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Research Article

MEASURING AND EVALUATING AGILITY IN SUPPLY CHAIN USING FUZZY HIERARCHICAL ANALYSIS

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ABSTRACT
The present research aims to gauge and evaluate the supply chain agility based on fuzzy hierarchical analysis among auto parts manufacturers in Shiraz. This is a practical descriptive survey study with statistical population including the managers of auto parts manufacturing companies in Shiraz. Samples were selected by clustering sampling. Data were gathered by hierarchical questionnaires and TOPSIS with validity verified by university professors and reliability confirmed based on inconsistency. Studying the weight of research criteria by AHP, it was cleared that information technology (0.178), employees' skills (0.155), merging processes (0.150), responsiveness (0.113), programming (0.084), flexibility (0.069), introducing new products (0.064), delivery reliability (0.056), cost reduction (0.045), customer satisfaction (0.047), and product quality (0.038) took the most to least weight in hierarchical questionnaires. Prioritizing agility options by TOPSIS revealed that delivery range (0.84), procurement range (0.73), production conformity (0.51), procurement conformity (0.5), supplies range (0.40), delivery conformity (0.61), and production range (0.15) are in the list of top to least important.

Keywords: *Agility, Prioritization, Hierarchical Questionnaires and TOPSIS*

INTRODUCTION
Within last decade, because of commercial agreements, alleviated commercial obstacles, and more accessible global consumers, companies have faced growing global competition (Lee, 2002). The supply chain is, therefore, of organizations strategic points. To survive in today's dynamic and volatile markets, supply chain needs a tool to meet peripheral challenges. This is just agility that can provide the supply chain with this capability (ZarehNejad, 2011). In such competitive market, it is virtually necessary to produce flexibility and responsiveness and consider agility in order to survive. To overtake competitors in global markets, companies should ally themselves with suppliers and customers and proceed with their operations and activities coupled with each other to reach the desired agility (Jafarnejad *et al.,* 2010). Agile supply chain management is a modern approach helping organizations with achieving competitive objectives and meeting customers' needs in current extremely competitive and turbulent market. This is a method based on efficient information and organizational integration in the whole supply chain and a vital factor for organizational competitiveness (Tarokh and Mahyar, 2010). To create an agile supply chain, first it should be defined as agility has a broad concept and various dimensions encompassing different organizational aspects. Agility has been widely studied; its concept in case of supply chain has though not been sufficiently explored. Accordingly, a technique is needed to gauge the level of agility in supply chain. Despite the obvious advantages, enterprises operating in complicated environments are encountering the challenges of gauging agility (Jafarzadeh *et al.,* 2010). Applying hierarchical analysis, this research tries to evaluate agility level in supply chain of auto parts industries.

Research Literature
Supply Chain Management
Supply chain management is an integrated philosophy in managing mainstream distribution from suppliers to end-users. As a Mediterranean philosophy, it includes the levels and limits of integrated behaviors in order provide the ground for customers and suppliers to cooperate with each other within external integration (Handfield and Nichols, 2000). A set of management processes, supply chain

management comprises of management relations, information and flowing material into defined borders in order to service customers and offer them economic value when managing physical channels and related information from resources to consume (Stadler and Cristopher, 2000). Supply chain management is a combination of art and science improving the way of finding raw material companies need for production or providing services. It is composed of five main components including:

Planning

Planning is the strategic part of supply chain management. To manage all resources applied to meet customers' demand, you need a strategy. Developing a set of parameters to supervise efficiency, cost reduction and high quality delivery is a major part of planning.

Sourcing

Selecting suppliers providing you with your required products and services to produce a product or service, developing pricing, delivery and payment processes, applying parameters of monitoring and improving relations with suppliers, and finally practicing these processes to manage inventories and services received from suppliers such as receiving shipments and identifying them are of necessary processes in this regard.

Manufacturing

This step includes all activities required for producing, packaging, and preparing for delivery.

