A THEORETICAL DECISION MAKING FRAMEWORK ON THE ASSESSMENT OF LEAGILITY INDEX IN A SUPPLY CHAIN MANAGEMENT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology in Mechanical Engineering

By

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CERTIFICATE

This is to certify that the thesis entitled "A theoretical decision making framework on the assessment of leagility index in a supply chain management" submitted by Sri Maussam Chakravarty, Roll No.109ME0364 in fulfillment of the requirements for the award of the degree of Bachelor of Technology in Mechanical Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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ABSTRACT

Recent market globalization has enforced the manufacturing as well as service industries not only to ensure product variety, but also to make every effort for the lowest product price and the ability to respond quickly to the uncertain volatile marketplace. For successful survival in the highly competitive global business environment, manufacturing paradigm has shifted from 'lean' towards 'agile' and now towards the more advanced 'leagile' principles. Leagile approach is basically the combination of lean and agile principles in which leanness emphasizes on elimination of 'wastes' whereas agility introduces speediness, flexibility as well as responsiveness into the manufacturing system. Therefore, leagile concept explores the salient features of both lean and agile approaches which help manufacturing organizations (as well as service sectors) to gain competitive business advantage. The extent of leagility is indeed very difficult to compute due to existence of ill-defined (vague) performance indices whose evaluation is based on human judgment only. Since subjective human judgment often bears some kind of imprecision, uncertainty as well as vagueness; application of traditional decision making tools and techniques seem inappropriate in this context. In order to tackle such inconsistency and incompleteness in the said decision-making process; present work proposes a theoretical framework towards supply chain leagility assessment in fuzzy environment. Fuzzy numbers set theory, fuzzy operational rules and the concept of fuzzy degree of similarity have been explored to compute supply chain's overall leagility index and finally, to identify ill(poor)-performing supply chain areas (barriers of leagility). A case empirical example has also been provided.

Keywords: Lean; agile; leagile; fuzzy set theory

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CHAPTER 1

INTRODUCTION AND STATE OF ART

1. INTRODUCTION AND STATE OF ART

With the advancement of global economic integration as well as manufacturing, the competition among enterprises is continually transformed into competition amongst successful operation of their supply chains. This forced the business enterprises to actively invest in supply chain management (SCM), and to establish a sound strategic alliance against competitors. SCM attempts to reduce supply chain risk and uncertainty, thus improving customer service and optimizing inventory levels, business processes, and cycle times, and resulting in increased competitiveness, customer satisfaction and profitability. In this context, the supply chain management is increasingly being recognized as an effective way to enhance competitive advantage of organizations in manufacturing realm. Getting the right product, at the right price, at the right time is very important for a company towards survival. In recent years, lean and agile have awakened great interest in the research of supply chain management.

Naylor et al. (1999) defined the two paradigms as follows: Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule; whilst agility means utilizing market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace. Booth (1996) and Christopher (2000) thought that there was a need to adopt the lean manufacturing paradigm and now manufacturers should strive to become agile. In reality, the two paradigms can be viewed as complement to each other. They share a common objective, meeting customer demands at the least total cost. In many cases, a hybrid leagile supply chain strategy can also be adopted.

Leagile concept is the combination of lean and agile manufacturing within a supply chain strategy by positioning the decoupling point. A leagile system has the characteristics of both lean and agile systems, acting together in order to exploit market opportunities in a cost-

efficient manner. The system being defined as leagile could be an entire supply chain or a single manufacturing plant with individual lean and agile sub groups containing a decoupling point, which separates the lean and agile portions of the system. The decoupling point is the point in the material flow streams to which the customer's order penetrates (Mason-Jones et al., 2000a; Prince and Kay, 2003).

Literatures are readily available regarding the implementation of lean as well as agile production approaches. Hamid (2011) identified various factors as a driver to the success of lean services implementation. Behrouzi and Wong (2011) developed a flexible model dynamics in measuring leanness extent. Vinodh and Vimal (2012) presented thirty-criterion leanness assessment methodology using fuzzy logic.

Jassbi et al. (2010) developed an approach based on Adaptive Neuro Fuzzy Inference System (ANFIS) for evaluating agility in supply chain considering agility capabilities such as Flexibility, Competency, Cost, Responsiveness and Quickness. Vinodh et al. (2010) investigated to assess the agility level of an organization using a multi-grade fuzzy approach. Mason-Jones et al. (2000b) classified supply chain design and operations according to the Lean, Agile and Leagile Paradigms that enabled to match the supply chain type according to marketplace necessity. Bruce et al. (2004) discussed the characteristics of the textiles and apparel industry and identified the perspectives of lean, agile and leagility within existing supply chain fiction, which offered as solutions to achieving quick response and reduced lead times. Narasimhan et al. (2006) attempted an empirical study to determine whether leanness and agility forms occurred with any degree of uniformity in manufacturing plants. The result illustrated the existence of homogeneous groups that resembled lean and agile performing plants. The authors identified important differences pertaining to their constituent performance and also revealed that while the pursuit of agility might presume leanness, pursuit of leanness might not presume agility.

