible; hence, linguistic values, whose membership functions are usually characterized by triangular fuzzy numbers, can be utilized to estimate preference ratings instead of conventional numerical equivalence method. Due to the fact that uncertainty should be considered in some or all of the pair-wise comparison values, the pair-wise comparison under traditional AHP, which needs to select arbitrary values in the process, may not be appropriate. It is therefore more natural or realistic that a decision maker is allowed to provide fuzzy judgments instead of precise comparisons. A number of methods have been developed to deal with fuzzy comparison matrices. For example, Chang proposed an extent analysis method, which sums up each row of a fuzzy comparison matrix, normalizes them and then compares them by defining a degree of possibility of one fuzzy number being greater than or equal to another one. The extent analysis method gives crisp weight estimates for fuzzy comparison matrices. Zhu made a discussion on the extent analysis method and improved the formulation of possibility degree for comparing two triangular fuzzy numbers. Leung and Cao proposed a fuzzy consistency definition with consideration of a tolerance deviation and determined fuzzy weights via a-level sets and the extension principle. Buckley directly fuzzified Saaty's original procedure of computing weights in hierarchical analysis to get fuzzy weights. Csutora and Buckley proposed a Lambda-Max method, which is the direct fuzzification of the well-known kmax method. Wang presented a modified fuzzy Logarithmic Least Square Method (LLSM) for fuzzy analytic hierarchy process. Numerous research papers have been done with the application of fuzzy AHP. The application of fuzzy AHP has become popular in recent years, too.

In this article we use extended hierarchy (EA) model of Chang. This model and its TFN described at previous parts of this paper.

**Step 3:** Supply chains rating by fuzzy TOPSIS. In this paper, we further extended to the concept of TOPSIS to develop a methodology for solving supplier selection problems in fuzzy environment [16]. Considering the fuzziness in the decision data and group decision-making process, linguistic variables are used to ratings of each alternative with respect to each criterion. We can convert the decision matrix into a fuzzy decision matrix and construct a weighted-normalized fuzzy decision matrix once the decision-makers' fuzzy ratings have been pooled. According to the concept of TOPSIS, we define the Fuzzy Positive Ideal Solution (FPIS) and the Fuzzy Negative Ideal Solution (FNIS). And then, a vertex method is applied in this paper to calculate the distance between two fuzzy ratings. Using the vertex method, we can calculate the distance of each alternative from FPIS and FNIS, respectively. Finally, a closeness coefficient of each alternative is defined to determine the ranking order of all alternatives. The higher value of closeness coefficient indicates that an alternative is closer to FPIS and farther from FNIS simultaneously.

A systematic approach to extend the TOPSIS is proposed to solve the supplier-selection problem under a fuzzy environment in this section. In this paper the ratings of qualitative criteria are considered as linguistic variables. Because linguistic assessments merely approximate the subjective judgment of decision-makers, we can consider linear trapezoidal membership functions to be adequate for capturing the vagueness of these linguistic assessments [17-18]. These linguistic