Delivery

This is called logistics. Logistics is the management of the flow of goods between the point of origin and the point of consumption in order to meet some requirements, of customers or corporations. The management of customers' order and the development of a network of warehouses and a system of payment bills shape this step.

Return

The challenging part of supply chain is receiving incomplete items and items turned back by customers and supporting customers having problem with what they have received (Fiorino, 1989).

Definition of Agility

All definitions stress on the speed and flexibility as the major indicators of an agile organization. Similarly, the effective responsiveness to changes and unreliability is another sign of agility (Sharifi and Zhang, 1999). Definitions of agility are summarized as follow (Abbasspour *et al.*, 2012):

Table 1: Definitions of agility

Ikva/ Lee High (1991)	**A system that changes its product models and its product line quickly and in a right time in order to respond to customers' needs**
Golman *et al.*, (1995)	Organizational ability to productively function in a competitive market with varying needs of customers
Flinder and Kurka (1997)	An ability to successfully provide high quality products with low cost in short time and various sizes to offer value added to customers by customization
Dov (1999)	An organizational ability to effectively and efficiently respond to needs and reactive and hyper-reactive opportunities in face of unreliable and unpredicted environments
Raskche and David (2005)	An ability to dynamically change and/or reshape the commercial process in order to survive with potential needs
Ashrafi *et al.*, (2005)	An organizational ability to touch the environmental changes and effective and efficient respond to changes
Monavar *et al.*, (2009)	An ability to have excellent function in quality distribution, flexibility and costs (simultaneously proceeding)
Sharp *et al.*, (2012)	The ability of an organization to act as a human system living to grow and learn from varying waves so that it can be a natural and inevitable part of organizational life not a separate part or a threatening event

Some authors believe that in isolate methods and identifying and interpreting changes benefits, responsiveness to changes are of major factors of agility. Another common components arising from definitions of agility are high quality and customization. Other definitions include: the ability to quickly respond to market changes as a key component of enterprises' success and survival in markets (Vinodh and Arvind, 2011).

Peripheral Changes, Major Factor of Demanded Agility

Making change seems to be one of the major features of organizations in our modern competitive era. It is difficult to find an organization not observing any change within three to six month or even one year. Regarding the current context of business world, organizations have no way but making some changes in their insights, approaches, procedures and their projected results. Sharifi and Zhang (1999) categorized varying areas of business as follows:

- ❖ Market instability resulting from the growth of a small part of the market, multiplicity of new products and declining life cycle of products
- ❖ Intensive competition resulting from fast-varying market, high cost pressure, increasing competitiveness, and short-term development of new products
- ❖ Customers' varying needs resulting from customization, increased qualitative expectations, and faster handling
- ❖ Fast-changing technologies by introducing new and efficient production facilities, and software and hardware integrity of systems
- ❖ Changes in social factors made to preserve environment, workforce expectation and legal and law pressures
  - The increasing access to technology
  - Intensive competition over developing technology
  - Globalization of markets and commercial competition
  - The fast-increasing access to technology
  - Changes in salaries and job skills
  - Environmental responsibility and resource limitations
- ❖ The increased customers' expectation

Empowering by Agility

Empowering organizations by agility is a set of major and effective factors inside organizations (Gunasekaran, 2008). In other words, these are intra-organizational factors that are not only affected by agility stimulators but also create a special capability (capabilities of agility) (Sharifi and Zhang, 1999). Many researchers have referred to these intra-organizational factors as agility providers or agility enablers such as organization, employees, technology, individuals, information technology, virtual enterprise, simultaneous engineering, fast produced sample, teamwork, knowledge, capability to reshape, management of fundamental competencies, innovation, strategy, system, entrepreneurship, information system, strategic capabilities, process,, operation, customers, culture leadership, reward system, suppliers, guidelines, work processes, knowledge management, human resources, supply chain, the quality of human resource, leadership style, organizational culture, organizational structure, research, and development (Song *et al.*, 2011).