Successful implementation of leagile principles in SCM necessitates its overall performance index to be measured. Most of the leagile criterions being subjective in nature; decision-making must be carried out by considering expert judgment of the decision-makers. Since linguistic human judgment bears some sort of ambiguity and vagueness in the decision-making; fruitful application of fuzzy set theory deserves mention in this context. Apart from estimating an overall leagility index; industries should identify ill (poor)-performing supply chain areas (called barriers of leagility) which require substantial future improvement to boost up overall supply chain's leagility. A theoretical framework has been proposed here to assess supply chain's overall leagility index in fuzzy environment.

CHAPTER 2

FUZZY NUMBERS:OPERATIONAL RULES

2. Fuzzy Numbers: Operational Rules

Definition 2.1: A real fuzzy number A is described as any fuzzy subset of the real line R with membership function f_A that can be generally defined as (Dubois and Prade, 1983):

(a) f_A is a continuous mapping from R to the closed interval $[0, \varpi]$, $0 \le \varpi \le 1$;

(b) $f_A(x) = 0$, for all $x \in (-\infty, a]$;

(c) f_A is strictly increasing on $[a, b]$;

(d) $f_A(x) = 1$, for all $x \in [b, c]$;

(e) $f_A(x)$ is strictly decreasing on $[c, d]$;

(f) $f_A(x) = 0$, for all $x \in (d, \infty]$.

Here a, b, c and d are real numbers. Unless elsewhere specified, it is assumed that A is convex and bounded $(i.e. -\infty < a, d < \infty)$.

Definition 2.2: The fuzzy number $A = [a, b, c, d; \varpi]$ is a trapezoidal fuzzy number if its membership function is given by:

$$f_A(x) = \begin{cases} f_A^L(x), & a \le x \le b, \\ \varpi, & b \le x \le c, \\ f_A^R(x), & c \le x \le d, \\ 0, & otherwise. \end{cases} \tag{1}$$

Here $f_A^L : [a, b] \to [0, \varpi]$ and $f_A^R : [c, d] \to [0, \varpi]$ are two continuous mappings from the real line R to the closed interval $[0, \varpi]$.

Definition2.3: it is obvious that f_A^L, the left membership function of fuzzy number A, is continuous and strictly increasing on $[a, b]$, and $f_R^L(x)$, the right membership function of the fuzzy number A, is continuous and strictly decreasing on $[c, d]$. If $\varpi = 1$, then A is a normal fuzzy number; otherwise, it is said to be a non-normal fuzzy number. If $b \ne c$, A is referred

to as a fuzzy interval (Dubois and Prade, 1983; 1986) or a flat fuzzy number (Matarazzo and Munda, 2001). If $f_A^L(x)$ and $f_R^L(x)$ are both linear, then A is referred to as a trapezoidal fuzzy number and is usually denoted by $A=(a,b,c,d;\varpi)$ or simply $A=(a,b,c,d)$ if $\varpi=1$. Fig. 1 is an illustration of the trapezoidal fuzzy number $A=(a,b,c,d;\varpi)$. In particular, when $b=c$, the trapezoidal fuzzy number is reduced to a triangular fuzzy number; and can be denoted by $A=(a,b,d;\varpi)$ or $A=(a,b,d)$ if $\varpi=1$. So, triangular fuzzy numbers are special cases of trapezoidal fuzzy numbers:

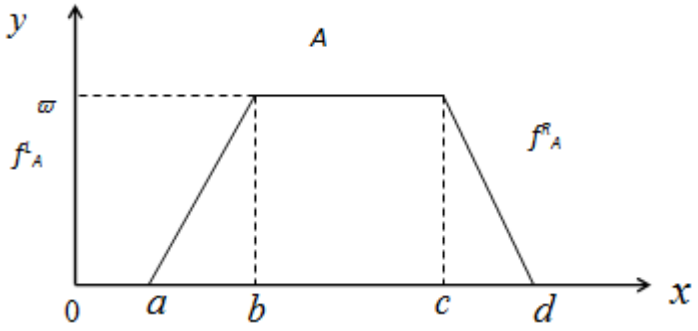

Fig. 1: Trapezoidal fuzzy number

Suppose that $A_1=(a_1,b_1,c_1,d_1)$ and $A_2=(a_2,b_2,c_2,d_2)$ are two trapezoidal fuzzy numbers, then the operational rules of the trapezoidal fuzzy numbers $\tilde{a}$ and $\tilde{b}$ are shown as follows (Yu et al., 2013):

$$A_1+A_2=(a_1,b_1,c_1,d_1)+(a_2,b_2,c_2,d_2)$$
$$=(a_1+a_2,b_1+b_2,c_1+c_2,d_1+d_2) \quad (2)$$

$$A_1-A_2=(a_1,b_1,c_1,d_1)+(a_2,b_2,c_2,d_2)$$
$$=(a_1-a_2,b_1-b_2,c_1-c_2,d_1-d_2) \quad (3)$$

$$A_1\otimes A_2=(a_1,b_1,c_1,d_1)\otimes(a_2,b_2,c_2,d_2)$$
$$=(a_1a_2,b_1b_2,c_1c_2,d_1d_2) \quad (4)$$

$$\frac{A_1}{A_2}=\frac{(a_1,b_1,c_1,d_1)}{(a_2,b_2,c_2,d_2)}=\left(\frac{a_1}{d_2},\frac{b_1}{c_2},\frac{c_1}{b_2},\frac{d_1}{a_2}\right) \quad (5)$$