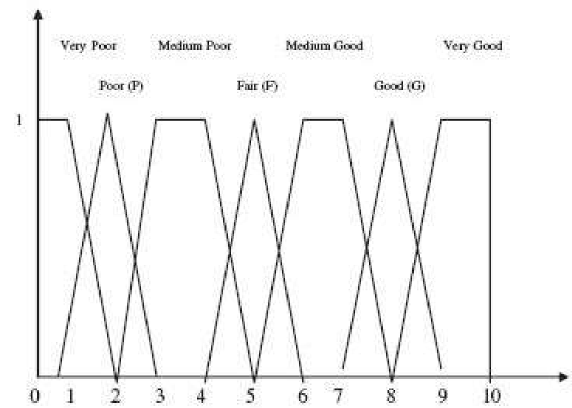


Fig. 3: Linguistic variables for importance weight of each criterion

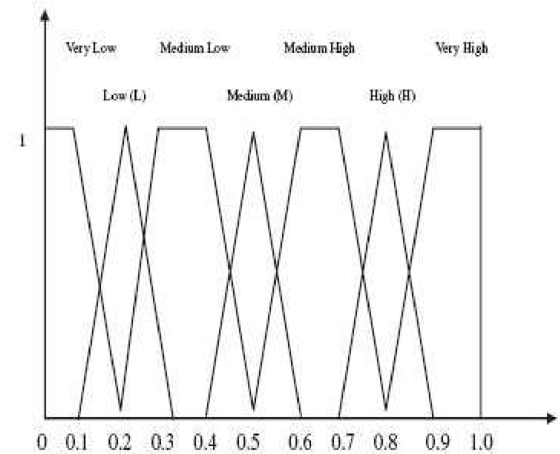


Fig. 4: Linguistic variables for ratings

variables can be expressed in positive trapezoidal fuzzy numbers, as in Fig. 2 and 3. It is suggested in this paper that the decision-makers use the linguistic variables shown in Fig. 4 and 5 to evaluate the importance of the criteria and the ratings of alternatives with respect to qualitative criteria. For example, the linguistic variable ''Medium High (MH)'' can be represented as (.5,.6,.7,.8) then fuzzy numbers of criteria which were determined in this step will be turned to certain numbers using fuzzy theory according to main components of competitiveness of supply chain that are inventory cost, reliability and flexibility.

## ASSUMPTIONS OF SUGGESTED TECHNIQUE

**Evaluation and improvement:** Suggested technique is a technique for measuring competitiveness of supply chain and try to identify strengths and weakness of that supply chain so that by means of this, performance

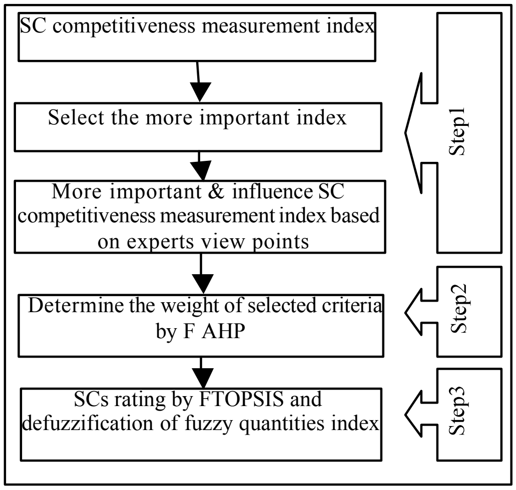


Fig. 5: Suggested technique and its performance stages

ideals for supply chain of organization will be determined.

**Comprehensive evaluation:** The technique aims at measuring competitiveness of supply chain and determining strategic position of a chain against to the other chains. Suggested technique gives this opportunity so that measuring will be done using amounts all of effective criteria and Also opinions of all persons who are responsible and customer of product.

**Fuzziness:** Today's world is full of change that continuation of processes does not make begin certain of past problems possible. So tendency toward using fuzzy logic in management literature and operational research is alto. in suggested technique fuzzy logic is used because of its high efficiency.

Innovation and characteristics of suggested technique

Innovation and characteristics of suggested technique are clarified in three categories:

1) Designing suggested technique 2) performing suggested technique and 3) suggested technique as managerial tool.

## DESIGNING SUGGESTED TECHNIQUE

**Flexibility:** Measuring technique of competitiveness of supplying chain has a high flexibility in designing in a way that superior management as main decider can decrease or increase number of stages or changes weights of criteria.

**Simplify and convenience:** Implementation of this technique is not expensive and time-wasting. In addition, it will prepare much general information for stores deciders and also because of it`s understandable and fluent algorithm and it`s easy application.

Table 1: Criteria

| Criteria | Degree | Value s |
|---|---|---|
| Capital velocity | 4 | M |
| ROI | 3 | L |
| Profile increase rate | 2 | VL |
| Order cycle | 3 | L |
| Satisfaction degree | 5 | H |
| Market share | 4 | M |
| Information sharing | 4 | M |
| Innovative cycle | 5 | H |
| Intelligent capital | 3 | L |
| Flexibility | 5 | H |
| Delivery lead time | 3 | L |
| Holding cost | 2 | VL |

Table 2: Selected criteria

| Value s | Quantities | Criteria |
|---|---|---|
| 4 | M | Capital velocity |
| 5 | H | Satisfaction degree |
| 4 | M | Market share |
| 4 | M | Information sharing |
| 5 | H | Innovative cycle |
| 5 | H | Flexibility |

**Multiple:** In designing suggested technique, several purpose in stuck on mind: 1) determining measuring competitiveness of supply chain 2) presenting strategic situation of a supply chain against to the competitor chains 3) examining the situation and existing performance of supply chains 4) presenting a frame for determining aims and ideals of performance.