Agile Supply Chain

To achieve competitive advantages of the varying business environment, making their operation efficient, and to have an acceptable level of agility, companies should struggle to cooperate with their suppliers and customers (Christopher and Towill, 2002). In such a case, an agile supply chain is shaped. An agile supply chain can effectively respond to environmental changes. Agility in supply chain can be defined as: "the ability of a supply chain to have a fast-response to existing changes in the market and to customers' needs" (Jafarnejad and Shahaee, 2007). According to Masson, agile supply chain means taking advantage of market knowledge and the concept of virtual company in order to effectively use profitable opportunities of oscillating markets (Mason *et al.*, 2000).

Creating Agile Supply Chain

One of the biggest challenges of current organizations is that they have to respond to the growing instability of demands. For some reasons, life cycle of products and technologies has been shortened, competitive pressures frequently impose changes in products and the variation of customers' demands is higher than before. To meet this challenge, organizations have to put their efforts into gain higher agility, because it helps organizations to respond to volume and variation changes as soon as possible. Put it differently, organizations have to regulate outputs in short time in order to match it with market demands and quickly change from one form to another. For an agile business, demand instability is not an acute and problematic challenge, because the organizational structure and the supply chain relations enable organizations to meet any demands.

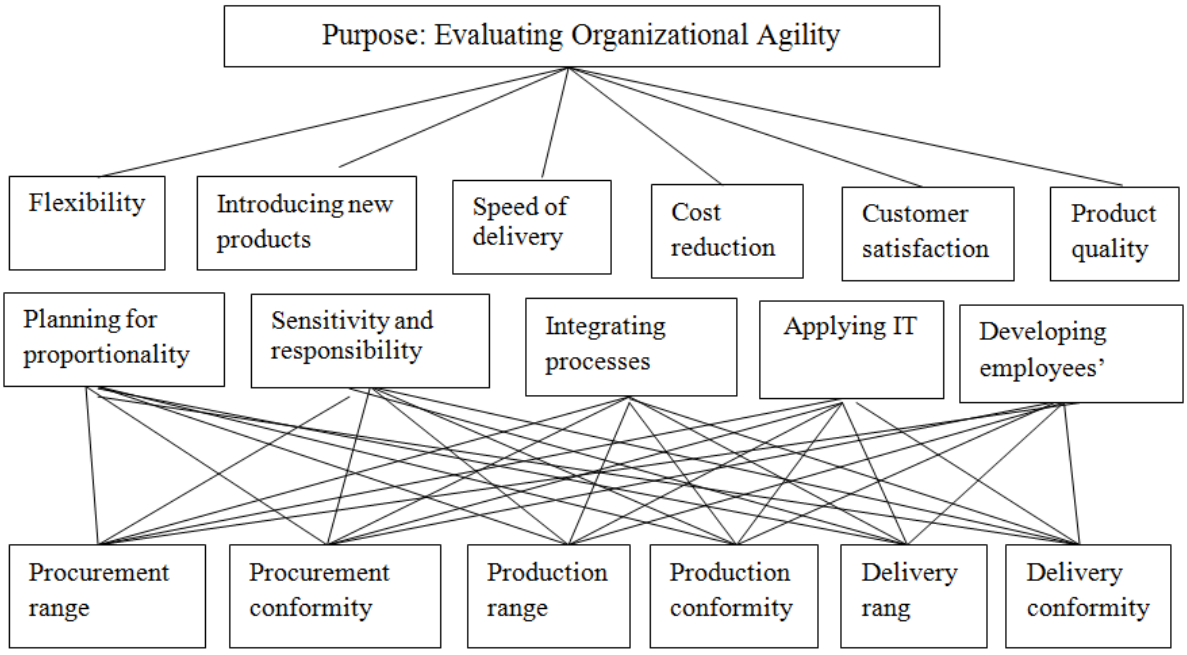

Figure 1: Research conceptual model

Agility does not mean being able to match. Lean manufacturing or lean production has been widely studied (in industries, leanness of supply and demands is necessarily synonymous with automobile). Lean production approach decreases the part inventories and moves toward updated production. Leanness may be a component of agility in certain circumstances; leanness though does not enable organizations to meet the growing needs of customers. Agility, however, can do this. To reach agility, the supply chain should have the following distinct characteristics:

Cooperative Relations: this strategy refers to the ability to attract purchasersand suppliers to work in cooperation with each other and jointly develop product and information system.