CHAPTER 3

SIMILARITY MEASURE BETWEEN GENERALIZED TRAPEZOIDAL FUZZY NUMBERS (GTFN)

3. Similarity Measure between Generalized Trapezoidal Fuzzy Numbers(GTFN)

In this work, the concept of a similarity measure between two Generalized Trapezoidal Fuzzy Numbers (*GTFN*) has been adopted in order to identify ill (poor) performing supply chain entities. The mathematical basis is provided below.

The similarity measure between two generalized trapezoidal fuzzy numbers A and B are defined as follows:

$$S(A,B) = se \times sp \tag{6}$$

where, $se = \begin{cases} e^{-|a_1 - b_1|}, & a_1 = a_4 \text{ and } b_1 = b_4 \\ e^{-(k+z+h)}, & otherwise \end{cases}$ (7)

Also, k is the span deference; z is the centre deference; h is the centre width deference between A and B, respectively.

$$k = |(a_4 - a_1) - (b_4 - b_1)|$$

$$z = \left| \frac{(a_4 + a_1)}{2} - \frac{(b_4 + b_1)}{2} \right|$$

$$h = |(a_3 - a_2) - (b_3 - b_2)|$$

and,

$$sp = \frac{DP + \min\,(P(A), P(B))}{DP + \max\,(P(A), P(B))} \tag{8}$$

where,

$$P(A) = \sqrt{(a_1 - a_2) + w_a^2} + \sqrt{(a_3 - a_4) + w_a^2} + (a_3 - a_2) - (a_4 - a_1)$$

$$P(B) = \sqrt{(b_1 - b_2) + w_b^2} + \sqrt{(b_3 - b_4) + w_b^2} + (b_3 - b_2) - (b_4 - b_1)$$

$P(A)$ and $P(B)$ are the perimeters of A and B.

DP is an amending value to avoid zeros in the numerator and denominator, $DP \in (0, 0.1)$

CHAPTER 4

EMPIRICAL DATA ANALYSIS

4. Empirical Data Analysis

In this part of work, empirical data has been analyzed to exhibit application feasibility of aforesaid decision-making tools in fuzzy environment. Assuming the candidate enterprise adapted leagile principle and has taken part in this decision-making, it is required to compute an overall index with respect to the organization leagile performance. An expert committee (decision-making group) consisting of five decision-makers has been formed. The unique decision-making group has been instructed to go for several brainstorming sessions to finalize leagility indices (metrics) and corresponding priority weight (importance) towards evaluating overall organizational leagility extent. The said decision-making group has been instructed to visit (periodically or continuous monitoring) the candidate firm and to monitor ongoing performance of each leagile entities in the supply chain. Thereafter, the team has been permitted to provide their judgment (expert opinion) on performance extent (appropriateness rating) of various leagile indices (in the SC) corresponding to the candidate enterprise. In this decision-making, five leagility based criterions have been considered viz. C_1: Virtual Enterprises, C_2: Collaborative Relationships, C_3: Strategic Management, C_4: Knowledge and IT Management, C_5: Customer and Market Sensitiveness. These above criterions have been described to enlighten, how they stimulate the extent body leagility in accordance with their sub-criteria as listed in Table 1 and Table 2, respectively.

Aforesaid leagility criterions being intangible (qualitative) in nature; the decision-making should rely on subjective judgment (expressed in linguistic terms) of the decision-makers. Expert opinions have been collected in linguistic terms in terms of rating and weight of individual leagile criterion. The conversion scheme of linguistic terms into appropriate fuzzy representation has been shown in Table 3. Empirical data have been analyzed; and the results obtained thereof, have been illustrated in subsequent sections.

The procedural steps of the proposed leagility framework followed by results of empirical data analysis have been summarized as follows:

Step 1: Collection of experts' opinion (in linguistic terms) against priority weight and appropriateness rating for leagility evaluation indices

The expert panel has been requested to assign priority weights against individual sub-criterions (at 2nd level) and main criterions (at 1st level) as well as appropriateness ratings of individual sub-criterions (at 2nd level) through linguistic terminology as revealed in Table 3. Expert opinion has been depicted in (Tables 4-6).

