**Benchmarking: An International Journal**

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# A fuzzy embedded leagility assessment module in supply chain

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Received 6 December 2013
Revised 19 November 2015
Accepted 1 December 2015

## Abstract

**Purpose** – In today's ever-changing global business environment, successful survival of manufacturing firms/production units depends on the extent of fulfillment of dynamic customers' demands. Appropriate supply chain strategy is of vital concern in this context. Lean principles correspond to zero inventory level; whereas, agile concepts motivate safety inventory to face and withstand in turbulent market conditions. The leagile paradigm is gaining prime importance in the contemporary scenario which includes salient features of both leanness and agility. While lean strategy affords markets with predictable demand, low variety and long product life cycle; agility performs best in a volatile environment with high variety, mass-customization and short product life cycle. Successful implementation of leagile concept requires evaluation of the total performance metric and development of a route map for integrating lean production and agile supply in the total supply chain. To this end, the purpose of this paper is to propose a leagility evaluation framework using fuzzy logic.

**Design/methodology/approach** – A structured framework consisting of leagile capabilities/attributes as well as criterions has been explored to assess an overall leagility index, for a case enterprise and the data, obtained thereof, has been analyzed. Future opportunities toward improving leagility degree have been identified as well. This paper proposes a Fuzzy Overall Performance Index to assess the combined agility and leanness measure (leagility) of the organizational supply chain.

**Findings** – The proposed method has been found fruitful from managerial implication viewpoint.

**Originality/value** – This paper aimed to present an integrated fuzzy-based performance appraisement module in an organizational leagile supply chain. This evaluation module helps to assess existing organizational leagility degree; it can be considered as a ready reference to compare performance of different leagile organization (running under similar supply chain architecture) and to benchmark candidate leagile enterprises; so that best practices can be transmitted to the less-performing organizations. Moreover, there is scope to identify ill-performing areas (barriers of leagility) which require special managerial attention for future improvement.

**Keywords** Benchmarking, Decision support systems

**Paper type** Research paper

## 1. Introduction: lean, agile and leagile manufacturing concept

In this era of globalization, modern manufacturing enterprises are continuously facing tough market competitions. The remarkable industrial growth in past few decades has completely revolutionized their traditional manufacturing strategies, giving emergence to the modern concepts of lean, agile, and nowadays, leagile manufacturing. These new strategies enable the enterprises to survive in the turbulent environment of violent competitions laid down by their competitors. The requirement of faster delivery within due date, the ability of being flexible to satisfy fluctuating market demand have been the prime motivations that has provoked manufacturing enterprises to look for the

Authors gratefully acknowledge the support rendered by Professor Gunasekaran, Editor-in-Chief, *Benchmarking, An International Journal*. Special thanks to the anonymous reviewers for their valuable constructive comments and suggestions to prepare the paper a good contributor.

Benchmarking: An International Journal
Vol. 23 No. 7, 2016
pp. 1937-1982

1463-5771
DOI 10.1108/BIJ-12-2013-0113

available best alternatives, and implement it in their daily manufacturing practices. This led to the development of a new concept of leagality, which is an integration of lean and agile principles. Agile manufacturing is adopted where demand is volatile and lean manufacturing is adopted where there is a stable demand. However, in some situations it is advisable to utilize a different paradigm on either side of the material flow decoupling point to enable a total supply chain strategy. This approach is termed as leagile paradigm (Mason-Jones, 2000a, b).

Recent advancements have shown that leagile principle has immense potential to counteract the existing complexity of the market scenario. Therefore, leagile principles are, nowadays, attracting modern manufacturing enterprises; researchers as well as management practitioners are aiming to find its potential benefits almost in all industrial sectors throughout the globe.

### *1.1 Lean manufacturing*

Lean manufacturing focusses on cost reduction by eliminating non-value added activities so that several advantages can be obtained such as minimization/elimination of waste, increased business opportunities and to gain competitive advantage. Lean manufacturing is generally adopted where there is a stable demand and to ensure a level schedule. The term "lean manufacturing," which first appeared in 1990s (Womack *et al.*, 1990; Holweg, 2007) when it was used to refer to the elimination of waste in the production process, has been announced as the production system of the twenty-first century. Historically, the concept of lean manufacturing was originated with Toyota Production Systems; and Toyota had increasingly become known for its effectiveness in implementing Just-In-Time manufacturing systems. Lean manufacturing is called "lean" as it uses less or the minimum, of everything required to produce a product or perform a service. Lean operations eliminate seven tedious wastes, namely overproduction, over processing, motion, waiting, transportation, defects and inventory.

### *1.2 Agile manufacturing*

Agile manufacturing is the ability to respond and create new windows of opportunity in a turbulent market environment, driven by the individualization of customers' requirements cost effectively, rapidly and continuously. Agile manufacturing is essentially the utilization of market knowledge and virtual corporation to exploit profitable opportunities in a volatile marketplace (Power *et al.*, 2001; Katayama and Bennett, 1999; Christopher, 2000).

Agile manufacturing is used to represent the ability of a producer of goods and services to thrive in the face of continuous change. These changes can occur in markets, in technologies, in business relationships and in all facets of the business enterprise. On the contrary, lean manufacturing, the emphasis is on cost-cutting. The requirement for organizations, to become more flexible and responsive to customers' expectations, led to the concept of agile manufacturing as a differentiation from the lean organization.

### *1.3 Leagile manufacturing*

Leagility is the combination of the lean and agile paradigms within a supply chain strategy by proper positioning the decoupling point. A leagile system has the characteristics of both lean and agile parts, acting together in order to exploit market opportunities in a cost-efficient manner. The system 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, b; Prince and Kay, 2003). It is the point where order driven and the forecast-driven activities meet. A decoupling point within a factory enables lean and agile practices to complement each other at the operational level to improve overall performance and profitability of the factory. The most important reason behind combining these two concepts is to take advantages of both in a single unit; because, there is always a need for responding to volatile demand downstream and providing level scheduling upstream from the marketplace (Van Hoek *et al.*, 2001). Naylor *et al.* (1999) believed that they can complement each other in the right operational conditions and should not be viewed as competitive, rather as mutually supportive. Agility is dynamic and context specific, aggressively change embracing and growth oriented (Goldman *et al.*, 1995). Agile manufacturing promises not only improved manufacturing performance, but also the support of future business strategies designed to improve the way in which an enterprise competes in the marketplace. On a strategic level, agile manufacturing is seemed very attractive for its potential to cope up with future uncertainty and the prospect of producing a wide range of highly customized products at mass production prices. Therefore, these two concepts can be combined within successfully designed and operated supply chains; where agile manufacturing concepts are applied to the part of the supply chain under the greatest pressure to operate in an environment of fluctuating demand in terms of volume and variety. Lean concepts can then be applied to the rest of the supply chain to create and encourage level demand necessary to achieve the cost benefits associated with this production strategy. The innovation being sought is the application of lean and agile concepts at different stages of the same manufacturing process route so that the benefits of both strategies can be maximized.

## 2. State of art and problem definition

Naylor *et al.* (1999) compared lean and agile paradigm highlighting the similarities and differences as agile manufacturing is best suited to satisfy a fluctuating demand and lean manufacturing requires a level schedule. They combined both the paradigm within a total supply chain strategy particularly considering market knowledge and positioning of the decoupling point. Mason-Jones *et al.* (2000a) integrated lean production and agile supply in the total supply chain and supplemented by information enrichment which required evaluation of the total performance metric and development of a route map. Adopting such an approach to supply chain re-engineering ensured that customer service levels were improved at the same time lead times and costs were greatly reduced. 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. Herer *et al.* (2002) introduced transshipments, which represented a common practice in multi-location inventory systems involving monitored movement of stock between locations at the same level of the supply chain and established a model, how transshipments could be used to enhance both agility and leanness. Stratton and Warburton (2003) explored the role of inventory and capacity in accommodating the lean as well as agile supply chain variation and identified how Theory of Inventive Problem Solving (TRIZ) separation principles and Theory of Constraints (TOC) tools might be combined in the integrated development of responsive and efficient supply chains. Prince and Kay (2003) described the circumstances on which, manufacturing organizations required an integrated agile

and lean characteristic in their supply chain. They also described the development of the virtual group (VG) concept, which was the application of virtual cells to functional layouts. VGs enabled the appropriate application of lean and agile concepts to different stages of production within a factory. The identification of VGs was achieved through enhanced production flow analysis. Bruce *et al.* (2004) discussed the characteristics of the textiles and apparel industry and identified the perspectives of leanness, agility 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. They 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. Agarwal *et al.* (2006) presented a framework which encapsulated the market sensitiveness, process integration, information driver as well as flexibility measures of supply chain performance. They investigated the relationship among lead-time, cost, quality and service level and presented a case study on three types of supply chain: lean, agile and leagile in the context of fast moving consumer goods business. Krishnamurthy and Yauch (2007) proposed a theoretical model of leagile manufacturing and analyzed the utility of leagility concept to a single corporate with multiple business units. They explained whether a decoupling point would be necessary to distinguish the lean and agile portions of the enterprise.

Rahimnia *et al.* (2009) presented a case study to apply the decoupling point concept in a healthcare delivery system considering the leagile concept. By grouping healthcare services into three pipelines, the aforesaid study identified decoupling points for the supply chain. It also argued that while discussing leagility in a professional service organization, the important role of human resources should be highlighted. Chan *et al.* (2009) proposed an integrated process planning and scheduling model inheriting the salient features of outsourcing; and leagile principles to compete in the existing market scenario. The authors also proposed a new hybrid Enhanced Swift Converging Simulated Annealing (ESCSA) algorithm, to solve the complex real-time scheduling problems. It had an inherent feature of the genetic algorithm, simulated annealing and the fuzzy logic controller. Rahimnia and Moghadasian (2010) highlighted the application of leagility and its characteristics in a mass service organization. Despite the low customization in mass services, fast food restaurants faced changing needs of the customers. To respond to these demands, the case organization could adopt new strategies so that it could be able to serve the customer with short lead times, low costs and high variety. Huang and Li (2010) illustrated how a personal computer original equipment manufacturer in Taiwan achieved leagility through re-engineering of its supply chain. The case study showed how the company adjusted its production processes from build-to-order to configuration-to order so as to achieve leagility.

Konecka (2010) emphasized the importance of the risk management in supply chains strategy such as lean, agile and leagile. These studies facilitated the choice of an appropriate supply chain strategy based on the risk analysis. Moron and Haan (2011) presented a practical case study on Polish distributer in Poland. They stated that during the volatile period an agile approach provided the flexibility and competitiveness needed. However, when the market matured; the overly expensive agility caused last minute crisis; then a lean approach enabled the optimization of processes needed to supply customer in a more reliable way.

Azevedo *et al.* (2012) proposed an index to evaluate the extent of agility and leanness of individual companies and the corresponding supply chain. The index was obtained from a set of agile and lean supply chain practices integrated in an assessment model, named Agile and Delphi technique which was used to develop a series of weighted agile and lean supply chain management practices and also the importance of the paradigms through experts in automotive. Soni and Kodali (2012) addressed the issue of lack of standard constructs in frameworks of lean, agile and leagile supply chain by evaluating reliability and validity of lean, agile and leagile supply chain constructs in Indian manufacturing industry. Principle component analysis was performed on these constructs to find out the pillars of each type of supply chain followed by evaluating reliability and validity of these pillars to establish the underlying constructs.

Literature has been found rich enough in delivering in-depth understanding of lean, agile and leagile concepts in supply chain management. Potential benefits of individual supply chain strategies in appropriate situation have been well documented. The need for combining lean as well as agile principles in a total supply chain has also been clearly highlighted. While adopting a particular supply chain strategy; performance assessment is indeed necessary. Relatively less work has been found reported in literature concerning different aspects of performance appraisement of leagility-driven supply chain. Motivated by this, present work attempts to develop an efficient leagility assessment module in fuzzy context. Data obtained from a case organization at eastern part of India has been explored to reflect application feasibility of the proposed method.

The rest of the paper has been organized as follows. Section 3 presents basic knowledge on fuzzy logic that will be required in data analysis as well as interpretation phase. Section 4 provides detailed understanding of the proposed evaluation framework; its procedural steps, etc. Case study has been reported in Section 5. Managerial and research implications of this work has been documented in Section 6. Finally, Section 7 draws conclusions of this research.

## 3. Fuzzy preliminaries

Fuzzy logic is basically a multi-value logic which permits intermediate values to be defined between conventional ones like true/false, low/high, good/bad, etc. It is an established fact that, as the complexities surrounding a system increase, making a precise statement about the state of the system becomes very difficult.

To deal with vagueness in human thought, Zadeh (1965) first introduced the fuzzy set theory, which has the capability to represent/manipulate data and information possessing based on non-statistical uncertainties. Moreover fuzzy set theory has been designed to mathematically represent uncertainty and vagueness and to provide formalized tools for dealing with the imprecision inherent to decision-making problems. Some basic definitions of fuzzy sets, fuzzy numbers and linguistic variables are reviewed from Zadeh (1975), Buckley (1985), Negi (1989), Kaufmann and Gupta (1991). The basic definitions and notations below will be used throughout this paper until otherwise stated.

### *3.1 Definitions of fuzzy sets*

*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 $\tilde{A}$ (Kaufmann and Gupta, 1991).

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

$$\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geqslant \min\left(\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)\right) \quad (1)$$

For all $x_1$, $x_2$ in $X$ and all $\lambda \in [0, 1]$, where min denotes the minimum operator (Klir and Yuan, 1995).

*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 (Klir and Yuan, 1995).

### 3.2 Definitions of fuzzy numbers

*Definition 4.* A fuzzy number is a fuzzy subset in the universe of discourse $X$ that is both convex and normal. Figure 1 shows a fuzzy number $\tilde{n}$ in the universe of discourse $X$ that conforms to this definition (Kaufmann and Gupta, 1991).