Process Integrity: as a basis for the supply chain, this signifies that the supply chain is a center for partners to join to a network.

Information integrity: as the supply chain infrastructure, it is the capability to use information technology in order to share data between purchasers and suppliers and to effectively create virtual supply chains. Virtual supply chains are based on information not warehouse inventory.

Responsiveness to Customers: as the foundation of supply chain, it includes the ability to identify and respond to customers' current needs, all-inclusive changes, and unreliability (Khoshsima, 2003).

Research Hypotheses

- Delivery flexibilityis currently the highest ranked priority among agility dimensions of supply chain.

- Applying information technology is the most important factor in the success of agile supply chain.

MATERIALS AND METHODS

This is a practical descriptive survey study with statistical population including the managers of auto parts manufacturing companies in Shiraz. As TOPSIS and AHP were exercised in this research and it is not based on statistical analyses, there is no need to determine specifically a statistical population and sample. To prioritize and rank the components and criteria of the conceptual model, 20 expert managers and employees were asked to offer their comments.

Data were gathered by hierarchical and TOPSIS questionnaires. For hierarchical questionnaire, as comparisons are carried out in paired form, the questionnaire has been designed accordingly. In TOPSIS questionnaire, the state of each dimension has been studied based on each component and experts are asked to determine the importance of each component by numbering from 0 to 9. Zero is the weakest state and number 9 refers to the best condition.

To confirm the reliability of AHP questionnaire, the consistency of AHP questionnaires is considered. If it is smaller than 0.1, the consistency is confirmed and data are reliable.

The consistency of questionnaire was calculated at 0.08. It is smaller than 0.1 showing the proportionality of the questionnaire.

To implement AHP and TOPSIS, EXPERT CHOICE and EXCELL were used respectively.