Step 2: Approximation of linguistic information: transformation into appropriate fuzzy numbers

Linguistic expert judgment has been transformed into appropriate fuzzy numbers in accordance with Table 3. Based on the fuzzy average rule, aggregated fuzzy weight for individual 1st level criteria (Table 4) as well as individual 2nd level sub-criteria (Table 5) have been computed. Similarly, aggregated fuzzy appropriateness ratings against individual 2nd level sub-criterions have been computed (Table 6).

Step 3: Computation of Fuzzy Performance Index (FPI)

In order to evaluate the Fuzzy Performance Index (FPI), the aggregated fuzzy appropriateness ratings (Table 6) against individual 2nd level sub-criterions have been exploited and then (Eq. 9) has been followed to calculate appropriateness ratings of individual 1st level main criterions (Table 7).

Appropriateness rating for each of the 1st level evaluation index U_i (rating of i_{th} index) has been computed as follows:

$$U_i = \frac{\sum U_{ij} \otimes w_{ij}}{\sum w_{ij}} \tag{9}$$

In this expression (Eq. 9), U_{ij} is denoted as the aggregated fuzzy appropriateness rating against j_{th} index (at 2nd level) which is under i_{th} index in the 1st level. Also w_{ij} is the aggregated fuzzy weight against j_{th} index (at 2nd level) which is under i_{th} index at 1st level.

And then, the Fuzzy Performance Index (FPI) (leagility extent) has been computed by exploiting (Eq. 10).

$$FPI = \frac{\sum U_i \otimes w_i}{\sum w_i} \tag{10}$$

In this expression, U_i is denoted as computed fuzzy appropriateness rating (consequenced by Eq. 9) against i_{th} index (at 1st level). Also w_i is the aggregated fuzzy weight against i_{th} index at 1st level.

The Fuzzy Performance Index (FPI) thus computed as [0.490, 0.603, 1.144, 1.406]. The FPI can be compared with predefined or standard fuzzy leagility assessment scale set by the top management of the enterprise to check and compare existing leagility level to identify ill (week) performing areas of SC network elements which require subsequent future improvement.

Step 4: Computation of Fuzzy Performance Importance Index (FPII): Identification of ill-performing areas

After evaluating the FPI, it becomes indeed necessary to compute the ill (poor) performing leagility indices (at 2nd level) of the general hierarchy criteria.

From the above perspective, the concept of Fuzzy Performance Importance Index (FPII) has been fruitfully explored. The concept of computing FPII has been reported by (Lin et al., 2006a) which combines appropriateness rating and importance weight of different evaluation indices at 2nd level. The higher the FPII of a factor (evaluation index), the higher is the contribution towards supply chain's leagility.

$$FPII_{ij} = w_{ij}^{'} \times U_{ij} \tag{11}$$

$$w_{ij}^{'} = \left[\left[(1,1,1,1;1)\right] - w_{ij}\right] \tag{12}$$

The Fuzzy Performance Importance Index (FPII) and Ideal Fuzzy Performance Importance Index against individual 2nd level indices has been calculated by following the (Eq. 11 and 12) as revealed in (Table 8).

Additionally, to compute the Ideal Performance Importance Index (IFPII), the following equations (Eq. 13 and 14) have been adopted to find ill-performing indices as follows:

$$IFPII_{ij} = \max\left\lfloor FPII_{ij}[a_{ij}, b_{ij}, c_{ij}, d_{ij}]\right\rfloor \tag{13}$$

$$IFPII_{ij} = \min\left\lfloor FPII_{ij}[a_{ij}, b_{ij}, c_{ij}, d_{ij}]\right\rfloor \tag{14}$$

$\max FPII_{ij}$ = defined maximum value evaluate from all computed FPII set. $B \in$ Beneficial criteria, $C \in$ Cost criteria

Subsequently, the (Eq. 6, 7 and 8) has been followed in order to compute the ill performing criterions; depicted in (Table 9). It facilitates the managers to amend ill performing indices. Managers might be able to improve and amend their company performances up to the desirable extent.

CHAPTER 5

CONCLUSION

5. CONCLUSION

Aforesaid study examines application feasibility of fuzzy based decision-making tool to evaluate a leagility index in industrial supply chain. Assuming five leagile criterions viz. Virtual Enterprises, Collaborative Relationships, Strategic Management, Knowledge and IT Management, and Customer and Market Sensitiveness; the leagility index of the enterprise has been computed with respect to the performance of leagile Supply Chain. Subjectivity of leagility indices have been tackled by means of fuzzy set theory. The work has further been extended to compute ill-performing supply chain areas (leagile barriers).