*Definition 5.* The $\alpha$-cut of fuzzy number $\tilde{n}$ is defined as:

$$\tilde{n}^{\alpha} = \left\{x_i : \mu_{\tilde{n}}(x_i) \geqslant \alpha, x_i \in X\right\}, \quad (2)$$

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

The symbol $\tilde{n}^{\alpha}$ 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 $\tilde{n}$, if $n_l^{\alpha} > 0$ and $n_u^{\alpha} \leqslant 1$ for all $\in [0, 1]$, then $\tilde{n}$ is called a standardized (normalized) positive fuzzy number (Negi, 1989):

*Definition 6.* Suppose, a positive triangular fuzzy number (PTFN) is $\tilde{A}$ and that can be defined as $(a, b, c)$ shown in Figure 2. The membership function $\mu_{\tilde{n}}(x)$ is defined as:

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-a)/(b-a), & \text{if } a \leqslant x \leqslant b, \\ (c-x)/(c-b), & \text{if } b \leqslant x \leqslant c, \\ 0, & \text{otherwise,} \end{cases} \quad (3)$$

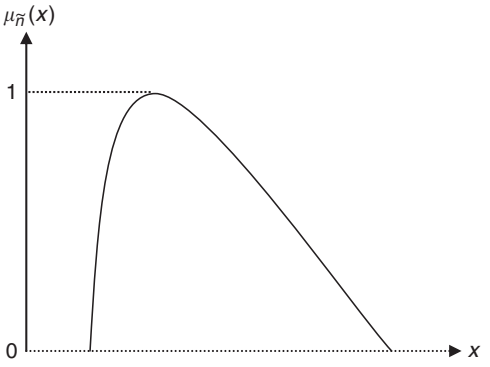


**Figure 1.**
A fuzzy number $\tilde{n}$

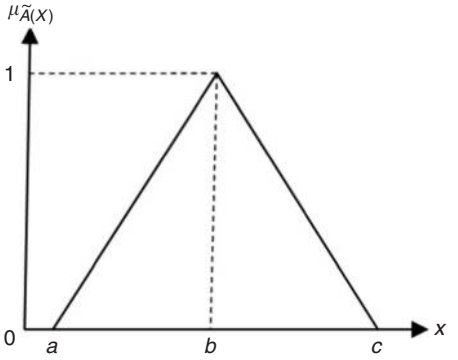


**Figure 2.**
A triangular fuzzy number $\tilde{A}$

Based on extension principle, the fuzzy sum $\oplus$ and fuzzy subtraction $\Theta$ of any two triangular fuzzy numbers are also triangular fuzzy numbers; but the multiplication $\otimes$ of any two triangular fuzzy numbers is only approximate triangular fuzzy number (Zadeh, 1975). Let us have a two PTFN s, such as $\tilde{A}_1 = (a_1, b_1, c_1)$, and $\tilde{A}_2 = (a_2, b_2, c_2)$, and a positive real number $r = (r, r, r)$, some algebraic operations can be expressed as follows:

$$\tilde{A}_1 \oplus \tilde{A}_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2) \tag{4}$$

$$\tilde{A}_1 \,\Theta\, \tilde{A}_2 = (a_1 - a_2, b_1 - b_2, c_1 - c_2), \tag{5}$$

$$\tilde{A}_1 \otimes \tilde{A}_2 = (a_1 a_2, b_1 b_2, c_1 c_2), \tag{6}$$

$$r \otimes \tilde{A}_1 = (ra_1, rb_1, rc_1), \tag{7}$$

$$\tilde{A}_1 \emptyset \tilde{A}_2 = \left(a_1/c_2, b_1/b_2, c_1/a_2\right), \tag{8}$$

The operations of $\vee$ (max) and $\wedge$ (min) are defined as:

$$\tilde{A}_1(\vee)\tilde{A}_2 = (a_1 \vee a_2, b_1 \vee b_2, c_1 \vee c_2), \tag{9}$$

$$\tilde{A}_1(\wedge)\tilde{A}_2 = (a_1 \wedge a_2, b_1 \wedge b_2, c_1 \wedge c_2), \tag{10}$$

Here, $r > 0$ and $a_1, b_1, c_1 > 0$.

Also the crisp value of triangular fuzzy number set $\tilde{A}_1$ can be determined by defuzzification which locates the best non-fuzzy performance (BNP) value. Thus, the BNP values of fuzzy number are calculated by using the center of area method as follows (Moeinzadeh and Hajfathaliha, 2010):

$$\mathrm{BNP}_i = \frac{[(c-a)+(b-a)]}{3} + a, \quad \forall_i, \tag{11}$$

*Definition 7.* A matrix $\tilde{\mathbf{D}}$ is called a fuzzy matrix if at least one element is a fuzzy number (Buckley, 1985).

*3.3 Linguistic variable*

*Definition 8.* A linguistic variable is the variable whose values are not expressed in numbers but words or sentences in a natural or artificial language (Zadeh, 1975). 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 (Zimmermann, 1991). 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.

*3.4 The concept of generalized trapezoidal fuzzy numbers (GTFNs)*

By the definition given by Chen (1985), a GTFN can be defined as $\tilde{A} = (a_1, a_2, a_3, a_4; w_{\tilde{A}})$, as shown in Figure 3 and the membership function $\mu_{\tilde{A}}(x)$: $R \to [0, 1]$ is defined as follows:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1} \times w_{\tilde{A}}, & x \in (a_1, a_2) \\ w_{\tilde{A}}, & x \in (a_2, a_3) \\ \frac{x-a_4}{a_3-a_4} \times w_{\tilde{A}}, & x \in (a_3, a_4) \\ 0, & x \in (-\infty, a_1) \cup (a_4, \infty) \end{cases} \tag{12}$$

Here, $a_1 \leqslant a_2 \leqslant a \leqslant a_4$ and $w_{\tilde{A}} \in [0, 1]$.

The elements of the GTFNs $x \in R$ are real numbers, and its membership function $\mu_{\tilde{A}}(x)$ is the regularly and continuous convex function, it shows that the membership degree to the fuzzy sets. If $-1 \leqslant a_1 \leqslant a_2 \leqslant a_3 \leqslant a_4 \leqslant 1$, then $\tilde{A}$ is called the normalized trapezoidal fuzzy number. Especially, if $w_{\tilde{A}} = 1$, then $\tilde{A}$ is called trapezoidal fuzzy number $(a_1, a_2, a_3, a_4)$; if $a_1 < a_2 = a_3 < a_4$, then $\tilde{A}$ is reduced to a triangular fuzzy number. If $a_1 = a_2 = a_3 = a_4$, then $\tilde{A}$ is reduced to a real number.

Suppose that $\tilde{a} = (a_1, a_2, a_3, a_4; w_{\tilde{a}})$ and $\tilde{b} = (b_1, b_2, b_3, b_4; w_{\tilde{b}})$ are two GTFNs, then the operational rules of the GTFNs $\tilde{a}$ and $\tilde{b}$ are shown as follows (Chen and Chen, 2009):

$$\begin{aligned} \tilde{a} \oplus \tilde{b} &= (a_1, a_2, a_3, a_4; w_{\tilde{a}}) \oplus (b_1, b_2, b_3, b_4; w_{\tilde{b}}) \\ &= (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4; \min(w_{\tilde{a}}, w_{\tilde{b}})) \end{aligned} \tag{13}$$

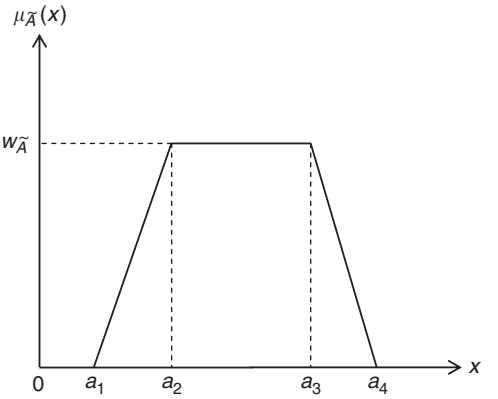


**Figure 3.**
Trapezoidal fuzzy number $\tilde{A}$

$$\tilde{a}-\tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{a}})-(b_1, b_2, b_3, b_4; w_{\tilde{b}}) = (a_1-b_4, a_2-b_3, a_3-b_2, a_4-b_1; \min(w_{\tilde{a}}, w_{\tilde{b}})) \quad (14)$$

$$\tilde{a} \otimes \tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{a}}) \otimes (b_1, b_2, b_3, b_4; w_{\tilde{b}}) = (a, b, c, d; \min(w_{\tilde{a}}, w_{\tilde{b}})) \quad (15)$$

Here:

$$a = \min(a_1 \times b_1, a_1 \times b_4, a_4 \times b_1, a_4 \times b_4)$$

$$b = \min(a_2 \times b_2, a_2 \times b_3, a_3 \times b_2, a_3 \times b_3)$$

$$c = \max(a_2 \times b_2, a_2 \times b_3, a_3 \times b_2, a_3 \times b_3)$$

$$d = \max(a_1 \times b_1, a_1 \times b_4, a_4 \times b_1, a_4 \times b_4)$$

If $a_1$, $a_2$, $a_3$, $a_4$, $b_1$, $b_2$, $b_3$, $b_4$ are real numbers, then:

$$\tilde{a} \otimes \tilde{b} = (a1 \times b1, a2 \times b2, a3 \times b3, a4 \times b4; \min(w_{\tilde{a}}, w_{\tilde{b}}))$$

$$\tilde{a}/\tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{a}})/(b_1, b_2, b_3, b_4; w_{\tilde{b}}) = (a_1/b_4, a_2/b_3, a_3/b_2, a_4/b_1; \min(w_{\tilde{a}}, w_{\tilde{b}})) \quad (16)$$

Chen and Chen (2003) proposed the concept of COG point of GTFNs, and suppose that the COG point of the GTFN $\tilde{a} = (a_1, a_2, a_3, a_4; w_{\tilde{a}})$ is $(x_{\tilde{a}}, y_{\tilde{a}})$, then:

$$y_{\tilde{a}} = \begin{cases} \dfrac{w_{\tilde{a}} \times \left(\frac{a_3-a_2}{a_4-a_1}+2\right)}{6}, & \text{if } a_1 \neq a_4 \\ \dfrac{w_{\tilde{a}}}{2}, & \text{if } a_1 = a_4 \end{cases} \quad (17)$$

$$x_{\tilde{a}} = \frac{y_{\tilde{a}} \times (a_2+a_3)+(a_1+a_4) \times (w_{\tilde{a}}-y_{\tilde{a}})}{2 \times w_{\tilde{a}}} \quad (18)$$

*3.5 Ranking of GTFNs (Thorani et al., 2012)*

The centroid of a trapezoid is considered as the balancing point of the trapezoid (Figure 4). Divide the trapezoid into three plane figures. These three plane figures are a triangle (APB), a rectangle (BPQC) and a triangle (CQD), respectively. Let the centroids of the three plane figures be $G_1$, $G_2$ and $G_3$, respectively. The incenter of these centroids $G_1$, $G_2$ and $G_3$ is taken as the point of reference to define the ranking of GTFNs. The reason for selecting this point as a point of reference is that each centroid point are balancing points of each individual plane figure, and the Incentre of these centroid points is a much more balancing point for a GTFN. Therefore, this point would be a better reference point than the centroid point of the trapezoid.

Consider a GTFN $\tilde{A} = (a, b, c, d; w)$, (Figure 4). The centroids of the three plane figures are $G_1 = ((a+2b)/3, (w/3))$, $G_2 = ((b+c)/2, (w/2))$ and $G_3 = ((2c+d)/3, (w/3))$, respectively.

Equation of the line $\overline{G_1G_3}$ is $y = (w/3)$ and $G_2$ does not lie on the line $\overline{G_1G_3}$. Therefore, $G_1G_2$ and $G_3$ are non-collinear and they form a triangle.

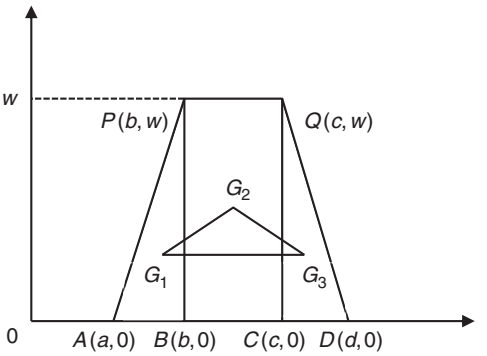


**Figure 4.**
Trapezoidal fuzzy number

**Source:** Thorani *et al*. (2012)

We define the Incentre $I_{\tilde{A}}(\overline{x}_0, \overline{y}_0)$ of the triangle with vertices $G_1$, $G_2$ and $G_3$ of the GTFN $\tilde{A} = (a, b, c, d; w)$ as:

$$I_{\tilde{A}}(\overline{x}_0, \overline{y}_0) = \left( \frac{\alpha\left(\frac{a+2b}{3}\right) + \beta\left(\frac{b+c}{2}\right) + \gamma\left(\frac{2c+d}{3}\right)}{\alpha+\beta+\gamma}, \frac{\alpha\left(\frac{w}{3}\right) + \beta\left(\frac{w}{2}\right) + \gamma\left(\frac{w}{3}\right)}{\alpha+\beta+\gamma} \right) \tag{19}$$

Here:

$$\alpha = \frac{\sqrt{(c-3b+2d)^2 + w^2}}{6}$$

$$\beta = \frac{\sqrt{(2c+d-a-2b)^2}}{3}$$

$$\gamma = \frac{\sqrt{(3c-2a-b)^2 + w^2}}{6}$$

As a special case, for triangular fuzzy number $\tilde{A} = (a, b, c, d; w)$, i.e. $c = b$ the incentre of centroids is given by:

$$I_{\tilde{A}}(\overline{x}_0, \overline{y}_0) = \left( \frac{x\left(\frac{a+2b}{3}\right) + yb + z\left(\frac{2b+d}{3}\right)}{x+y+z}, \frac{x\left(\frac{w}{3}\right) + y\left(\frac{w}{2}\right) + z\left(\frac{w}{3}\right)}{x+y+z} \right) \tag{20}$$

Here:

$$x = \frac{\sqrt{(2d-2b)^2 + w^2}}{6}$$

$$y = \frac{\sqrt{(d-a)^2}}{3}$$

$$z = \frac{\sqrt{(2b-2a)^2 + w^2}}{6}$$

The ranking function of the GTFN $\tilde{A} = (a, b, c, d; w)$, which maps the set of all fuzzy numbers to a set of real numbers is defined as:

$$R(\tilde{A}) = x_0 \times y_0 = \left( \frac{x\left(\frac{a+2b}{3}\right) + yb + z\left(\frac{2b+d}{3}\right)}{x+y+z} \times \frac{x\left(\frac{w}{3}\right) + y\left(\frac{w}{2}\right) + z\left(\frac{w}{3}\right)}{x+y+z} \right) \tag{21}$$

This is the area between the incenter of the centroids $I_{\tilde{A}}(\overline{x}_0, \overline{y}_0)$ as defined in Equation (19) and the original point.