RESULTS AND DISCUSSION

TOPSIS and Hierarchical Analysis

Weighting Criteria

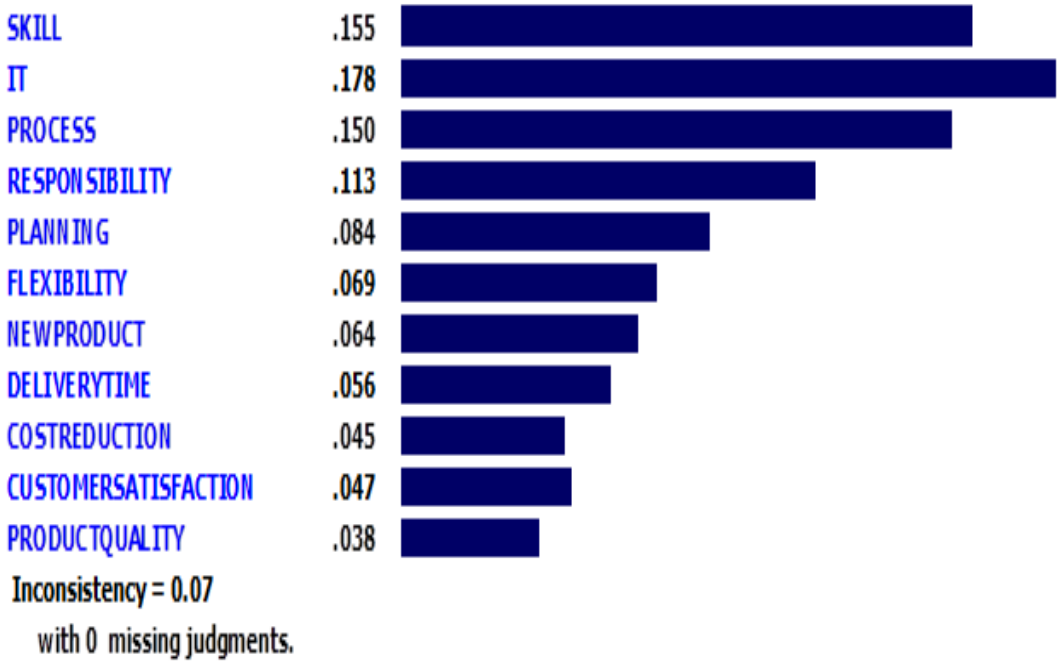

Figure 2: Criteria weight

Given the above figure, information technology (0.178), employees' skills (0.155), process integration (0.150), responsiveness (0.113), planning (0.084), flexibility (0.69), new product (0.064), delivery time (0.056), cost reduction (0.045), customer satisfaction (0.047), and product quality (0.038) have the highest to lowest weight respectively. The weight diagram has been presented in the following figure.

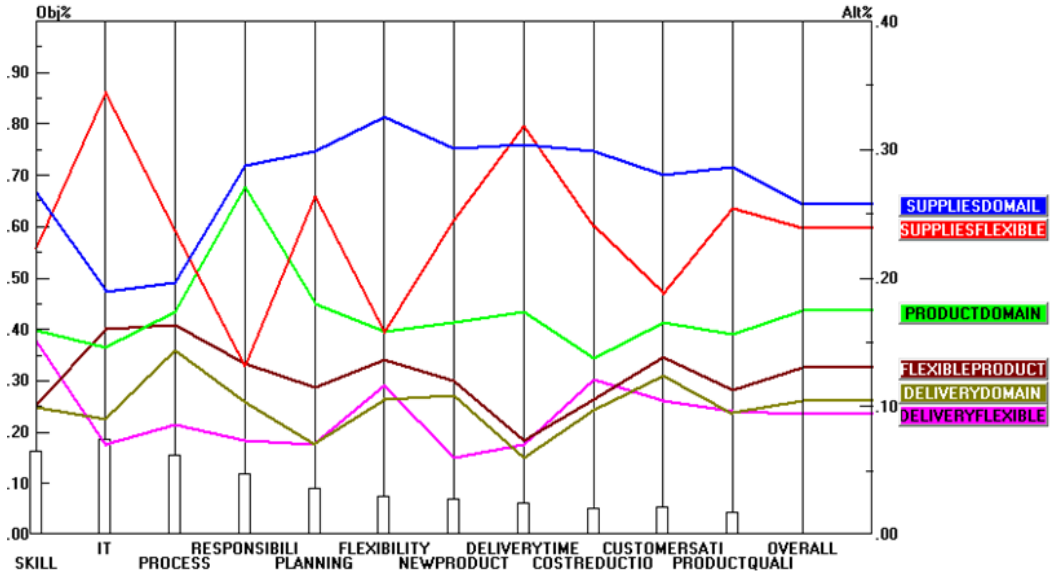

Figure 3: Weight diagram

Prioritizing Different Sections of the Statistical Population by TOPSIS

The following table presents the results of experts' comments.

Table 2: Decision Matrix

	Product Quality	**Customer Satisfaction**	**Cost Reduction**	**Delivery Speed**	**New Product**	**Flexibility**	**Appropriate Planning**	**Sensitivity and Responsiveness**	**Process Integration**	**Applying information technology**	**Developing employees' skills**
Procurement rang	3.18	3.21	3.26	3.31	3.38	4.68	4.38	7.28	6.98	6.48	1.98
Procurement conformity	2.99	3.24	3.57	3.49	3.60	4.49	4.19	7.09	6.79	6.29	1.79
Production range	1.82	2.05	2.06	1.73	1.68	3.32	3.02	5.92	5.62	5.12	0.62
Production conformity	2.83	3.03	2.74	2.16	2.19	4.33	4.03	6.93	6.63	6.13	1.63
Delivery range	3.31	3.19	2.92	2.74	2.43	4.81	4.51	7.41	7.11	6.61	2.11
Delivery conformity	1.82	1.79	1.45	1.36	1.45	3.32	3.02	5.92	5.62	5.12	0.62