Table 1: General Hierarchy Criteria (GHC) for leagility assessment

Goal	Criteria	Sub-Criteria
Leagility assessment	Virtual enterprise, C_1	Virtual retail stores, C_{11}
		E-fulfilment logistics, C_{12}
		Outsourcing, C_{13}
		Integrated logistics management, C_{14}
		E-commerce, C_{15}
	Collaborative relationship, C_2	Enterprise wide relationship management, C_{21}
		Supplier relationship management, C_{22}
		Logistics service providers, C_{23}
		Collaborative planning, forecast and replenishment, C_{24}
		Collaborative order fulfilment visibility, C_{25}
	Strategic management, C_3	Inventory management, C_{31}
		Cycle time reduction, C_{32}
		Time management, C_{33}
		Process management, C_{34}
		Production planning, C_{35}
		Quality status, C_{36}
		Vendor management, C_{37}
	Knowledge and IT management, C_4	E-business, C_{41}
		Decentralization, C_{42}
		Supply chain visibility, C_{43}
		Information system, C_{44}
		Electronic data interchange, C_{45}
	Customer and market sensitiveness, C_5	Customer focus, C_{51}
		Market sensitivity, C_{52}
		Culture and change management, C_{53}
		Mass customization, C_{54}
		Product quality, C_{55}

Table 2: Definition of leagile criterions

Leagile Criterions	Definitions
Virtual enterprise	A virtual enterprise is a temporary alliance of businesses that comes to share skills or core competencies and resources in order to better respond to business opportunities, and whose cooperation is supported by computer networks. [Source: http://en.wikipedia.org/wiki/Virtual_enterprise, Zhou and Nagi, 2002; OBrien and Al-Biqami 1998]
Collaborative relationship	A relationship in which the capacity to act or effect change is shared by all persons in the relationship rather than being assigned to one person who is seen as the authority or expert. Collaborative relationships are characterized by commitment, cooperation, and connectedness in striving for a common goal. [Source: Wagner et al., 2010; Hoegl and Wagner, 2005; Phelps, 1996]
Strategic management	Strategic management consists of the analysis, decisions, and actions an organization undertakes in order to create and sustain competitive advantages. Strategic management can be defined as the art and science of formulating, implementing, and evaluating cross-functional decisions that enable an organization to achieve its objectives. [Source: David, 2011; Ketchen and Giunipero, 2004]
Knowledge and IT management	The knowledge and IT management refers to a multi-disciplined approach to achieve organizational objectives by making the best use of knowledge and resources related to information technology. The Knowledge management focuses on processes such as acquiring, creating and sharing knowledge and to build up the cultural and technical foundations. The aim of IT management is to generate value through the use of technology. [Source: Raub and Wittich, 2004]
Customer and market sensitiveness	It is the consciousness of the customers towards cost windows or range within which they make dealings. All the customers are always cost sensitive and concentrate basically to buy products on cheap rates. However, cost sensitivity of a customer substantially depends on condition of the market. [Source: Sharpe, 1972; Lin et al., 2006b]

Table 2 (Continued): Definition of leagile Sub-criterions

Leagile Sub Criterions	Definitions
Virtual Enterprise	
Virtual retail stores	It is a retail presence on the Web. The virtual store is an online store that provides a list of merchandise and an order form. They might have also provided a telephone number, e-mail and a live text chat, in which the customer interacts in real time with a company representative.
E- fulfilment logistics	E-fulfillment logistics is an integration of people, processes and technology within the supply chain that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements.
Outsourcing	Outsourcing is contracting with another company or person to do a particular function.
Integrated logistics management	Integrated logistics management is a service-oriented process. It incorporates actions that help to move the product from the raw material source to the final customer.
E-commerce	Business transactions conducted on the internet. E-commerce involves digitally enabled commercial transactions between and amongst organizations and individuals.
Collaborative Relationship	
Enterprise wide relationship management	Enterprise relationship management is basically a business strategy for value creation that is not based on cost containment, but rather on the leveraging of network-enabled processes and activities to transform the relationships between the organization and all its internal and external constituencies in order to maximize current and future opportunities.
Supplier relationship management	Supplier relationship management is the discipline of strategically planning and managing of all interactions with third party organizations that supply goods and services to an organization in order to maximize the value of those interactions.
Logistics service providers	A third-party logistics provider (abbreviated 3PL, or sometimes TPL) is a firm that provides service to its customers of outsourced (or third party) logistics services for part, or all of their supply chain management functions. Third party logistics providers typically specialize in integrated operation, warehousing and transportation services that can be scaled and customized to customers' needs based on market conditions and the demands and delivery service requirements for their products and materials. Often, these services go beyond logistics and include value-added services related to the production or procurement of goods, i.e., services that integrate parts of the supply chain. Then the provider is called third-party supply chain management provider (3PSCM) or supply chain management service provider (SCMSP). Third Party Logistics System is a process which targets a particular