The mode ($m$) of the GTFN $\tilde{A} = (a, b, c, d; w)$, is defined as:

$$m = \frac{1}{2} \int_0^w (b+c)\, dx = \frac{w}{2}(b+c) \tag{22}$$

The spread ($s$) of the GTFN $\tilde{A} = (a, b, c, d; w)$, is defined as:

$$s = \int_0^w (d-a)\, dx = w(d-a) \tag{23}$$

The left spread ($ls$) of the GTFN $\tilde{A} = (a, b, c, d; w)$, is defined as:

$$ls = \int_0^w (b-a)\, dx = w(b-a) \tag{24}$$

The right spread ($rs$) of the GTFN $\tilde{A} = (a, b, c, d; w)$, is defined as:

$$rs = \int_0^w (d-c)\, dx = w(d-c) \tag{25}$$

Using the above definitions we now define the ranking procedure of two GTFNs.

Let $\tilde{A} = (a_1, b_1, c_1, d_1; w_1)$ and $\tilde{B} = (a_2, b_2, c_2, d_2; w_2)$ be two GTFNs. The working procedure to compare $\tilde{A}$ and $\tilde{B}$ is as follows:

Step 1: find $R(\tilde{A})$ and $R(\tilde{B})$:

Case (i) If $R(\tilde{A}) > R(\tilde{B})$ then $\tilde{A} > \tilde{B}$

Case (ii) If $R(\tilde{A}) < R(\tilde{B})$ then $\tilde{A} < \tilde{B}$

Case (iii) If $R(\tilde{A}) = R(\tilde{B})$ comparison is not possible, then go to step 2.

Step 2: find $m(\tilde{A})$ and $m(\tilde{B})$:

Case (i) If $m(\tilde{A}) > m(\tilde{B})$ then $\tilde{A} > \tilde{B}$

Case (ii) If $m(\tilde{A}) < m(\tilde{B})$ then $\tilde{A} < \tilde{B}$

Case (iii) If $m(\tilde{A}) = m(\tilde{B})$ comparison is not possible, then go to step 3.

Step 3: find $s(\tilde{A})$ and $s(\tilde{B})$:

Case (i) If $s(\tilde{A}) > s(\tilde{B})$ then $\tilde{A} < \tilde{B}$

Case (ii) If $s(\tilde{A}) < s(\tilde{B})$ then $\tilde{A} > \tilde{B}$

Case (iii) If $s(\tilde{A}) = s(\tilde{B})$ comparison is not possible, then go to step 4.

Step 4: find $ls(\tilde{A})$ and $ls(\tilde{B})$:

Case (i) If $ls(\tilde{A}) > ls(\tilde{B})$ then $\tilde{A} > \tilde{B}$

Case (ii) If $ls(\tilde{A}) < ls(\tilde{B})$ then $\tilde{A} < \tilde{B}$

Case (iii) If $ls(\tilde{A}) = ls(\tilde{B})$ comparison is not possible, then go to step 5.

Step 5: examine $w_1$ and $w_2$:

Case (i) If $w_1 > w_2$ then $\tilde{A} > \tilde{B}$

Case (ii) If $w_1 < w_2$ then $\tilde{A} < \tilde{B}$

Case (iii) If $w_1 = w_2$ then $\tilde{A} \approx \tilde{B}$

## 4. Leagility evaluation: a conceptual framework

Leagile supply chain is a new conception that proposed in the context of diversified and personalized customer demands; it can quickly response fast changing demands, and modularize all kinds of personalized products as much as possible (Zhang *et al.*, 2012). Successful implication of leagility-driven supply chain requires its performance to be assessed.

The procedural hierarchical framework (Table I) for leagility evaluation assessment module has been illustrated as follows. The assessment framework is based on a leagile capabilities-attribute-criterion hierarchy; and it consists of five leagile enablers (at first level), 40 leagile attributes (at second level) and 188 leagile criterions (at third level). This descriptive model is very much comprehensive; it has been partially adapted from the work (Vinodh and Aravindraj, 2012) and extended up to third level with the help of extensive literature survey from internet. The model addresses all major dimensions (leagile capabilities) of leagility such as virtual enterprise; collaborative relationship; strategic management; knowledge and IT management; customer and market sensitiveness; termed as first level evaluation indices or leagile capabilities. In the proposed three-level evaluation hierarchy, the first level indices have been comprised by examining business operation environments, measuring leagile drives and thereby identifying of leagile supply chain capabilities. The second level of the framework assesses the leagile enabled attributes and synthesizes appropriateness ratings as well as priority weights. The third level of the evaluation module assesses the leagile criterions and synthesizes appropriateness ratings (performance extent) and priority weights. As the module encompasses various leagile capabilities, attributes as well as leagile criterions; subjectivity of the evaluation indices incorporates various decision-making uncertainty, ambiguity and vagueness. Therefore, a fuzzy logic approach has been utilized toward avoiding imprecision, inconsistency and incompleteness in the decision-making information and to deduce the human error and creation of expert knowledge and interpretation of a large amount of vague data. Above mentioned framework finds a performance representative "crisp value" against each of the third level leagile criterion and finally obtains performance ranking order for different leagile criterions. It is assumed that, higher the crisp value; higher be the performance extent for the said leagile criterion. Procedural steps of leagility appraisement have been summarized as follows:

(1) Construction of general hierarchy model (set of capabilities/attributes/criterions) toward evaluating leagility extent.

(2) Formation of an expert team (decision-making group) consisting of a finite number of decision makers (DMs). It is solely the task of the top management to select DMs from important managerial hierarchy level of the enterprise as well as from academia.

(3) Selection of appropriate linguistic scale to collect expert opinion in relation to priority weight as well as performance rating of different leagility evaluation indices.

(4) Selection of a suitable fuzzy scale to transform DMs linguistic evaluation information into appropriate fuzzy numbers for further data analysis and interpretation.

(5) Collection of survey data (expert judgment) in relation to performance ratings and importance weights of leagile indices using linguistic terms.

(6) Approximation of the linguistic ratings and weights by using fuzzy numbers. Fuzzy weighted average method is used to aggregate decision-making information.

| Goal | Leagile enablers (first level) | Leagile attributes (second level) | Leagile criterions (third level) | References/citations |
|---|---|---|---|---|
| Leagility ($C$) | Virtual enterprises ($C_1$) | Virtual retail stores ($C_{11}$) | Customer care ($C_{111}$) | Vrechopoulos (2001), Source: www.bartertrends.com/creating-a-virtual-retail-store.html |
| | | | Merchandise and security ($C_{112}$) | |
| | | | Effective shopping ($C_{113}$) | |
| | | | Virtual store atmosphere ($C_{114}$) | |
| | | | Virtual store ($C_{115}$) | |
| | | E-fulfilment logistics ($C_{12}$) | Meeting customer expectations ($C_{121}$) | Source: www.globalmillenniamarketing.com/article_fulfillment_ecommerce_ebusiness.htm |
| | | | Inventory availability ($C_{122}$) | |
| | | | On time delivery ($C_{123}$) | Source: www.logwinlogistics.com/services/specials/efulfillment.html, Deborah (2002) |
| | | | Outsourcing the functions to third party ($C_{124}$) | Deborah (2002) |
| | | | Transparency and complete documentation of all processes ($C_{125}$) | Source: www.logwinlogistics.com/services/specials/efulfillment.html |
| | | Outsourcing ($C_{13}$) | Information technology outsourcing ($C_{131}$) | Source: www.sourcingmag.com/content/what_is_outsourcing.asp<br>Source: http://en.wikipedia.org/wiki/Information_technology_outsourcing |
| | | | Business process outsourcing ($C_{132}$) | Source: www.sourcingmag.com/content/what_is_outsourcing.asp |
| | | | Operational outsourcing ($C_{133}$) | Source: http://operationstech.about.com/od/officestaffingandmanagem/a/OutSrcAdvantg.htm |
| | | Integrated logistics management ($C_{14}$) | Collaborating supply chain players ($C_{141}$) | Source: www.four-soft.com/integrated_logistics_management.asp |
| | | | Process integrity ($C_{142}$) | |
| | | Internal SCM ($C_{15}$) | Management support ($C_{151}$) | Source: home.kelley.iupui.edu/tatikond/.../Ana_presentation.ppt - United States, Chuda Basnet (2013) |

(*continued*)

**Table I.**
General hierarchy model for leagility evaluation

Table I.

| Goal | Leagile enablers (first level) | Leagile attributes (second level) | Leagile criterions (third level) | References/citations |
|---|---|---|---|---|
| | | | Structure ($C_{152}$) | |
| | | | Human resource management ($C_{153}$) | |
| | | | Communication ($C_{154}$) | |
| | | | Information systems ($C_{155}$) | |
| | | Supply chain partner selection ($C_{16}$) | Purchasing and supply forecast ($C_{161}$) | Source: www.ism.ws/pubs/content.cfm?ItemNumber=9722 |
| | | | Response time ($C_{162}$) | |
| | | | Production and logistics management ($C_{163}$) | Wu and Barnes (2010) |
| | | | Partnership management ($C_{164}$) | |
| | | | Financial capability ($C_{165}$) | |
| | | | Technology and knowledge management ($C_{166}$) | |
| | | | Marketing capability ($C_{167}$) | |
| | | | Industrial and organizational competitiveness ($C_{168}$) | |
| | | | Human resource management ($C_{169}$) | |
| | | Organizational structure ($C_{17}$) | Environment ($C_{171}$) | Source: faculty.mu.edu.sa/download.php?fid=4218 |
| | | | Strategy ($C_{172}$) | |
| | | | Technology ($C_{173}$) | |
| | | | Human resources ($C_{174}$) | |
| | | Distributed virtual manufacturing ($C_{18}$) | Component objects ($C_{181}$) | Olofsgard *et al.* (2002) |
| | | | Persistent storage objects ($C_{182}$) | |
| | | | Service objects ($C_{183}$) | |
| | | | Interface objects ($C_{184}$) | |

(*continued*)

| Goal | Leagile enablers (first level) | Leagile attributes (second level) | Leagile criterions (third level) | References/citations |
|---|---|---|---|---|
| | | Logistics management ($C_{19}$) | Movement of information ($C_{191}$) | Source: www.globalmillenniamarketing.com/article_fulfillment_ecommerce_ebusiness.htm |
| | | | Visibility to their supply chain ($C_{192}$) | |
| | | | Accessibility of shipments ($C_{193}$) | |
| | | E-commerce ($C_{110}$) | Customers satisfaction ($C_{1101}$) | |
| | | | Delivery fulfilment ($C_{1102}$) | |
| | | | Complete visibility across supply chain ($C_{1103}$) | |
| | | | Flexibility in order ($C_{1104}$) | |
| | Collaborative relationships ($C_2$) | Enterprise wide relationship management ($C_{21}$) | Database marketing strategies ($C_{211}$) | Source: www.information-management.com/issues/19990501/19-1.html |
| | | | Marketing campaign management ($C_{212}$) | |
| | | | Extensive interfacing requirement of call centers and websites ($C_{213}$) | |
| | | | Centralized system in CRS ($C_{214}$) | |
| | | | Empowerment of employee ($C_{215}$) | |
| | | | Automated and systematized communications channels ($C_{216}$) | |
| | | Supplier relationship management ($C_{22}$) | Organizational structure ($C_{221}$) | Source: http://en.wikipedia.org/wiki/Supplier_relationship_management |
| | | | Clearly and jointly agreed governance framework ($C_{222}$) | |
| | | | Supplier engagement model ($C_{223}$) | |
| | | | Joint activities ($C_{224}$) | |
| | | | Value measurement ($C_{225}$) | |
| | | | Systematic collaboration ($C_{226}$) | |
| | | | Technology and systems ($C_{227}$) | |

(*continued*)

**Table I.**

Table I.

| Goal | Leagile enablers (first level) | Leagile attributes (second level) | Leagile criterions (third level) | References/citations |
|---|---|---|---|---|
| | | Logistics service providers ($C_{23}$) | Ware housing ($C_{231}$)<br>Materials handling ($C_{232}$)<br>Purchasing ($C_{233}$)<br>Protective packaging ($C_{234}$)<br>Cooperate with production/ operations ($C_{235}$)<br>Information maintenance ($C_{236}$) | Source: www.adameurope.eu/prj/7095/.../CourieL_WP2_ Chapter2_final.pdf, Pache and Medina (2007) |
| | | Collaborative planning, forecast and replenishment ($C_{24}$) | Develop front end agreement ($C_{241}$)<br>Create the joint business plan ($C_{242}$)<br>Create the sales forecast ($C_{243}$)<br>Identify exceptions for sales forecast ($C_{244}$)<br>Resolve/collaborate on exception items ($C_{245}$)<br>Create order forecast ($C_{246}$)<br>Identify exceptions for order forecast ($C_{247}$)<br>Resolve/collaborate on exception items ($C_{248}$)<br>Order generation ($C_{249}$) | Source: http://en.wikipedia.org/wiki/Collaborative_ planning,_forecasting,_and_replenishment |
| | | Collaborative order fulfilment visibility ($C_{25}$) | Business process ($C_{251}$)<br>Process management ($C_{252}$)<br>Infrastructure ($C_{253}$) | Alt *et al.* (2005) |

(*continued*)

Table I.

| Goal | Leagile enablers (first level) | Leagile attributes (second level) | Leagile criterions (third level) | References/citations |
|---|---|---|---|---|
| | Strategic management ($C_3$) | Nature of management ($C_{31}$) | Corporate ($C_{311}$) | Source: www.huntingdon.edu/uploadedFiles/.../david_sm13_ppt_01.ppt |
| | | | Business ($C_{312}$) | Source: http://en.wikipedia.org/wiki/Strategic_management |
| | | | Functional ($C_{313}$) | |
| | | | Operational ($C_{314}$) | |
| | | Inventory management ($C_{32}$) | Proper merchandise assortment while ordering, shipping, handling ($C_{321}$) | Source: http://en.wikipedia.org/wiki/Inventory |
| | | | Systems and processes that identify inventory requirements ($C_{322}$) | |
| | | | Replenishment techniques ($C_{323}$) | |
| | | | Monitoring of material movements ($C_{324}$) | |
| | | | ABC analysis ($C_{325}$) | |
| | | Cycle time reduction ($C_{33}$) | Pull-oriented lean manufacturing ($C_{331}$) | Source: www.rmdonovan.com/cycle_time-reduction/ |
| | | | Demand flow manufacturing ($C_{332}$) | |
| | | | Cross-functional integration ($C_{333}$) | |
| | | | Supply chain management ($C_{334}$) | |
| | | Time management ($C_{34}$) | Creating an environment conducive to effectiveness ($C_{341}$) | Source: http://en.wikipedia.org/wiki/Time_management |
| | | | Setting of priorities ($C_{342}$) | |
| | | | Carrying out activity around those priorities ($C_{343}$) | |
| | | | Process of reduction of time spent on non-priorities ($C_{344}$) | |