Second Phase: Making Decision Matrix Dimensionless

In this step, the values of decision matrix cells are divided by the size of the vector of the same index. Table 3 presents the dimensionless matrix.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}}$$

Table 3: Dimensionless Matrix

	Product Quality	**Customer Satisfaction**	**Cost Reduction**	**Delivery Speed**	**New Product**	**Flexibility**	**Appropriate Planning**	**Sensitivity and Responsiveness**	**Process Integration**	**Applying information technology**	**Developing employees' skills**
Procurement rang	0.36	0.36	0.38	0.41	0.42	0.36	0.36	0.36	0.36	0.36	0.35
Procurement conformity	0.34	0.041	0.41	0.43	0.45	0.03	0.35	0.35	0.35	0.35	0.32
Production range	0.21	0.198	0.24	0.21	0.21	0.15	0.25	0.29	0.29	0.29	0.11
Production conformity	0.32	0.28	0.32	0.27	0.27	0.21	0.34	0.34	0.34	0.34	0.29
Delivery range	0.38	0.75	0.34	0.34	0.30	0.44	0.38	0.37	0.37	0.37	0.38
Delivery conformity	0.21	0.19	0.17	0.17	0.18	0.18	0.25	0.29	0.29	0.29	0.11
Procurement rang	0.30	0.23	0.24	0.26	0.24	0.18	0.32	0.33	0.33	0.33	0.25

Third Phase: Multiplying Probability (Weight) by Softened Matrix

In this part, the calculated weights in hierarchical analysis are multiplied by column values of each index to achieve stochastic matrix multiplied by intensity.

Table 4: Multiplying probability by decision matrix

	Product Quality	**Customer Satisfaction**	**Cost Reduction**	**Delivery Speed**	**New Product**	**Flexibility**	**Appropriate Planning**	**Sensitivity and Responsiveness**	**Process Integration**	**Applying information technology**	**Developing employees' skills**
Procurement rang	0.014	0.017	0.017	0.023	0.027	0.025	0.030	0.041	0.054	0.064	0.054
Procurement conformity	0.013	0.002	0.018	0.024	0.029	0.002	0.029	0.040	0.053	0.062	0.050
Production range	0.008	0.009	0.011	0.012	0.013	0.010	0.021	0.033	0.044	0.052	0.017
Production conformity	0.012	0.013	0.014	0.015	0.017	0.014	0.029	0.038	0.051	0.061	0.045
Delivery range	0.014	0.035	0.015	0.019	0.019	0.030	0.032	0.042	0.056	0.066	0.059
Delivery conformity	0.008	0.009	0.008	0.010	0.012	0.012	0.021	0.033	0.044	0.052	0.017
Procurement rang	0.011	0.011	0.011	0.015	0.015	0.012	0.027	0.037	0.050	0.059	0.039

Fourth Phase: Determining the Positive and Negative Ideal Solution

In this part, the largest value of each column is introduced as the positive ideal solution and the smallest value of each column is considered as the negative ideal solution.

Table 5: The positive and negative ideal solution

	Product Quality	**Customer Satisfaction**	**Cost Reduction**	**Delivery Speed**	**New Product**	**Flexibility**	**Appropriate Planning**	**Sensitivity and Responsiveness**	**Process Integration**	**Applying information technology**	**Developing employees' skills**
Positive ideal	0.014	0.035	0.018	0.024	0.029	0.03	0.032	0.042	0.056	0.066	0.059
Negative ideal	0.008	0.002	0.008	0.01	0.012	0.002	0.021	0.033	0.044	0.052	0.017