Implementation of suggested technique

1. Understandable and instruct able: simplify accompanied with having consistent and strong logic have mode suggested technique understandable for organization managers and acceptance probability for them is very high.
2. Extendibility: Some special and limited assumption in this technique is not pointed so the technique is extendable in all of chains.

## PROPOSED MODEL IMPLEMENTATION

**Step 1:** Select the best criteria for SCMs performance appraisal. In this stage, after gathering the view points of experts about criteria, we enter them in the EXCEL software.

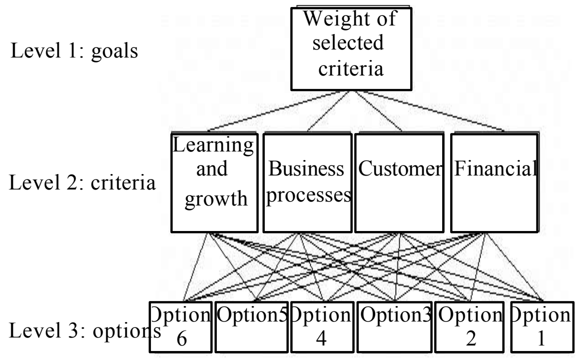


Fig. 6: 3 main operational levels in supply chains

Table 3: Options relative importance in AHP

| | Financial | Customer | Business processes | Learning and growth |
|---|---|---|---|---|
| Capital velocity | 0.243 | 0.219 | 0.091 | 0.123 |
| Satisfaction degree | 0.225 | 0.261 | 0.009 | 0.001 |
| Market share | 0.188 | 0.023 | 0.253 | 0.0146 |
| Information sharing | 0.220 | 0.095 | 0.275 | 0.252 |
| Innovative cycle | 0.014 | 0.141 | 0.163 | 0.252 |
| Flexibility | 0.110 | 0.261 | 0.216 | 0.226 |

Table 4: Final ranking of SCs

| Rank | Degree | Option |
|---|---|---|
| 1 | 83.30 | SC 1 (A) |
| 2 | 82.10 | SC 2 (B) |
| 3 | 78.81 | SC 3 (C) |

Consequently six criteria were selected to next stage. All of our criteria illustrate on Table 1 and our important criteria which are exaggerate by questionnaire illustrate on Table 2 (each degree more than 3).

**Step 2:** Determining relative importance (weight-giving) of chosen criteria of first step by using FAHP technique. According to previous section about AHP our hierarchy illustrate below. We used FDM software in this step (Table 4).

After analysis of these criteria, we examine the weight of criteria according to Table 3.

With attention to mentioned data we, final rank of SCs present at below.

## CONCLUSION

Many practitioners and researchers have presented the advantages of supply chain management. In order to increase the competitive advantage, many companies consider that a well designed and implemented supply chain system is an important tool.

Therefore, supplier selection problem becomes the most important issue to implement a successful supply chain system. In general, supplier selection problems adhere to uncertain and imprecise data and fuzzy-set theory is adequate to deal with them. In a decision-making process, the use of linguistic variables in decision problems is highly beneficial when performance values cannot be expressed by means of numerical values. In other words, very often, in assessing of possible suppliers with respect to criteria and importance weights, it is appropriate to use linguistic variables instead of numerical values. Due to the decision-makers' experience, feel and subjective estimates often appear in the process of supplier selection problem, an extension version of TOPSIS and AHP in a fuzzy environment is proposed in this paper. The fuzzy ( Table 3).

AHP method can weigh the critical criteria for competitiveness of supply chains and fuzzy TOPSIS method can deal with the ratings of both quantitative as well as qualitative criteria and select the suitable supplier effectively. It appears from the foregoing sections that fuzzy TOPSIS method may be a useful additional tool for the problem of supplier selection in supply chain system. In fact, the fuzzy TOPSIS method is very flexible. According to the closeness coefficient, we can determine not only the ranking order but also the assessment status of all possible suppliers.

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