(*continued*)

Table I.

| Goal | Leagile enablers (first level) | Leagile attributes (second level) | Leagile criterions (third level) | References/citations |
|---|---|---|---|---|
| | | Development of new technology ($C_{35}$) | Publicly performed research ($C_{351}$)<br>Direct subsidies for private research ($C_{352}$)<br>Tax incentives ($C_{353}$)<br>Intellectual property rights ($C_{354}$) | Bannon and Roodman (2004) |
| | | Process management ($C_{36}$) | Processes need to align to business goals ($C_{361}$)<br>Customer focus ($C_{362}$)<br>Importance of benchmarks ($C_{363}$)<br>Establish process owners ($C_{364}$) | Source: http://en.wikipedia.org/wiki/Business_Process_Improvement |
| | | Production planning ($C_{37}$) | Effective utilization of resources ($C_{371}$)<br>Steady flow of production ($C_{372}$)<br>Estimate the resources ($C_{373}$)<br>Ensure optimum inventory ($C_{374}$)<br>Co-ordinate activities of departments ($C_{375}$)<br>Minimize wastage of raw materials ($C_{376}$)<br>Improves labor productivity ($C_{377}$)<br>Helps to capture the market ($C_{378}$)<br>Facilitate quality improvement ($C_{379}$)<br>Results in consumer satisfaction ($C_{3710}$)<br>Reduce the production costs ($C_{3711}$) | Source: http://kalyan-city.blogspot.com/2012/01/what-is-production-planning-meaning.html |

(*continued*)

| Goal | Leagile enablers (first level) | Leagile attributes (second level) | Leagile criterions (third level) | References/citations |
|---|---|---|---|---|
| | | Quality status ($C_{38}$) | Developing the quality strategy ($C_{381}$)<br>Establishing goals and objectives ($C_{382}$)<br>Identifying specific quality initiatives ($C_{383}$)<br>Implementing action plans ($C_{384}$) | Beecroft (1999) |
| | | Product design and service ($C_{39}$) | Cheaper, to disassemble ($C_{391}$)<br>Refurbish or recycle after the initial use phase ($C_{392}$)<br>Durability of products ($C_{393}$)<br>Product modularity and upgradeability ($C_{394}$) | Source: www.brass.cf.ac.uk/uploads/wpstratmgtofPSSsAW1005.pdf |
| | | Manufacturing setup ($C_{310}$) | Manufacturing basic setup ($C_{3101}$)<br>Security ($C_{3102}$)<br>Manufacturing core functions setup ($C_{3103}$)<br>Manufacturing production functions setup ($C_{3104}$)<br>Manufacturing management functions setup ($C_{3105}$)<br>Manufacturing planning functions setup ($C_{3106}$) | Source: http://mbs.microsoft.com/downloads/public/GP10Docs/MfgSetup.pdf |
| | | Human resources ($C_{311}$) | The hiring process ($C_{3111}$)<br>Classification ($C_{3112}$)<br>Compensation ($C_{3113}$)<br>Benefits ($C_{3114}$)<br>Employee relation ($C_{3115}$)<br>Legal compliance ($C_{3116}$)<br>Performance management ($C_{3117}$) | Source: www.co.moore.nc.us/index.php/what-exactly-is-hr?lang= |

(*continued*)

**Table I.**

Table I.

| Goal | Leagile enablers (first level) | Leagile attributes (second level) | Leagile criterions (third level) | References/citations |
|---|---|---|---|---|
| | | Vendor management ($C_{312}$) | Risk analysis ($C_{3121}$)<br>Due diligence in vendor selection ($C_{3122}$)<br>Documenting the vendor relationship contract issues ($C_{3123}$)<br>Ongoing supervision and monitoring of vendors ($C_{3124}$) | Source: www.cunaopsscouncil.org/news/323.html |
| | Knowledge and IT management ($C_4$) | E-business ($C_{41}$) | Strategy ($C_{411}$)<br>Website effectiveness ($C_{412}$)<br>Integration of business processes ($C_{413}$)<br>E-business management ($C_{414}$) | John Sparrow (2001) |
| | | Re-engineered working pattern ($C_{42}$) | Process focus ($C_{421}$)<br>Managing change and risk ($C_{422}$)<br>Document improvement ($C_{423}$) | Source: http://142.51.19.180/drdnotes/3146_cox_ch13.htm |
| | | Decentralization ($C_{43}$) | Locality of expertise modeling ($C_{431}$)<br>Lower control complexity of the expertise modeling process ($C_{432}$)<br>Privacy or individualization ($C_{433}$)<br>Graceful degradation of the overall performance ($C_{434}$) | Yimam and Kobsa (2000) |
| | | Supply chain visibility ($C_{44}$) | Demand visibility ($C_{441}$) | Source: www.krannert.purdue.edu/centers/dcmme_gscmi/downloads/2012%20spring/gordonWipro.pdf |
| | | | Fulfilment visibility ($C_{442}$)<br>Procurement visibility ($C_{443}$)<br>Manufacturing visibility ($C_{444}$)<br>Transportation visibility ($C_{445}$) | Source: Vernon (2008) |

(*continued*)

| Goal | Leagile enablers (first level) | Leagile attributes (second level) | Leagile criterions (third level) | References/citations |
|---|---|---|---|---|
| | | Equipment engineering system (EES) ($C_{45}$) | Data collection and pre-processing ($C_{451}$)<br>Data storage and management ($C_{452}$)<br>Tool template library ($C_{453}$)<br>Data selection, query and retrieval ($C_{454}$)<br>Data display and visualization ($C_{455}$)<br>Data analysis and transformation ($C_{456}$)<br>Production and process monitoring ($C_{457}$)<br>Tool and process characterization ($C_{458}$) | Source: www.sematech.org/videos/SemiconWest-06/p039141.pdf |
| | | Information system ($C_{46}$) | Transaction processing systems ($C_{461}$)<br>Management information systems ($C_{462}$)<br>Decision support systems ($C_{463}$)<br>Executive information systems ($C_{464}$) | Source: http://araku.ac.ir/~a_fiantial/ISR_Lec_[4].pdf |
| | | Electronic data interchange (EDI) ($C_{47}$) | Exchange of structured business information ($C_{471}$)<br>Faster transactions support ($C_{472}$)<br>Improved business cycle time ($C_{473}$)<br>Application service ($C_{474}$)<br>Translation service ($C_{475}$)<br>Communication service ($C_{476}$) | Source: http://220.227.161.86/22529ittstm_U10_cp6.pdf, Source: http://en.wikipedia.org/wiki/Electronic_data_interchange |

(*continued*)

**Table I.**

Table I.

| Goal | Leagile enablers (first level) | Leagile attributes (second level) | Leagile criterions (third level) | References/citations |
|---|---|---|---|---|
| | Customer and market sensitiveness ($C_5$) | Customer focus ($C_{51}$) | Customer-driven products and process ($C_{511}$) | Vinodh and Aravindraj (2013) |
| | | | Accurate customer voice translation ($C_{512}$) | |
| | | | Avenues for increasing customer values ($C_{513}$) | |
| | | Market sensitivity ($C_{52}$) | Market trend analysis ($C_{521}$) | |
| | | | Gathering of customer responses ($C_{522}$) | |
| | | | Market winning criteria ($C_{523}$) | |
| | | Culture and change management ($C_{53}$) | Institutionalization of change management programs ($C_{531}$) | |
| | | | Development of communication plans ($C_{532}$) | |
| | | | Continuous and lifelong learning ($C_{533}$) | |
| | | Product service level ($C_{54}$) | Design for serviceability ($C_{541}$) | |
| | | | Well-equipped service centers ($C_{542}$) | |
| | | | Extensive service facilities ($C_{543}$) | |
| | | Mass customisation ($C_{55}$) | Focus on product variety ($C_{551}$) | |
| | | | Products tuned to customers' requirements ($C_{552}$) | |
| | | | Market dynamism ($C_{553}$) | |
| | | Quality of product ($C_{56}$) | Implementation of total quality management principles ($C_{561}$) | |
| | | | Formation of quality circles ($C_{562}$) | |
| | | | Adoption of standard quality measures ($C_{563}$) | |

Assume a three-level evaluation criteria hierarchy consisting of $m$ capabilities (at first level). Under each first level capability there exist $n$ number of attributes (at second level). Each second level attribute is followed by $p$ number of criterions.

Fuzzy appropriateness rating ($U_{ij}$) of $j$th second level attribute ($C_{ij}$) is computed as follows:

$$U_{ij} = \frac{\sum_{k=1}^{p} w_{ijk} \otimes U_{ijk}}{\sum_{k=1}^{p} w_{ijk}} \tag{26}$$

here $U_{ijk}$ is the fuzzy appropriateness rating of $k$th leagile criterion ($C_{ijk}$) at third level $w_{ijk}$ the fuzzy priority weight of $k$th leagile criterion ($C_{ijk}$) at third level fuzzy appropriateness rating ($U_i$) of $i$th first level capability ($C_i$) is computed as follows:

$$U_i = \frac{\sum_{j=1}^{n} w_{ij} \otimes U_{ij}}{\sum_{j=1}^{n} w_{ij}} \tag{27}$$

here $U_{ij}$ is the fuzzy appropriateness rating of $j$th leagile attribute ($C_{ij}$) at second level computed from Equation (26), $w_{ij}$ the fuzzy priority weight of $j$th leagile attribute ($C_{ij}$) at second level:

(7) Determination of Fuzzy Overall Performance Index (FOPI) and finding the existing leagility level.

Finally, FOPI is computed as follows:

$$FOPI = \frac{\sum_{i=1}^{m} w_i \otimes U_i}{\sum_{i=1}^{m} w_i} \tag{28}$$

here $U_i$ is the fuzzy appropriateness rating of $i$th leagile capability ($C_i$) at first level computed from Equation (27), $w_i$ the fuzzy priority weight of $i$th leagile capability ($C_i$) at first level:

(8) Determination of Fuzzy Performance Importance Index (FPII) corresponding to individual third level leagile criterions.

FPII is computed as follows (Lin *et al.*, 2006):

$$FPII_k = \left[1 - w_{ijk}\right] \otimes U_{ijk} \tag{29}$$

Representative crisp value corresponding to individual $FPII_k$(($k$th) third level criterion) is used to determine performance ranking order of third level leagile criterions:

(9) Perform gap analysis and identify the barriers (ill-performing areas) to achieve leagility.

## 5. Case application

This evaluation framework has been case studied in a famous locomotive part manufacturing organization at eastern part of India. The study presents the application of the conceptual model of leagility embedded with lean and agile principles. A fuzzy logic approach has been used for the evaluation of leagility in supply chains. It is aimed to compute the performance of supply chain using both lean and agile concepts

(as leagility supply chains) using a fuzzy logic approach. General hierarchy model for leagility evaluation has been furnished in Table I. Definitions of linguistic variables for assignment of priority weight and performance ratings have been shown in Table II, which is basically a nine-member linguistic-term set. Linguistic evaluation information needs to be converted into appropriate fuzzy numbers. A fuzzy scale (Table II) consisting of GTFNs has been explored to convert DMs linguistic evaluation into fuzzy numbers. An expert group consists of ten DMs has been constructed by the top management. The expert group has been instructed to utilize aforesaid linguistic scale toward assigning appropriateness rating against each of the third level leagile criterions; priority weights against individual leagile capabilities (at first level), attributes (at second level) as well as criterions (at third level). Priority weight of leagile criterions (in linguistic term) assigned by the DMs has been shown in Table III. Table IV represents appropriateness rating (in linguistic terms) of leagile criterions assigned by the DMs. Linguistic priority weight of leagile attributes (at second level) as well as leagile enablers (at first level) given by DMs have been shown in Tables V and VI, respectively. Linguistic data have been converted into appropriate fuzzy numbers as depicted in Table II. The "Aggregated average rule" has been utilized to accumulate DMs opinion. Table VII represents aggregated fuzzy priority weight as well as aggregated fuzzy rating of individual leagile criterions. Aggregated fuzzy priority weight and computed fuzzy rating (computed using Equation (26)) of leagile attributes have been given in Table VIII. Aggregated fuzzy priority weight and computed fuzzy rating (computed using Equation (27)) of leagile enablers have been tabulated in Table IX. The FOPI thus becomes (Equation (28)): (0.399, 0.554, 1.170, 1.580, 1.000).

Table X represents computed values of FPII against individual third level leagile criterions (using Equation (29)) and corresponding performance ranking order.

## 6. Managerial and research implications

The paradigm combining lean and agile principles invites a new management framework. The leagile framework allows firms and supply networks to configure an appropriate profile to face successfully the market volatility and fight to secure competitive advantages. It is particularly important for the firms and enterprises exploiting markets in terms of cost, quality, response time and service level where the consumers seek for better responsiveness to meet unpredictable ever-changing demands.