Fifth Phase: Calculating the Distance Values

To evaluate distance values, the following formula is used:

$$S_{i*} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \qquad i = 1,2,3,4$$

Ideal Distance

A. distance span from the positive value

Table 6: Distance span from the positive value

Option	Positive Ideal
Procurement rang	0.020
Procurement conformity	0.045
Production range	0.062
Production conformity	0.035
Delivery range	0.012
Delivery conformity	0.063
Procurement rang	0.042

B. distance span from the negative value

Table 6: Distance span from the negative value

Option	negative Ideal
Procurement rang	0.055
Procurement conformity	0.045
Production range	0.011
Production conformity	0.037
Delivery range	0.066
Delivery conformity	0.012
Procurement rang	0.029

Approaching the Ideal Solution

Table 8: The closeness of distance from ideal

Option	negative Ideal
Procurement rang	0.733
Procurement conformity	0.500
Production range	0.151
Production conformity	0.514
Delivery range	0.846
Delivery conformity	0.160
Procurement rang	0.408

In this part, distances from positive and negative ideals are calculated by the following formula:

$$C_{1*} = \frac{S_{1-}}{S_{1*} + S_{1-}}$$

In this formula:
C* = approaching to the ideal state
S_{1-} = distance from the negative ideal
S_{1+} = distance from the positive ideal
Based on values relating to closeness, the distance from ideal is obtained as above (table 8):
Given the results achieved by studying the options of supply chain options, the different parts of agility are prioritized from highest score to the lowest one:

Table 9: Prioritization of the different parts of agility

Option	Distance from Ideal
Procurement rang	0.846
Procurement conformity	0.733
Production range	0.514
Production conformity	0.5
Delivery range	0.408
Delivery conformity	0.16
Procurement rang	0.151

Results

Weighting Criteria

Studying the weight of research criteria, it was cleared that information technology (0.178), employees' skills (0.155), merging processes (0.150), responsiveness (0.113), programming (0.084), flexibility (0.069), introducing new products (0.064), delivery reliability (0.056), cost reduction (0.045), customer satisfaction (0.047), and product quality (0.038) took the most to least weight in hierarchical questionnaires. Accordingly, it is concluded that information technology is the most important criterion.

Prioritizing Options

Options were prioritized by TOPSIS. In this analysis, weights were first multiplied by TOPSIS decision matrix. After converting decision matrix to multiplied matrix, prioritization was carried out based on TOPSIS phases. Finally, prioritization revealed that the delivery range (0.84), procurement range (0.73), production conformity (0.51), procurement conformity (0.5), supplies range (0.40), delivery conformity (0.61), and production range (0.15) are in the list of top to least important priorities.

Suggestions

Using information technology should be in proportion to the employees' and managers' knowledge. All supply chain levels should be involved in implementing IT systems. And all individuals should be mobilized to efficiently use these systems. The employees' skills to use information technology and the delivery time should increase according to customers' needs. Such skills can be acquired by right employments and in-service training. To intensify responsiveness to the system, it is at times necessary to transfer some similar processes into the system and to integrate products under a single operation unit. This would reduce supervision costs and create a good coordination among different parts. To make the chain agile, responsiveness is highly important. This means that different parts should be constantly supported and employees and beneficiaries should be able to use it for their organization. Accordingly, further coordination is projected between various parts. A good planning in order to efficiently use supply chain can be effective in managing costs and working time. A good and accurate program can reduce functional weaknesses based on error and trial in organization. Flexibility is always needed. The supply chain should be designed as to always place different options before the organization. Here, using several distribution channels and collecting raw materials are recommended in this regard. Providing new products for the supply chain and offering them can heighten the flexibility of this chain.

A system is suggested to be launchedfor managing customer relations. This helps you to accurately study the level of customers' satisfaction and complains. By means of this a continuous improvement is anticipated.

Cultural indices are suggested to be explored in order to launch an updated production system to prevent from unreliability among employees and to study the power distance between top managers.

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