	function in the management. It may be like warehousing, transportation, raw material provider,
Collaborative planning, forecast and replenishment	CPFR is a concept that aims to enhance supply chain integration by supporting and assisting joint practices and to coordinate plans in order to improve efficiencies and increase sales and service.
Collaborative order fulfilment visibility	Collaborative order fulfilment visibility is the active data input. It manages the flow of information from when the goods are complete and dispatched from the supplier's factory through to the port and then on arrival at destination. It allows all parties to know if the order is complete; all the products are being shipped; is it on time. It helps with the logistics and document preparation for customs clearances.
Strategic Management	
Inventory management	Inventory management is the process of efficiently overseeing the constant flow of units into and out of an existing inventory.
Cycle time reduction	Cycle time reduction is identifying and implementing more efficient ways to do things. Reducing cycle time requires eliminating or reducing non value added activity, which is an activity that does not add value to the product such as repair due to defects, machine set-up, inspection, and test and schedule delays.
Time management	Time management is the act or process of planning and exercising conscious control over the amount of time spent on specific activities, especially to increase effectiveness, efficiency or productivity.
Process management	Process management is the group of activities of planning and monitoring the performance of a process.
Production planning	Production planning means to fix the production goals and to estimate the resources which are required to achieve these goals. It prepares a detailed plan for achieving the production goals economically, efficiently and in time.
Quality status	Quality status is a benchmark of product, organization and services should aspire to reach.
Vendor management	Vendor management is the discipline of establishing service, quality, cost satisfying goals and selecting and managing third party companies to consistently meet these goals.
Knowledge and IT Management	
E- business	E-business is the application of information and communication technologies in support of all the activities of business. E-business allows companies to link their internal and external processes more efficiently and effectively, and work more closely with suppliers and partners to better satisfy the needs and expectations of their customers, leading to improvements in overall business performance.
Decentralization	Decentralization is the process of redistributing or dispersing functions, powers, people or things away from a central location or authority.
Supply chain visibility	It is the ability to access or view relevant data or information as

	it relates to logistics and the supply chain. The goal of SCV is to improve and strengthen the supply chain by making data readily available to all stakeholders, including the customer.
Information system	Information system, an integrated set of components for collecting, storing, and processing data and for delivering information, knowledge, and digital products.
Electronic data interchange	Electronic data interchange is a document standard which when implemented acts as common interface between two or more computer applications in terms of understanding the document transmitted. It is commonly used by big companies for e-commerce purposes, such as sending orders to warehouses or tracking their order.
Customer and Market Sensitiveness	
Customer focus	The orientation of an organization toward serving its clients' needs. Having a customer focus is usually includes maintaining an effective customer relations and service program ensuring that all aspects of the company put its customer's satisfaction first.
Market sensitivity	A market position that can easily be changed from one direction to another direction based on news. News that was reported during the previous session may influence the next session and cause stocks to advance or decline. During volatile session in a sensitive market, stocks are typically impacted by every piece of news whether good or bad. For example, if a company reports lower-than-expected earnings, the news may send stocks spiraling downwards.
Culture and change management	Managing change within a community, a culture or a corporation. It always creates ripples of complication, and changing a company's processes and systems, and can have a profound effect on the overall organization; but, if a company takes a structured, goal-oriented, data-driven approach to change, it can actually increase productivity and profitability.
Mass customization	Mass customization is the use of flexible computer aided manufacturing systems to produce custom output.
Quality of product	Product quality means to incorporate features that have a capacity to meet consumer needs and gives customer satisfaction by improving products and making them free from any deficiencies or defects.

Table 3: 9-member linguistic term set

Linguistic term (Priority weight)	Linguistic term (appropriateness rating)	Fuzzy representation: Generalized trapezoidal fuzzy numbers set
Absolutely Low (AL)	Absolutely Poor (AP)	(0,0,0)
Very Low (VL)	Very Poor (VP)	(0,0,0.2,0.7)
Low (L)	Poor (P)	(0.04,0.1,0.18,0.23)
Fairly Low (FL)	Fairly Poor (FP)	(0.17,0.22,0.36,0.42)
Medium (M)	Moderate (M)	(0.32,0.41,0.58,0.65)
Fairly High (FH)	Fairly Good (FG)	(0.58,0.63,0.80,0.86)
High (H)	Good (G)	(0.72,0.78,0.92,0.97)
Very High (VH)	Very Good (VG)	(0.93,0.98,1,1)
Absolutely High (AH)	Absolutely Good (AG)	(1,0.98,1,1)

Table 4: Priority weights against individual 1st level indices as assigned by DMs and corresponding aggregated fuzzy weights

Main-indices	Priority weight expressed in linguistic terms					Aggregated fuzzy weight
	DM1	DM2	DM3	DM4	DM5	
C_1	VH	FH	FH	AH	FH	[0.734,0.770,0.880,0.916]
C_2	VH	H	FH	H	AH	[0.790,0.830,0.928,0.960]
C_3	H	H	FH	H	AH	[0.748,0.790,0.912,0.954]
C_4	AH	FH	FH	AH	VH	[0.818,0.840,0.920,0.944]
C_5	AH	FH	FH	FH	VH	[0.734,0.770,0.880,0.916]

Table 5: Priority weight against individual 2nd level sub-indices as assigned by DMs and corresponding aggregated fuzzy weight