The major implications of this research are standardization of leagility evaluation methodology and adoption of new strategic technique for an organizational supply chain management. As far as practitioners/consultants realm is concerned, the proposed leagility evaluation platform and fuzzy-based appraisement framework

**Table II.**
Definitions of linguistic variables for priority weight and attribute ratings (A-9 member linguistic-term set)

| Linguistic terms (attribute ratings) | Linguistic terms (priority weights) | Generalized trapezoidal fuzzy numbers |
|---|---|---|
| Absolutely poor (AP) | Absolutely low (AL) | (0,0,0,0;1) |
| Very poor (VP) | Very low (VL) | (0,0,0.02,0.07;1) |
| Poor (P) | Low (L) | (0.04,0.10,0.18,0.23;1) |
| Medium poor (MP) | Medium low (ML) | (0.17,0.22,0.36,0.42;1) |
| Medium (M) | Medium (M) | (0.32,0.41,0.58,0.65;1) |
| Medium good (MG) | Medium high (MH) | (0.58,0.63,0.80,0.86;1) |
| Good (G) | High (H) | (0.72,0.78,0.92,0.97;1) |
| Very good (VG) | Very high (VH) | (0.93,0.98,1,1;1) |
| Absolutely good (AG) | Absolutely high (AH) | (1,1,1,1;1) |

| Leagile criterions ($C_{ijk}$) | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_{111}$ | MH | H | AH | MH | VH | H | H | AH | H | MH |
| $C_{112}$ | H | M | H | VH | MH | H | MH | H | VH | AH |
| $C_{113}$ | MH | AH | AH | VH | H | H | H | AH | H | H |
| $C_{114}$ | AH | H | VH | AH | AH | H | AH | VH | H | H |
| $C_{115}$ | MH | VH | H | H | MH | VH | MH | H | VH | H |
| $C_{121}$ | AH | MH | H | VH | MH | H | AH | AH | H | H |
| $C_{122}$ | H | H | VH | MH | H | H | H | MH | H | VH |
| $C_{123}$ | MH | H | H | H | M | H | AH | AH | H | H |
| $C_{124}$ | H | VH | VH | AH | AH | H | VH | MH | VH | H |
| $C_{125}$ | H | MH | MH | MH | H | AH | H | MH | H | VH |
| $C_{131}$ | VH | VH | AH | AH | VH | MH | H | H | AH | H |
| $C_{132}$ | H | AH | H | H | MH | AH | VH | M | MH | MH |
| $C_{133}$ | MH | MH | VH | H | H | MH | H | AH | AH | H |
| $C_{141}$ | H | MH | MH | H | VH | H | VH | H | H | MH |
| $C_{142}$ | VH | H | H | H | H | H | MH | VH | H | H |
| $C_{151}$ | MH | M | H | VH | MH | VH | H | MH | H | AH |
| $C_{152}$ | H | AH | MH | H | H | MH | AH | AH | H | MH |
| $C_{153}$ | VH | AH | H | H | H | AH | MH | H | VH | AH |
| $C_{154}$ | MH | H | AH | H | VH | MH | AH | VH | H | H |
| $C_{155}$ | H | VH | MH | AH | H | MH | H | MH | H | AH |
| $C_{161}$ | H | H | AH | H | H | H | VH | H | H | VH |
| $C_{162}$ | MH | AH | H | VH | VH | M | MH | MH | VH | H |
| $C_{163}$ | MH | MH | AH | VH | H | AH | H | H | H | H |
| $C_{164}$ | VH | AH | VH | H | H | H | AH | AH | AH | VH |
| $C_{165}$ | VH | H | H | MH | H | VH | H | MH | MH | H |
| $C_{166}$ | H | H | H | H | VH | MH | VH | AH | AH | VH |
| $C_{167}$ | MH | H | AH | MH | H | H | MH | H | H | MH |
| $C_{168}$ | MH | H | H | MH | H | H | H | AH | H | H |
| $C_{169}$ | H | VH | VH | AH | VH | VH | H | VH | H | AH |
| $C_{171}$ | VH | H | MH | MH | H | VH | VH | H | H | MH |
| $C_{172}$ | H | VH | MH | MH | AH | H | H | H | VH | VH |
| $C_{173}$ | MH | H | MH | VH | VH | VH | H | VH | MH | AH |
| $C_{174}$ | H | H | H | H | VH | MH | AH | H | MH | H |
| $C_{181}$ | VH | VH | M | AH | H | MH | H | H | H | VH |
| $C_{182}$ | MH | VH | AH | H | H | H | AH | H | VH | MH |
| $C_{183}$ | H | H | MH | VH | VH | M | MH | AH | H | MH |
| $C_{184}$ | VH | VH | MH | AH | H | H | H | MH | VH | AH |
| $C_{191}$ | AH | AH | H | H | AH | AH | AH | H | H | H |
| $C_{192}$ | H | MH | AH | VH | AH | MH | MH | AH | MH | H |
| $C_{193}$ | VH | MH | MH | MH | H | AH | AH | MH | H | AH |
| $C_{1101}$ | MH | H | AH | H | VH | H | H | AH | H | MH |
| $C_{1102}$ | H | M | H | VH | MH | H | MH | H | VH | AH |
| $C_{1103}$ | H | AH | AH | VH | H | H | H | AH | H | H |
| $C_{1104}$ | AH | H | VH | AH | AH | H | AH | VH | H | H |
| $C_{211}$ | MH | VH | H | H | MH | VH | MH | H | VH | H |
| $C_{212}$ | AH | MH | H | VH | MH | H | AH | AH | H | H |
| $C_{213}$ | H | H | VH | MH | H | H | H | MH | H | VH |
| $C_{214}$ | MH | H | H | H | M | H | AH | AH | H | H |
| $C_{215}$ | MH | VH | VH | AH | AH | H | VH | MH | VH | H |

(*continued*)

**Table III.** Priority weight of leagile criterions (in linguistic term) assigned by the decision makers (DMs)

| Leagile criterions ($C_{ijk}$) | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_{216}$ | H | MH | MH | MH | H | AH | H | MH | H | VH |
| $C_{221}$ | MH | VH | AH | AH | VH | MH | H | H | AH | H |
| $C_{222}$ | H | AH | H | H | MH | AH | VH | M | MH | MH |
| $C_{223}$ | H | MH | VH | H | H | MH | H | AH | AH | H |
| $C_{224}$ | H | MH | MH | H | VH | H | VH | H | H | MH |
| $C_{225}$ | VH | H | H | H | H | H | MH | VH | H | H |
| $C_{226}$ | MH | M | H | VH | MH | VH | H | MH | H | AH |
| $C_{227}$ | VH | VH | MH | AH | H | H | H | MH | VH | AH |
| $C_{231}$ | AH | AH | H | H | AH | AH | AH | H | H | H |
| $C_{232}$ | H | MH | AH | VH | AH | MH | MH | AH | MH | H |
| $C_{233}$ | VH | MH | MH | MH | H | AH | AH | MH | H | AH |
| $C_{234}$ | MH | H | AH | H | VH | H | H | AH | H | MH |
| $C_{235}$ | H | M | H | VH | MH | H | MH | H | VH | AH |
| $C_{236}$ | H | AH | AH | VH | H | H | H | AH | H | H |
| $C_{241}$ | AH | H | VH | AH | AH | H | AH | VH | H | H |
| $C_{242}$ | MH | VH | H | H | MH | VH | MH | H | VH | H |
| $C_{243}$ | AH | MH | H | VH | MH | H | AH | AH | H | H |
| $C_{244}$ | H | H | VH | MH | H | H | H | MH | H | VH |
| $C_{245}$ | H | H | H | H | M | H | AH | AH | H | H |
| $C_{246}$ | MH | VH | VH | AH | AH | H | VH | MH | VH | H |
| $C_{247}$ | H | MH | MH | MH | H | AH | H | MH | H | VH |
| $C_{248}$ | VH | VH | AH | AH | VH | MH | H | H | AH | H |
| $C_{249}$ | H | AH | H | H | MH | AH | VH | M | MH | MH |
| $C_{251}$ | MH | MH | VH | H | H | MH | H | AH | AH | H |
| $C_{252}$ | MH | MH | MH | H | VH | H | VH | H | H | MH |
| $C_{253}$ | VH | H | H | H | H | H | MH | VH | H | H |
| $C_{311}$ | AH | M | H | VH | MH | VH | H | MH | H | AH |
| $C_{312}$ | H | AH | MH | H | H | MH | AH | AH | H | MH |
| $C_{313}$ | VH | AH | H | H | H | AH | MH | H | VH | AH |
| $C_{314}$ | MH | H | AH | H | VH | MH | AH | VH | H | H |
| $C_{321}$ | H | VH | MH | AH | H | MH | H | MH | H | AH |
| $C_{322}$ | H | H | AH | H | H | H | VH | H | H | VH |
| $C_{323}$ | VH | AH | H | VH | VH | M | MH | MH | VH | H |
| $C_{324}$ | MH | MH | AH | VH | H | AH | H | H | H | H |
| $C_{325}$ | MH | AH | VH | H | H | H | AH | AH | AH | VH |
| $C_{331}$ | VH | H | H | MH | H | VH | H | MH | MH | H |
| $C_{332}$ | MH | H | H | H | VH | MH | VH | AH | AH | VH |
| $C_{333}$ | MH | H | AH | MH | H | H | MH | H | H | MH |
| $C_{334}$ | H | H | H | H | H | H | H | AH | H | H |
| $C_{341}$ | H | VH | VH | AH | VH | VH | H | VH | H | AH |
| $C_{342}$ | VH | H | MH | MH | H | VH | VH | H | H | MH |
| $C_{343}$ | H | VH | MH | MH | AH | H | H | H | VH | VH |
| $C_{344}$ | AH | H | MH | VH | VH | VH | H | VH | MH | AH |
| $C_{351}$ | H | H | H | H | VH | MH | AH | H | MH | H |
| $C_{352}$ | VH | VH | M | AH | H | MH | H | H | H | VH |
| $C_{353}$ | VH | VH | AH | H | H | H | AH | H | VH | MH |
| $C_{354}$ | H | H | MH | VH | VH | M | MH | AH | H | MH |
| $C_{361}$ | MH | H | AH | H | VH | H | H | AH | H | MH |
| $C_{362}$ | MH | M | H | VH | MH | H | MH | H | VH | AH |

**Table III.**

(*continued*)

| Leagile criterions ($C_{ijk}$) | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_{363}$ | MH | AH | AH | VH | H | H | H | AH | H | H |
| $C_{364}$ | AH | H | VH | AH | AH | H | AH | VH | H | H |
| $C_{371}$ | MH | VH | H | H | MH | VH | MH | H | VH | H |
| $C_{372}$ | AH | MH | H | VH | MH | H | AH | AH | H | H |
| $C_{373}$ | H | H | VH | MH | H | H | H | MH | H | VH |
| $C_{374}$ | MH | H | H | H | M | H | AH | AH | H | H |
| $C_{375}$ | H | VH | VH | AH | AH | H | VH | MH | VH | H |
| $C_{376}$ | MH | MH | MH | MH | H | AH | H | MH | H | VH |
| $C_{377}$ | VH | VH | AH | AH | VH | MH | H | H | AH | H |
| $C_{378}$ | H | AH | H | H | MH | AH | VH | M | MH | MH |
| $C_{379}$ | H | MH | VH | H | H | MH | H | AH | AH | H |
| $C_{3710}$ | MH | MH | MH | H | VH | H | VH | H | H | MH |
| $C_{3711}$ | VH | H | H | H | H | H | MH | VH | H | H |
| $C_{381}$ | AH | M | H | VH | MH | VH | H | MH | H | AH |
| $C_{382}$ | H | AH | MH | H | H | MH | AH | AH | H | MH |
| $C_{383}$ | VH | AH | H | H | H | AH | MH | H | VH | AH |
| $C_{384}$ | MH | H | AH | H | VH | MH | AH | VH | H | H |
| $C_{391}$ | H | VH | MH | AH | H | MH | H | MH | H | AH |
| $C_{392}$ | H | H | AH | H | H | H | VH | H | H | VH |
| $C_{393}$ | VH | AH | H | VH | VH | M | MH | MH | VH | H |
| $C_{394}$ | MH | MH | AH | VH | H | AH | H | H | H | H |
| $C_{3101}$ | VH | AH | VH | H | H | H | AH | AH | AH | VH |
| $C_{3102}$ | VH | H | H | MH | H | VH | H | MH | MH | H |
| $C_{3103}$ | H | H | H | H | VH | MH | VH | AH | AH | VH |
| $C_{3104}$ | MH | H | AH | MH | H | H | MH | H | H | MH |
| $C_{3105}$ | H | H | MH | MH | H | H | H | AH | H | H |
| $C_{3106}$ | H | VH | VH | AH | VH | VH | H | VH | H | AH |
| $C_{3111}$ | VH | H | MH | MH | H | VH | VH | H | H | MH |
| $C_{3112}$ | H | VH | MH | MH | AH | H | H | H | VH | VH |
| $C_{3113}$ | AH | H | MH | VH | VH | VH | H | VH | MH | AH |
| $C_{3114}$ | H | H | H | H | VH | MH | AH | H | MH | H |
| $C_{3115}$ | VH | VH | M | AH | H | MH | H | H | H | VH |
| $C_{3116}$ | VH | VH | AH | H | H | H | AH | H | VH | MH |
| $C_{3117}$ | H | H | MH | VH | VH | M | MH | AH | H | MH |
| $C_{3121}$ | VH | VH | MH | AH | H | H | H | MH | VH | AH |
| $C_{3122}$ | AH | AH | H | H | AH | AH | AH | H | H | H |
| $C_{3123}$ | H | MH | AH | VH | AH | MH | MH | AH | MH | H |
| $C_{3124}$ | VH | MH | MH | MH | H | AH | AH | MH | H | AH |
| $C_{411}$ | MH | H | AH | H | VH | H | H | AH | H | MH |
| $C_{412}$ | H | M | H | VH | MH | H | MH | H | VH | AH |
| $C_{413}$ | H | AH | AH | VH | H | H | H | AH | H | H |
| $C_{414}$ | AH | H | VH | AH | AH | H | AH | VH | H | H |
| $C_{421}$ | MH | VH | H | H | MH | VH | MH | H | VH | H |
| $C_{422}$ | AH | MH | H | VH | MH | H | AH | AH | H | H |
| $C_{423}$ | H | H | VH | MH | H | H | H | MH | H | VH |
| $C_{431}$ | AH | H | H | H | M | H | AH | AH | H | H |
| $C_{432}$ | H | VH | VH | AH | AH | H | VH | MH | VH | H |
| $C_{433}$ | AH | MH | MH | MH | H | AH | H | MH | H | VH |
| $C_{434}$ | VH | VH | AH | AH | VH | MH | H | H | AH | H |

(*continued*)

**Table III.**

| Leagile criterions ($C_{ijk}$) | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_{441}$ | H | AH | H | H | MH | AH | VH | M | MH | MH |
| $C_{442}$ | VH | MH | VH | H | H | MH | H | AH | AH | H |
| $C_{443}$ | H | MH | MH | H | VH | H | VH | H | H | MH |
| $C_{444}$ | VH | H | H | H | H | H | MH | VH | H | H |
| $C_{445}$ | AH | M | H | VH | MH | VH | H | MH | H | AH |
| $C_{451}$ | VH | VH | MH | AH | H | H | H | MH | VH | AH |
| $C_{452}$ | AH | AH | H | H | AH | AH | AH | H | H | H |
| $C_{453}$ | H | MH | AH | VH | AH | MH | MH | AH | MH | H |
| $C_{454}$ | VH | MH | MH | MH | H | AH | AH | MH | H | AH |
| $C_{455}$ | MH | H | AH | H | VH | H | H | AH | H | MH |
| $C_{456}$ | H | M | H | VH | MH | H | MH | H | VH | AH |
| $C_{457}$ | H | AH | AH | VH | H | H | H | AH | H | H |
| $C_{458}$ | AH | H | VH | AH | AH | H | AH | VH | H | H |
| $C_{461}$ | MH | VH | H | H | MH | VH | MH | H | VH | H |
| $C_{462}$ | AH | MH | H | VH | MH | H | AH | AH | H | H |
| $C_{463}$ | VH | H | VH | MH | H | H | H | MH | H | VH |
| $C_{464}$ | H | H | MH | H | M | H | AH | AH | H | H |
| $C_{471}$ | VH | VH | VH | AH | AH | H | VH | MH | VH | H |
| $C_{472}$ | H | MH | MH | MH | H | AH | H | MH | H | VH |
| $C_{473}$ | VH | VH | AH | AH | VH | MH | H | H | AH | H |
| $C_{474}$ | H | AH | H | H | MH | AH | VH | M | MH | MH |
| $C_{475}$ | H | MH | VH | H | H | MH | H | AH | AH | H |
| $C_{476}$ | H | MH | MH | H | VH | H | VH | H | H | MH |
| $C_{511}$ | VH | H | H | H | H | H | MH | VH | H | H |
| $C_{512}$ | AH | M | H | VH | MH | VH | H | MH | H | AH |
| $C_{513}$ | H | AH | MH | H | H | MH | AH | AH | H | MH |
| $C_{521}$ | VH | AH | H | H | H | AH | MH | H | VH | AH |
| $C_{522}$ | MH | H | AH | H | VH | MH | AH | VH | H | H |
| $C_{523}$ | H | VH | MH | AH | H | MH | H | MH | H | AH |
| $C_{531}$ | H | H | AH | H | H | H | VH | H | H | VH |
| $C_{532}$ | VH | AH | H | VH | VH | M | MH | MH | VH | H |
| $C_{533}$ | MH | MH | AH | VH | H | AH | H | H | H | H |
| $C_{541}$ | VH | AH | VH | H | H | H | AH | AH | AH | VH |
| $C_{542}$ | VH | H | H | MH | H | VH | H | MH | MH | H |
| $C_{543}$ | H | H | H | H | VH | MH | VH | AH | AH | VH |
| $C_{551}$ | MH | H | AH | MH | H | H | MH | H | H | MH |
| $C_{552}$ | H | H | H | H | H | H | H | AH | H | H |
| $C_{553}$ | H | VH | VH | AH | VH | VH | H | VH | H | AH |
| $C_{561}$ | VH | H | MH | MH | H | VH | VH | H | H | MH |
| $C_{562}$ | H | VH | MH | MH | AH | H | H | H | VH | VH |
| $C_{563}$ | AH | H | MH | VH | VH | VH | H | VH | MH | AH |

**Table III.**

provides a guideline and test-kit to achieve strategic fit by focussing on the leagility of a particular type of supply chain strategy.

Managerial decision-making process often experience uncertain-vague data which is really difficult to analyze. Fuzzy logic has the capability to overcome such imprecise linguistic human judgment. Fuzzy logic is an efficient tool to capture human perception to correlate with a mathematical base. Supply chain leagility, as a whole, is a conceptual philosophy difficult to model and to estimate an overall leagility index quantitatively. In this paper, an effort has been made to establish a scientific mathematical background to assess overall leagility degree for a given supply chain and to assess the

| Leagile criterions ($C_{ijk}$) | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_{111}$ | G | VG | MG | G | M | G | AG | M | G | VG |
| $C_{112}$ | MG | VG | G | G | G | MG | G | G | G | MG |
| $C_{113}$ | G | G | VG | M | G | VG | MG | G | MG | G |
| $C_{114}$ | G | MP | MG | G | M | VG | G | M | VG | AG |
| $C_{115}$ | VG | G | G | AG | G | G | MG | VG | VG | AG |
| $C_{121}$ | MG | VG | AG | VG | AG | MP | MG | G | G | G |
| $C_{122}$ | G | G | AG | AG | VG | G | G | G | MP | G |
| $C_{123}$ | AG | G | G | G | G | VG | VG | MG | G | AG |
| $C_{124}$ | M | MG | G | MG | AG | G | MG | VG | VG | G |
| $C_{125}$ | M | VG | AG | M | G | G | G | VG | G | MG |
| $C_{131}$ | MG | VG | MG | G | MG | MG | AG | G | G | M |
| $C_{132}$ | G | AG | M | G | M | VG | AG | MP | M | G |
| $C_{133}$ | MG | G | AG | M | G | AG | G | G | VG | G |
| $C_{141}$ | M | MG | G | VG | G | G | G | VG | G | M |
| $C_{142}$ | MP | M | AG | G | MG | MG | AG | G | G | G |
| $C_{151}$ | G | G | G | G | MG | M | MG | G | MG | AG |
| $C_{152}$ | AG | G | MG | MG | G | G | M | MG | MG | VG |
| $C_{153}$ | G | M | M | AG | VG | G | G | VG | G | G |
| $C_{154}$ | MG | G | G | G | MG | M | VG | VG | VG | G |
| $C_{155}$ | MG | G | G | MG | G | G | MG | G | MG | MG |
| $C_{161}$ | VG | MG | M | M | AG | AG | M | MP | G | VG |
| $C_{162}$ | G | MG | G | G | AG | VG | G | G | AG | VG |
| $C_{163}$ | G | G | AG | G | G | G | AG | M | AG | G |
| $C_{164}$ | M | VG | VG | G | G | MG | G | VG | G | MP |
| $C_{165}$ | MG | MG | G | G | AG | M | MG | G | G | G |
| $C_{166}$ | G | G | MG | MG | MG | VG | M | AG | AG | M |
| $C_{167}$ | MG | AG | VG | VG | M | G | G | G | MG | VG |
| $C_{168}$ | M | AG | AG | VG | AG | G | G | MG | M | AG |
| $C_{169}$ | G | G | G | G | VG | MG | M | M | G | G |
| $C_{171}$ | G | M | MG | MP | G | M | G | G | VG | MG |
| $C_{172}$ | MG | G | G | MG | MP | VG | VG | M | AG | VG |
| $C_{173}$ | M | AG | AG | M | MG | VG | MG | G | M | M |
| $C_{174}$ | G | AG | VG | G | M | VG | M | AG | MG | MG |
| $C_{181}$ | MG | G | M | MG | AG | VG | VG | VG | MP | M |
| $C_{182}$ | M | MP | VG | AG | VG | MG | G | G | MG | G |
| $C_{183}$ | VG | MG | G | G | VG | M | AG | AG | M | MP |
| $C_{184}$ | G | VG | M | AG | G | AG | M | VG | VG | G |
| $C_{191}$ | MG | G | VG | G | VG | G | VG | AG | G | MG |
| $C_{192}$ | M | G | G | MG | G | VG | G | G | VG | MG |
| $C_{193}$ | G | MG | MG | M | MG | G | G | MG | VG | G |
| $C_{1101}$ | G | VG | MG | G | M | G | AG | M | G | VG |
| $C_{1102}$ | MG | VG | G | G | G | MG | G | G | G | MG |
| $C_{1103}$ | G | G | VG | M | G | VG | MG | G | MG | G |
| $C_{1104}$ | G | MP | MG | G | M | VG | G | M | VG | AG |
| $C_{211}$ | VG | G | G | AG | G | G | MG | VG | VG | AG |
| $C_{212}$ | MG | VG | AG | VG | AG | MP | MG | G | G | G |
| $C_{213}$ | G | G | AG | AG | VG | G | G | G | MP | G |
| $C_{214}$ | AG | G | G | G | G | VG | VG | MG | G | AG |
| $C_{215}$ | M | MG | G | MG | AG | G | MG | VG | VG | G |

(*continued*)

**Table IV.** Appropriateness rating of leagile criterions (in linguistic term) assigned by the decision makers (DMs)

| Leagile criterions ($C_{ijk}$) | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_{216}$ | M | VG | AG | M | G | G | G | VG | G | MG |
| $C_{221}$ | MG | VG | MG | G | MG | MG | AG | G | G | M |
| $C_{222}$ | G | AG | M | G | M | VG | AG | MP | M | G |
| $C_{223}$ | MG | G | AG | M | G | AG | G | G | VG | G |
| $C_{224}$ | M | MG | G | VG | G | G | G | VG | G | M |
| $C_{225}$ | MP | M | AG | G | MG | MG | AG | G | G | G |
| $C_{226}$ | G | G | G | G | MG | M | MG | G | MG | AG |
| $C_{227}$ | G | VG | M | AG | G | AG | M | VG | VG | G |
| $C_{231}$ | MG | G | VG | G | VG | G | VG | AG | G | MG |
| $C_{232}$ | M | G | G | MG | G | VG | G | G | VG | MG |
| $C_{233}$ | G | MG | MG | M | MG | G | G | MG | VG | G |
| $C_{234}$ | G | VG | MG | G | M | G | AG | M | G | VG |
| $C_{235}$ | MG | VG | G | G | G | MG | G | G | G | MG |
| $C_{236}$ | G | G | VG | M | G | VG | MG | G | MG | G |
| $C_{241}$ | G | MP | MG | G | M | VG | G | M | VG | AG |
| $C_{242}$ | VG | G | G | AG | G | G | MG | VG | VG | AG |
| $C_{243}$ | MG | VG | AG | VG | AG | MP | MG | G | G | G |
| $C_{244}$ | G | G | AG | AG | VG | G | G | G | MP | G |
| $C_{245}$ | AG | G | G | G | G | VG | VG | MG | G | AG |
| $C_{246}$ | M | MG | G | MG | AG | G | MG | VG | VG | G |
| $C_{247}$ | M | VG | AG | M | G | G | G | VG | G | MG |
| $C_{248}$ | MG | VG | MG | G | MG | MG | AG | G | G | M |
| $C_{249}$ | G | AG | M | G | M | VG | AG | MP | M | G |
| $C_{251}$ | MG | G | AG | M | G | AG | G | G | VG | G |
| $C_{252}$ | M | MG | G | VG | G | G | G | VG | G | M |
| $C_{253}$ | MP | M | AG | G | MG | MG | AG | G | G | G |
| $C_{311}$ | G | G | G | G | MG | M | MG | G | MG | AG |
| $C_{312}$ | AG | G | MG | MG | G | G | M | MG | MG | VG |
| $C_{313}$ | G | M | M | AG | VG | G | G | VG | G | G |
| $C_{314}$ | MG | G | G | G | MG | M | VG | VG | VG | G |
| $C_{321}$ | MG | G | G | MG | G | G | MG | G | MG | MG |
| $C_{322}$ | VG | MG | M | M | AG | AG | M | MP | G | VG |
| $C_{323}$ | G | MG | G | G | AG | VG | G | G | AG | VG |
| $C_{324}$ | G | G | AG | G | G | G | AG | M | AG | G |
| $C_{325}$ | M | VG | VG | G | G | MG | G | VG | G | MP |
| $C_{331}$ | MG | MG | G | G | AG | M | MG | G | G | G |
| $C_{332}$ | G | G | MG | MG | MG | VG | M | AG | AG | M |
| $C_{333}$ | MG | AG | VG | VG | M | G | G | G | MG | VG |
| $C_{334}$ | M | AG | AG | VG | AG | G | G | MG | M | AG |
| $C_{341}$ | G | G | G | G | VG | MG | M | M | G | G |
| $C_{342}$ | G | M | MG | MP | G | M | G | G | VG | MG |
| $C_{343}$ | MG | G | G | MG | MP | VG | VG | M | AG | VG |
| $C_{344}$ | M | AG | AG | M | MG | VG | MG | G | M | M |
| $C_{351}$ | G | AG | VG | G | M | VG | M | AG | MG | MG |
| $C_{352}$ | MG | G | M | MG | AG | VG | VG | VG | MP | M |
| $C_{353}$ | M | MP | VG | AG | VG | MG | G | G | MG | G |
| $C_{354}$ | VG | MG | G | G | VG | M | AG | AG | M | MP |
| $C_{361}$ | G | VG | MG | G | M | G | AG | M | G | VG |
| $C_{362}$ | MG | VG | G | G | G | MG | G | G | G | MG |

**Table IV.**

(*continued*)

| Leagile criterions ($C_{ijk}$) | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_{363}$ | G | G | VG | M | G | VG | MG | G | MG | G |
| $C_{364}$ | G | MP | MG | G | M | VG | G | M | VG | AG |
| $C_{371}$ | VG | G | G | AG | G | G | MG | VG | VG | AG |
| $C_{372}$ | MG | VG | AG | VG | AG | MP | MG | G | G | G |
| $C_{373}$ | G | G | AG | AG | VG | G | G | G | MP | G |
| $C_{374}$ | AG | G | G | G | G | VG | VG | MG | G | AG |
| $C_{375}$ | M | MG | G | MG | AG | G | MG | VG | VG | G |
| $C_{376}$ | M | VG | AG | M | G | G | G | VG | G | MG |
| $C_{377}$ | MG | VG | MG | G | MG | MG | AG | G | G | M |
| $C_{378}$ | G | AG | M | G | M | VG | AG | MP | M | G |
| $C_{379}$ | MG | G | AG | M | G | AG | G | G | VG | G |
| $C_{3710}$ | M | MG | G | VG | G | G | G | VG | G | M |
| $C_{3711}$ | MP | M | AG | G | MG | MG | AG | G | G | G |
| $C_{381}$ | G | G | G | G | MG | M | MG | G | MG | AG |
| $C_{382}$ | AG | G | MG | MG | G | G | M | MG | MG | VG |
| $C_{383}$ | G | M | M | AG | VG | G | G | VG | G | G |
| $C_{384}$ | MG | G | G | G | MG | M | VG | VG | VG | G |
| $C_{391}$ | MG | G | G | MG | G | G | MG | G | MG | MG |
| $C_{392}$ | VG | MG | M | M | AG | AG | M | MP | G | VG |
| $C_{393}$ | G | MG | G | G | AG | VG | G | G | AG | VG |
| $C_{394}$ | G | G | AG | G | G | G | AG | M | AG | G |
| $C_{3101}$ | M | VG | VG | G | G | MG | G | VG | G | MP |
| $C_{3102}$ | MG | MG | G | G | AG | M | MG | G | G | G |
| $C_{3103}$ | G | G | MG | MG | MG | VG | M | AG | AG | M |
| $C_{3104}$ | MG | AG | VG | VG | M | G | G | G | MG | VG |
| $C_{3105}$ | M | AG | AG | VG | AG | G | G | MG | M | AG |
| $C_{3106}$ | G | G | G | G | VG | MG | M | M | G | G |
| $C_{3111}$ | G | M | MG | MP | G | M | G | G | VG | MG |
| $C_{3112}$ | MG | G | G | MG | MP | VG | VG | M | AG | VG |
| $C_{3113}$ | M | AG | AG | M | MG | VG | MG | G | M | M |
| $C_{3114}$ | G | AG | VG | G | M | VG | M | AG | MG | MG |
| $C_{3115}$ | MG | G | M | MG | AG | VG | VG | VG | MP | M |
| $C_{3116}$ | M | MP | VG | AG | VG | MG | G | G | MG | G |
| $C_{3117}$ | VG | MG | G | G | VG | M | AG | AG | M | MP |
| $C_{3121}$ | G | VG | M | AG | G | AG | M | VG | VG | G |
| $C_{3122}$ | MG | G | VG | G | VG | G | VG | AG | G | MG |
| $C_{3123}$ | M | G | G | MG | G | VG | G | G | VG | MG |
| $C_{3124}$ | G | MG | MG | M | MG | G | G | MG | VG | G |
| $C_{411}$ | G | VG | MG | G | M | G | AG | M | G | VG |
| $C_{412}$ | MG | VG | G | G | G | MG | G | G | G | MG |
| $C_{413}$ | G | G | VG | M | G | VG | MG | G | MG | G |
| $C_{414}$ | G | MP | MG | G | M | VG | G | M | VG | AG |
| $C_{421}$ | VG | G | G | AG | G | G | MG | VG | VG | AG |
| $C_{422}$ | MG | VG | AG | VG | AG | MP | MG | G | G | G |
| $C_{423}$ | G | G | AG | AG | VG | G | G | G | MP | G |
| $C_{431}$ | AG | G | G | G | G | VG | VG | MG | G | AG |
| $C_{432}$ | M | MG | G | MG | AG | G | MG | VG | VG | G |
| $C_{433}$ | M | VG | AG | M | G | G | G | VG | G | MG |
| $C_{434}$ | MG | VG | MG | G | MG | MG | AG | G | G | M |