Sub-indices	Priority weight expressed in linguistic terms					Aggregated fuzzy weight
	DM1	DM2	DM3	DM4	DM5	
C_{11}	FH	FH	FH	FH	FH	[0.580,0.630,0.800,0.860]
C_{12}	AH	FH	FH	H	FH	[0.692,0.730,0.864,0.910]
C_{13}	AH	H	H	H	FH	[0.748,0.790,0.912,0.954]
C_{14}	FH	FH	AH	FH	FH	[0.664,0.700,0.840,0.888]
C_{15}	FH	H	VH	AH	H	[0.790,0.830,0.928,0.960]
C_{21}	FH	VH	VH	AH	H	[0.832,0.870,0.944,0.966]
C_{22}	H	VH	H	AH	AH	[0.874,0.900,0.968,0.988]
C_{23}	AH	VH	H	H	FH	[0.790,0.830,0.928,0.960]
C_{24}	AH	VH	AH	H	H	[0.874,0.900,0.968,0.988]
C_{25}	H	VH	AH	FH	AH	[0.846,0.870,0.944,0.966]
C_{31}	AH	AH	AH	FH	AH	[0.916,0.910,0.960,0.972]
C_{32}	FH	FH	FH	FH	FH	[0.580,0.630,0.800,0.860]
C_{33}	H	H	FH	FH	FH	[0.636,0.690,0.848,0.904]
C_{34}	FH	FH	FH	FH	FH	[0.580,0.630,0.800,0.860]
C_{35}	AH	H	FH	H	FH	[0.720,0.760,0.888,0.932]
C_{36}	AH	AH	FH	FH	AH	[0.832,0.840,0.920,0.944]
C_{37}	AH	AH	FH	AH	AH	[0.916,0.910,0.960,0.972]
C_{41}	H	AH	FH	AH	AH	[0.860,0.870,0.944,0.966]
C_{42}	H	AH	FH	FH	FH	[0.692,0.730,0.864,0.910]
C_{43}	AH	FH	FH	FH	FH	[0.664,0.700,0.840,0.888]
C_{44}	FH	FH	FH	FH	H	[0.608,0.660,0.824,0.882]
C_{45}	FH	FH	FH	FH	H	[0.608,0.660,0.824,0.882]
C_{51}	AH	AH	H	H	AH	[0.888,0.900,0.968,0.988]
C_{52}	AH	AH	H	H	AH	[0.888,0.900,0.968,0.988]
C_{53}	FH	AH	FH	AH	AH	[0.832,0.840,0.920,0.944]
C_{54}	AH	AH	AH	AH	AH	[1.000,0.980,1.000,1.000]
C_{55}	AH	FH	FH	AH	AH	[0.832,0.840,0.920,0.944]

Table 6: Appropriateness ratings against individual 2nd level sub-indices as assigned by DMs and corresponding aggregated fuzzy ratings

Sub-indices	Appropriateness ratings expressed in linguistic terms					Aggregated fuzzy rating
	DM1	DM2	DM3	DM4	DM5	
C_{11}	AG	G	G	G	G	[0.776,0.820,0.936,0.976]
C_{12}	AG	G	G	G	G	[0.776,0.820,0.936,0.976]
C_{13}	AG	G	G	G	G	[0.776,0.820,0.936,0.976]
C_{14}	AG	FG	FG	FG	FG	[0.664,0.700,0.840,0.888]
C_{15}	AG	FG	FG	FG	FG	[0.664,0.700,0.840,0.888]
C_{21}	AG	FG	FG	FG	FG	[0.664,0.700,0.840,0.888]
C_{22}	AG	FG	FG	FG	FG	[0.664,0.700,0.840,0.888]
C_{23}	VG	G	G	G	G	[0.762,0.820,0.936,0.976]
C_{24}	G	G	G	G	G	[0.720,0.780,0.920,0.970]
C_{25}	G	FG	FG	FG	FG	[0.608,0.660,0.824,0.882]
C_{31}	AG	AG	AG	FG	FG	[0.832,0.840,0.920,0.944]
C_{32}	AG	AG	AG	FG	FG	[0.832,0.840,0.920,0.944]
C_{33}	VG	VG	VG	G	G	[0.846,0.900,0.968,0.988]
C_{34}	AG	AG	AG	G	G	[0.888,0.900,0.968,0.988]
C_{35}	AG	AG	AG	AG	AG	[1.000,0.980,1.000,1.000]
C_{36}	G	FG	AG	AG	AG	[0.860,0.870,0.944,0.966]
C_{37}	G	FG	VG	VG	VG	[0.818,0.870,0.944,0.966]
C_{41}	FG	FG	AG	AG	AG	[0.832,0.840,0.920,0.944]
C_{42}	FG	FG	FG	FG	FG	[0.580,0.630,0.800,0.860]
C_{43}	FG	FG	G	G	FG	[0.636,0.690,0.848,0.904]
C_{44}	G	FG	G	G	FG	[0.664,0.720,0.872,0.926]
C_{45}	G	AG	G	G	FG	[0.748,0.790,0.912,0.954]
C_{51}	G	AG	G	G	FG	[0.748,0.790,0.912,0.954]
C_{52}	G	AG	FG	FG	FG	[0.692,0.730,0.864,0.910]
C_{53}	FG	G	FG	FG	G	[0.636,0.690,0.848,0.904]
C_{54}	FG	G	FG	AG	G	[0.720,0.760,0.888,0.932]
C_{55}	FG	G	FG	AG	G	[0.720,0.760,0.888,0.932]