(*continued*)

**Table IV.**

| Leagile criterions ($C_{ijk}$) | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_{441}$ | G | AG | M | G | M | VG | AG | MP | M | G |
| $C_{442}$ | MG | G | AG | M | G | AG | G | G | VG | G |
| $C_{443}$ | M | MG | G | VG | G | G | G | VG | G | M |
| $C_{444}$ | MP | M | AG | G | MG | MG | AG | G | G | G |
| $C_{445}$ | G | G | G | G | MG | M | MG | G | MG | AG |
| $C_{451}$ | G | VG | M | AG | G | AG | M | VG | VG | G |
| $C_{452}$ | MG | G | VG | G | VG | G | VG | AG | G | MG |
| $C_{453}$ | M | G | G | MG | G | VG | G | G | VG | MG |
| $C_{454}$ | G | MG | MG | M | MG | G | G | MG | VG | G |
| $C_{455}$ | G | VG | MG | G | M | G | AG | M | G | VG |
| $C_{456}$ | MG | VG | G | G | G | MG | G | G | G | MG |
| $C_{457}$ | G | G | VG | M | G | VG | MG | G | MG | G |
| $C_{458}$ | G | MP | MG | G | M | VG | G | M | VG | AG |
| $C_{461}$ | VG | G | G | AG | G | G | MG | VG | VG | AG |
| $C_{462}$ | MG | VG | AG | VG | AG | MP | MG | G | G | G |
| $C_{463}$ | G | G | AG | AG | VG | G | G | G | MP | G |
| $C_{464}$ | AG | G | G | G | G | VG | VG | MG | G | AG |
| $C_{471}$ | M | MG | G | MG | AG | G | MG | VG | VG | G |
| $C_{472}$ | M | VG | AG | M | G | G | G | VG | G | MG |
| $C_{473}$ | MG | VG | MG | G | MG | MG | AG | G | G | M |
| $C_{474}$ | G | AG | M | G | M | VG | AG | MP | M | G |
| $C_{475}$ | MG | G | AG | M | G | AG | G | G | VG | G |
| $C_{476}$ | M | MG | G | VG | G | G | G | VG | G | M |
| $C_{511}$ | MP | M | AG | G | MG | MG | AG | G | G | G |
| $C_{512}$ | G | G | G | G | MG | M | MG | G | MG | AG |
| $C_{513}$ | AG | G | MG | MG | G | G | M | MG | MG | VG |
| $C_{521}$ | G | M | M | AG | VG | G | G | VG | G | G |
| $C_{522}$ | MG | G | G | G | MG | M | VG | VG | VG | G |
| $C_{523}$ | MG | G | G | MG | G | G | MG | G | MG | MG |
| $C_{531}$ | VG | MG | M | M | AG | AG | M | MP | G | VG |
| $C_{532}$ | G | MG | G | G | AG | VG | G | G | AG | VG |
| $C_{533}$ | G | G | AG | G | G | G | AG | M | AG | G |
| $C_{541}$ | M | VG | VG | G | G | MG | G | VG | G | MP |
| $C_{542}$ | MG | MG | G | G | AG | M | MG | G | G | G |
| $C_{543}$ | G | G | MG | MG | MG | VG | M | AG | AG | M |
| $C_{551}$ | MG | AG | VG | VG | M | G | G | G | MG | VG |
| $C_{552}$ | M | AG | AG | VG | AG | G | G | MG | M | AG |
| $C_{553}$ | G | G | G | G | VG | MG | M | M | G | G |
| $C_{561}$ | G | M | MG | MP | G | M | G | G | VG | MG |
| $C_{562}$ | MG | G | G | MG | MP | VG | VG | M | AG | VG |
| $C_{563}$ | M | AG | AG | M | MG | VG | MG | G | M | M |

**Table IV.**

extent of successful performance of the key indices that stimulate leagility. The fuzzy-based leagility evaluation model presented here can be effectively implemented in industries supply chain to attain competitive advantage in the market.

## 7. Conclusions

Improved supply chain agility and leanness imply that a supply chain is capable of quickly responding to variations in customer demand with cost and waste reduction. Leanness in a supply chain maximizes profits through cost reduction, while agility maximizes profit through providing exactly what the customer requires. This paper

| Leagile attributes ($C_{ij}$) | Weight | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $C_{11}$ | $w_{11}$ | MH | VH | MH | AH | AH | H | H | MH | VH | AH |
| $C_{12}$ | $w_{12}$ | AH | AH | H | H | AH | AH | AH | H | MH | H |
| $C_{13}$ | $w_{13}$ | MH | MH | AH | VH | AH | MH | MH | AH | MH | H |
| $C_{14}$ | $w_{14}$ | MH | MH | H | H | H | AH | AH | MH | H | AH |
| $C_{15}$ | $w_{15}$ | MH | H | AH | H | VH | H | H | AH | H | MH |
| $C_{16}$ | $w_{16}$ | AH | M | H | VH | MH | MH | MH | H | VH | AH |
| $C_{17}$ | $w_{17}$ | H | AH | MH | VH | H | MH | H | AH | H | H |
| $C_{18}$ | $w_{18}$ | AH | H | MH | AH | AH | H | AH | VH | H | H |
| $C_{19}$ | $w_{19}$ | MH | VH | H | H | MH | VH | MH | H | VH | H |
| $C_{110}$ | $w_{110}$ | AH | MH | H | VH | MH | H | AH | AH | H | MH |
| $C_{21}$ | $w_{21}$ | H | H | VH | MH | H | H | H | MH | H | VH |
| $C_{22}$ | $w_{22}$ | H | H | MH | MH | M | H | AH | AH | H | H |
| $C_{23}$ | $w_{23}$ | AH | VH | VH | AH | AH | H | MH | MH | VH | H |
| $C_{24}$ | $w_{24}$ | AH | MH | MH | MH | H | AH | H | MH | H | VH |
| $C_{25}$ | $w_{25}$ | VH | VH | AH | AH | VH | H | H | H | AH | H |
| $C_{31}$ | $w_{31}$ | H | AH | H | H | MH | AH | VH | M | MH | MH |
| $C_{32}$ | $w_{32}$ | H | MH | VH | AH | H | MH | H | AH | AH | H |
| $C_{33}$ | $w_{33}$ | H | MH | MH | H | VH | H | VH | H | AH | MH |
| $C_{34}$ | $w_{34}$ | VH | H | H | H | H | H | MH | VH | H | H |
| $C_{35}$ | $w_{35}$ | AH | M | H | VH | MH | VH | H | MH | H | AH |
| $C_{36}$ | $w_{36}$ | H | AH | MH | MH | H | MH | AH | AH | H | MH |
| $C_{37}$ | $w_{37}$ | MH | AH | H | H | H | AH | MH | H | AH | AH |
| $C_{38}$ | $w_{38}$ | MH | H | AH | H | VH | MH | AH | VH | H | H |
| $C_{39}$ | $w_{39}$ | H | VH | H | AH | H | MH | H | MH | H | AH |
| $C_{310}$ | $w_{310}$ | H | H | AH | H | H | H | VH | MH | MH | VH |
| $C_{311}$ | $w_{311}$ | VH | AH | H | VH | VH | M | MH | MH | VH | H |
| $C_{312}$ | $w_{312}$ | MH | AH | AH | VH | H | AH | H | AH | H | H |
| $C_{41}$ | $w_{41}$ | VH | AH | VH | H | H | H | AH | AH | AH | VH |
| $C_{42}$ | $w_{42}$ | VH | H | H | MH | H | VH | H | MH | MH | H |
| $C_{43}$ | $w_{43}$ | H | MH | H | H | VH | MH | VH | AH | AH | VH |
| $C_{44}$ | $w_{44}$ | MH | MH | AH | MH | H | H | MH | H | H | MH |
| $C_{45}$ | $w_{45}$ | H | H | H | MH | MH | MH | MH | AH | H | H |
| $C_{46}$ | $w_{46}$ | H | VH | VH | AH | VH | VH | H | VH | AH | AH |
| $C_{47}$ | $w_{47}$ | VH | H | MH | MH | H | VH | VH | H | H | MH |
| $C_{51}$ | $w_{51}$ | H | VH | MH | MH | AH | H | MH | H | VH | VH |
| $C_{52}$ | $w_{52}$ | AH | H | MH | VH | VH | VH | MH | VH | MH | AH |
| $C_{53}$ | $w_{53}$ | MH | H | H | H | VH | MH | AH | AH | MH | H |
| $C_{54}$ | $w_{54}$ | MH | VH | M | AH | H | MH | H | H | H | VH |
| $C_{55}$ | $w_{55}$ | VH | VH | AH | H | H | H | AH | H | VH | MH |
| $C_{56}$ | $w_{56}$ | H | H | MH | VH | VH | M | MH | AH | H | MH |

**Table V.**
Priority weight of leagile attributes (in linguistic term) given by decision maker (DMs)

| Leagile enablers ($C_i$) | Weight | DM1 | DM2 | DM3 | DM4 | DM5 | DM6 | DM7 | DM8 | DM9 | DM10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $C_1$ | $w_1$ | VH | AH | H | AH | VH | H | AH | AH | VH | MH |
| $C_2$ | $w_2$ | VH | AH | VH | AH | H | VH | VH | MH | MH | AH |
| $C_3$ | $w_3$ | AH | AH | AH | H | VH | H | MH | VH | VH | H |
| $C_4$ | $w_4$ | H | H | MH | VH | MH | AH | H | VH | H | AH |
| $C_5$ | $w_5$ | VH | MH | H | MH | H | MH | VH | AH | AH | MH |