Table 7: Computed fuzzy appropriate ratings against individual 1st level evaluation indices

Main-indices	Aggregated fuzzy ratings
C_1	[0.554,0.652,1.059,1.238]
C_2	[0.591,0.673,0.948,1.063]
C_3	[0.696,0.769,1.094,1.208]
C_4	[0.530,0.622,1.034,1.211]
C_5	[0.643,0.697,0.943,1.015]

Table 8: Fuzzy performance importance index (FPII) and ideal FPII

Sub-indices	Fuzzy Performance Importance Index ($FPII$)	Ideal Fuzzy Performance Importance Index ($IFPII$)
C_{11}	[0.326,0.303,0.187,0.137]	[0.373,0.333,0.194,0.138]
C_{12}	[0.239,0.221,0.127,0.088]	[0.373,0.333,0.194,0.138]
C_{13}	[0.196,0.172,0.082,0.045]	[0.373,0.333,0.194,0.138]
C_{14}	[0.223,0.210,0.134,0.099]	[0.373,0.333,0.194,0.138]
C_{15}	[0.139,0.119,0.060,0.036]	[0.373,0.333,0.194,0.138]
C_{21}	[0.112,0.091,0.047,0.030]	[0.373,0.333,0.194,0.138]
C_{22}	[0.084,0.070,0.027,0.011]	[0.373,0.333,0.194,0.138]
C_{23}	[0.160,0.139,0.067,0.039]	[0.373,0.333,0.194,0.138]
C_{24}	[0.091,0.078,0.029,0.012]	[0.373,0.333,0.194,0.138]
C_{25}	[0.094,0.086,0.046,0.030]	[0.373,0.333,0.194,0.138]
C_{31}	[0.070,0.076,0.037,0.026]	[0.373,0.333,0.194,0.138]
C_{32}	[0.349,0.311,0.184,0.132]	[0.373,0.333,0.194,0.138]
C_{33}	[0.308,0.279,0.147,0.095]	[0.373,0.333,0.194,0.138]
C_{34}	[0.373,0.333,0.194,0.138]	[0.373,0.333,0.194,0.138]
C_{35}	[0.280,0.235,0.112,0.068]	[0.373,0.333,0.194,0.138]
C_{36}	[0.144,0.139,0.076,0.054]	[0.373,0.333,0.194,0.138]
C_{37}	[0.069,0.078,0.038,0.027]	[0.373,0.333,0.194,0.138]
C_{41}	[0.116,0.109,0.052,0.032]	[0.373,0.333,0.194,0.138]
C_{42}	[0.179,0.170,0.109,0.077]	[0.373,0.333,0.194,0.138]
C_{43}	[0.214,0.207,0.136,0.101]	[0.373,0.333,0.194,0.138]
C_{44}	[0.260,0.245,0.153,0.109]	[0.373,0.333,0.194,0.138]
C_{45}	[0.293,0.269,0.161,0.113]	[0.373,0.333,0.194,0.138]
C_{51}	[0.084,0.079,0.029,0.011]	[0.373,0.333,0.194,0.138]
C_{52}	[0.078,0.073,0.028,0.011]	[0.373,0.333,0.194,0.138]
C_{53}	[0.107,0.110,0.068,0.051]	[0.373,0.333,0.194,0.138]
C_{54}	[0.000,0.015,0.000,0.000]	[0.373,0.333,0.194,0.138]
C_{55}	[0.121,0.122,0.071,0.052]	[0.373,0.333,0.194,0.138]

Table 9: Computed preference orders (ranking) of 2nd level sub-indices

Sub-indices	$S(A,B)$	Preference order (Ranking)
C_{11}	0.743	5
C_{12}	0.547	8
C_{13}	0.545	9
C_{14}	0.464	10
C_{15}	0.400	13
C_{21}	0.336	15
C_{22}	0.286	18
C_{23}	0.439	11
C_{24}	0.294	17
C_{25}	0.256	20
C_{31}	0.179	26
C_{32}	0.918	2
C_{33}	0.813	4
C_{34}	0.994	1
C_{35}	0.839	3
C_{36}	0.295	16
C_{37}	0.180	25
C_{41}	0.284	19
C_{42}	0.385	14
C_{43}	0.412	12
C_{44}	0.575	7
C_{45}	0.707	6
C_{51}	0.249	21
C_{52}	0.238	22
C_{53}	0.223	24
C_{54}	0.112	27
C_{55}	0.239	23

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