**Table VI.**
Priority weight of leagile enablers (in linguistic term) given by decision maker (DMs)

| Leagile criterions ($C_{ijk}$) | Aggregated priority weight ($w_{ijk}$) | Aggregated rating ($U_{ijk}$) |
|---|---|---|
| $C_{111}$ | (0.755,0.799,0.908,0.946;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{112}$ | (0.722,0.775,0.886,0.925;1.000) | (0.699,0.755,0.892,0.940;1.000) |
| $C_{113}$ | (0.811,0.851,0.940,0.971;1.000) | (0.694,0.753,0.878,0.922;1.000) |
| $C_{114}$ | (0.874,0.908,0.968,0.988;1.000) | (0.641,0.697,0.808,0.849;1.000) |
| $C_{115}$ | (0.741,0.795,0.908,0.946;1.000) | (0.825,0.869,0.948,0.974;1.000) |
| $C_{121}$ | (0.797,0.836,0.928,0.960;1.000) | (0.735,0.778,0.872,0.905;1.000) |
| $C_{122}$ | (0.734,0.790,0.912,0.954;1.000) | (0.742,0.788,0.888,0.924;1.000) |
| $C_{123}$ | (0.722,0.772,0.890,0.933;1.000) | (0.804,0.849,0.940,0.971;1.000) |
| $C_{124}$ | (0.846,0.889,0.956,0.977;1.000) | (0.708,0.760,0.874,0.914;1.000) |
| $C_{125}$ | (0.713,0.762,0.888,0.932;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{131}$ | (0.853,0.891,0.956,0.977;1.000) | (0.673,0.725,0.854,0.900;1.000) |
| $C_{132}$ | (0.715,0.762,0.874,0.914;1.000) | (0.622,0.677,0.786,0.828;1.000) |
| $C_{133}$ | (0.755,0.799,0.908,0.946;1.000) | (0.743,0.792,0.898,0.936;1.000) |
| $C_{141}$ | (0.720,0.775,0.900,0.943;1.000) | (0.668,0.731,0.856,0.901;1.000) |
| $C_{142}$ | (0.748,0.805,0.924,0.965;1.000) | (0.653,0.701,0.822,0.867;1.000) |
| $C_{151}$ | (0.708,0.760,0.874,0.914;1.000) | (0.666,0.720,0.858,0.908;1.000) |
| $C_{152}$ | (0.762,0.801,0.908,0.946;1.000) | (0.673,0.725,0.854,0.900;1.000) |
| $C_{153}$ | (0.832,0.871,0.948,0.974;1.000) | (0.710,0.768,0.876,0.915;1.000) |
| $C_{154}$ | (0.790,0.834,0.928,0.960;1.000) | (0.715,0.773,0.886,0.925;1.000) |
| $C_{155}$ | (0.755,0.799,0.908,0.946;1.000) | (0.650,0.705,0.860,0.915;1.000) |
| $C_{161}$ | (0.790,0.842,0.944,0.979;1.000) | (0.629,0.682,0.782,0.820;1.000) |
| $C_{162}$ | (0.729,0.780,0.882,0.917;1.000) | (0.804,0.849,0.940,0.971;1.000) |
| $C_{163}$ | (0.769,0.814,0.920,0.957;1.000) | (0.764,0.809,0.910,0.947;1.000) |
| $C_{164}$ | (0.895,0.928,0.976,0.991;1.000) | (0.674,0.732,0.842,0.881;1.000) |
| $C_{165}$ | (0.720,0.775,0.900,0.943;1.000) | (0.666,0.720,0.858,0.908;1.000) |
| $C_{166}$ | (0.825,0.869,0.948,0.974;1.000) | (0.675,0.725,0.840,0.882;1.000) |
| $C_{167}$ | (0.692,0.742,0.880,0.929;1.000) | (0.743,0.795,0.894,0.928;1.000) |
| $C_{168}$ | (0.720,0.772,0.904,0.951;1.000) | (0.759,0.799,0.880,0.910;1.000) |
| $C_{169}$ | (0.881,0.924,0.976,0.991;1.000) | (0.647,0.711,0.848,0.898;1.000) |
| $C_{171}$ | (0.741,0.795,0.908,0.946;1.000) | (0.578,0.640,0.780,0.832;1.000) |
| $C_{172}$ | (0.783,0.832,0.928,0.960;1.000) | (0.688,0.739,0.838,0.873;1.000) |
| $C_{173}$ | (0.790,0.837,0.924,0.952;1.000) | (0.609,0.666,0.784,0.829;1.000) |
| $C_{174}$ | (0.741,0.792,0.912,0.954;1.000) | (0.710,0.760,0.860,0.896;1.000) |
| $C_{181}$ | (0.757,0.810,0.906,0.939;1.000) | (0.648,0.702,0.804,0.841;1.000) |
| $C_{182}$ | (0.790,0.834,0.928,0.960;1.000) | (0.667,0.719,0.830,0.870;1.000) |
| $C_{183}$ | (0.708,0.760,0.874,0.914;1.000) | (0.669,0.719,0.816,0.852;1.000) |
| $C_{184}$ | (0.811,0.854,0.936,0.963;1.000) | (0.759,0.810,0.892,0.921;1.000) |
| $C_{191}$ | (0.860,0.890,0.960,0.985;1.000) | (0.783,0.832,0.928,0.960;1.000) |
| $C_{192}$ | (0.769,0.806,0.904,0.938;1.000) | (0.694,0.753,0.878,0.922;1.000) |
| $C_{193}$ | (0.769,0.806,0.904,0.938;1.000) | (0.645,0.703,0.846,0.897;1.000) |
| $C_{1101}$ | (0.769,0.814,0.920,0.957;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{1102}$ | (0.722,0.775,0.886,0.925;1.000) | (0.699,0.755,0.892,0.940;1.000) |
| $C_{1103}$ | (0.825,0.866,0.952,0.982;1.000) | (0.694,0.753,0.878,0.922;1.000) |
| $C_{1104}$ | (0.874,0.908,0.968,0.988;1.000) | (0.641,0.697,0.808,0.849;1.000) |
| $C_{211}$ | (0.741,0.795,0.908,0.946;1.000) | (0.825,0.869,0.948,0.974;1.000) |
| $C_{212}$ | (0.797,0.836,0.928,0.960;1.000) | (0.735,0.778,0.872,0.905;1.000) |
| $C_{213}$ | (0.734,0.790,0.912,0.954;1.000) | (0.742,0.788,0.888,0.924;1.000) |
| $C_{214}$ | (0.722,0.772,0.890,0.933;1.000) | (0.804,0.849,0.940,0.971;1.000) |
| $C_{215}$ | (0.832,0.874,0.944,0.966;1.000) | (0.708,0.760,0.874,0.914;1.000) |
| $C_{216}$ | (0.713,0.762,0.888,0.932;1.000) | (0.696,0.753,0.864,0.904;1.000) |

**Table VII.**
Aggregated priority weight as well as aggregated appropriateness rating of leagile criterions

(*continued*)

| Leagile criterions ($C_{ijk}$) | Aggregated priority weight ($w_{ijk}$) | Aggregated rating ($U_{ijk}$) |
|---|---|---|
| $C_{221}$ | (0.818,0.856,0.936,0.963;1.000) | (0.673,0.725,0.854,0.900;1.000) |
| $C_{222}$ | (0.715,0.762,0.874,0.914;1.000) | (0.622,0.677,0.786,0.828;1.000) |
| $C_{223}$ | (0.769,0.814,0.920,0.957;1.000) | (0.743,0.792,0.898,0.936;1.000) |
| $C_{224}$ | (0.720,0.775,0.900,0.943;1.000) | (0.668,0.731,0.856,0.901;1.000) |
| $C_{225}$ | (0.748,0.805,0.924,0.965;1.000) | (0.653,0.701,0.822,0.867;1.000) |
| $C_{226}$ | (0.708,0.760,0.874,0.914;1.000) | (0.666,0.720,0.858,0.908;1.000) |
| $C_{227}$ | (0.811,0.854,0.936,0.963;1.000) | (0.759,0.810,0.892,0.921;1.000) |
| $C_{231}$ | (0.860,0.890,0.960,0.985;1.000) | (0.783,0.832,0.928,0.960;1.000) |
| $C_{232}$ | (0.769,0.806,0.904,0.938;1.000) | (0.694,0.753,0.878,0.922;1.000) |
| $C_{233}$ | (0.769,0.806,0.904,0.938;1.000) | (0.645,0.703,0.846,0.897;1.000) |
| $C_{234}$ | (0.769,0.814,0.920,0.957;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{235}$ | (0.722,0.775,0.886,0.925;1.000) | (0.699,0.755,0.892,0.940;1.000) |
| $C_{236}$ | (0.825,0.866,0.952,0.982;1.000) | (0.694,0.753,0.878,0.922;1.000) |
| $C_{241}$ | (0.874,0.908,0.968,0.988;1.000) | (0.641,0.697,0.808,0.849;1.000) |
| $C_{242}$ | (0.741,0.795,0.908,0.946;1.000) | (0.825,0.869,0.948,0.974;1.000) |
| $C_{243}$ | (0.797,0.836,0.928,0.960;1.000) | (0.735,0.778,0.872,0.905;1.000) |
| $C_{244}$ | (0.734,0.790,0.912,0.954;1.000) | (0.742,0.788,0.888,0.924;1.000) |
| $C_{245}$ | (0.736,0.787,0.902,0.944;1.000) | (0.804,0.849,0.940,0.971;1.000) |
| $C_{246}$ | (0.832,0.874,0.944,0.966;1.000) | (0.708,0.760,0.874,0.914;1.000) |
| $C_{247}$ | (0.713,0.762,0.888,0.932;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{248}$ | (0.853,0.891,0.956,0.977;1.000) | (0.673,0.725,0.854,0.900;1.000) |
| $C_{249}$ | (0.715,0.762,0.874,0.914;1.000) | (0.622,0.677,0.786,0.828;1.000) |
| $C_{251}$ | (0.755,0.799,0.908,0.946;1.000) | (0.743,0.792,0.898,0.936;1.000) |
| $C_{252}$ | (0.706,0.760,0.888,0.932;1.000) | (0.668,0.731,0.856,0.901;1.000) |
| $C_{253}$ | (0.748,0.805,0.924,0.965;1.000) | (0.653,0.701,0.822,0.867;1.000) |
| $C_{311}$ | (0.750,0.797,0.894,0.928;1.000) | (0.666,0.720,0.858,0.908;1.000) |
| $C_{312}$ | (0.762,0.801,0.908,0.946;1.000) | (0.673,0.725,0.854,0.900;1.000) |
| $C_{313}$ | (0.832,0.871,0.948,0.974;1.000) | (0.710,0.768,0.876,0.915;1.000) |
| $C_{314}$ | (0.790,0.834,0.928,0.960;1.000) | (0.715,0.773,0.886,0.925;1.000) |
| $C_{321}$ | (0.755,0.799,0.908,0.946;1.000) | (0.650,0.705,0.860,0.915;1.000) |
| $C_{322}$ | (0.790,0.842,0.944,0.979;1.000) | (0.629,0.682,0.782,0.820;1.000) |
| $C_{323}$ | (0.764,0.815,0.902,0.931;1.000) | (0.804,0.849,0.940,0.971;1.000) |
| $C_{324}$ | (0.769,0.814,0.920,0.957;1.000) | (0.764,0.809,0.910,0.947;1.000) |
| $C_{325}$ | (0.860,0.893,0.956,0.977;1.000) | (0.674,0.732,0.842,0.881;1.000) |
| $C_{331}$ | (0.720,0.775,0.900,0.943;1.000) | (0.666,0.720,0.858,0.908;1.000) |
| $C_{332}$ | (0.811,0.854,0.936,0.963;1.000) | (0.675,0.725,0.840,0.882;1.000) |
| $C_{333}$ | (0.692,0.742,0.880,0.929;1.000) | (0.743,0.795,0.894,0.928;1.000) |
| $C_{334}$ | (0.748,0.802,0.928,0.973;1.000) | (0.759,0.799,0.880,0.910;1.000) |
| $C_{341}$ | (0.881,0.924,0.976,0.991;1.000) | (0.647,0.711,0.848,0.898;1.000) |
| $C_{342}$ | (0.741,0.795,0.908,0.946;1.000) | (0.578,0.640,0.780,0.832;1.000) |
| $C_{343}$ | (0.783,0.832,0.928,0.960;1.000) | (0.688,0.739,0.838,0.873;1.000) |
| $C_{344}$ | (0.832,0.874,0.944,0.966;1.000) | (0.609,0.666,0.784,0.829;1.000) |
| $C_{351}$ | (0.741,0.792,0.912,0.954;1.000) | (0.710,0.760,0.860,0.896;1.000) |
| $C_{352}$ | (0.757,0.810,0.906,0.939;1.000) | (0.648,0.702,0.804,0.841;1.000) |
| $C_{353}$ | (0.825,0.869,0.948,0.974;1.000) | (0.667,0.719,0.830,0.870;1.000) |
| $C_{354}$ | (0.708,0.760,0.874,0.914;1.000) | (0.669,0.719,0.816,0.852;1.000) |
| $C_{361}$ | (0.769,0.814,0.920,0.957;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{362}$ | (0.708,0.760,0.874,0.914;1.000) | (0.699,0.755,0.892,0.940;1.000) |
| $C_{363}$ | (0.811,0.851,0.940,0.971;1.000) | (0.694,0.753,0.878,0.922;1.000) |
| $C_{364}$ | (0.874,0.908,0.968,0.988;1.000) | (0.641,0.697,0.808,0.849;1.000) |

(*continued*)

**Table VII.**

| Leagile criterions ($C_{ijk}$) | Aggregated priority weight ($w_{ijk}$) | Aggregated rating ($U_{ijk}$) |
|---|---|---|
| $C_{371}$ | (0.741,0.795,0.908,0.946;1.000) | (0.825,0.869,0.948,0.974;1.000) |
| $C_{372}$ | (0.797,0.836,0.928,0.960;1.000) | (0.735,0.778,0.872,0.905;1.000) |
| $C_{373}$ | (0.734,0.790,0.912,0.954;1.000) | (0.742,0.788,0.888,0.924;1.000) |
| $C_{374}$ | (0.722,0.772,0.890,0.933;1.000) | (0.804,0.849,0.940,0.971;1.000) |
| $C_{375}$ | (0.846,0.889,0.956,0.977;1.000) | (0.708,0.760,0.874,0.914;1.000) |
| $C_{376}$ | (0.699,0.747,0.876,0.921;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{377}$ | (0.853,0.891,0.956,0.977;1.000) | (0.673,0.725,0.854,0.900;1.000) |
| $C_{378}$ | (0.715,0.762,0.874,0.914;1.000) | (0.622,0.677,0.786,0.828;1.000) |
| $C_{379}$ | (0.769,0.814,0.920,0.957;1.000) | (0.743,0.792,0.898,0.936;1.000) |
| $C_{3710}$ | (0.706,0.760,0.888,0.932;1.000) | (0.668,0.731,0.856,0.901;1.000) |
| $C_{3711}$ | (0.748,0.805,0.924,0.965;1.000) | (0.653,0.701,0.822,0.867;1.000) |
| $C_{381}$ | (0.750,0.797,0.894,0.928;1.000) | (0.666,0.720,0.858,0.908;1.000) |
| $C_{382}$ | (0.762,0.801,0.908,0.946;1.000) | (0.673,0.725,0.854,0.900;1.000) |
| $C_{383}$ | (0.832,0.871,0.948,0.974;1.000) | (0.710,0.768,0.876,0.915;1.000) |
| $C_{384}$ | (0.790,0.834,0.928,0.960;1.000) | (0.715,0.773,0.886,0.925;1.000) |
| $C_{391}$ | (0.755,0.799,0.908,0.946;1.000) | (0.650,0.705,0.860,0.915;1.000) |
| $C_{392}$ | (0.790,0.842,0.944,0.979;1.000) | (0.629,0.682,0.782,0.820;1.000) |
| $C_{393}$ | (0.764,0.815,0.902,0.931;1.000) | (0.804,0.849,0.940,0.971;1.000) |
| $C_{394}$ | (0.769,0.814,0.920,0.957;1.000) | (0.764,0.809,0.910,0.947;1.000) |
| $C_{3101}$ | (0.895,0.928,0.976,0.991;1.000) | (0.674,0.732,0.842,0.881;1.000) |
| $C_{3102}$ | (0.720,0.775,0.900,0.943;1.000) | (0.666,0.720,0.858,0.908;1.000) |
| $C_{3103}$ | (0.825,0.869,0.948,0.974;1.000) | (0.675,0.725,0.840,0.882;1.000) |
| $C_{3104}$ | (0.692,0.742,0.880,0.929;1.000) | (0.743,0.795,0.894,0.928;1.000) |
| $C_{3105}$ | (0.720,0.772,0.904,0.951;1.000) | (0.759,0.799,0.880,0.910;1.000) |
| $C_{3106}$ | (0.881,0.924,0.976,0.991;1.000) | (0.647,0.711,0.848,0.898;1.000) |
| $C_{3111}$ | (0.741,0.795,0.908,0.946;1.000) | (0.578,0.640,0.780,0.832;1.000) |
| $C_{3112}$ | (0.783,0.832,0.928,0.960;1.000) | (0.688,0.739,0.838,0.873;1.000) |
| $C_{3113}$ | (0.832,0.874,0.944,0.966;1.000) | (0.609,0.666,0.784,0.829;1.000) |
| $C_{3114}$ | (0.741,0.792,0.912,0.954;1.000) | (0.710,0.760,0.860,0.896;1.000) |
| $C_{3115}$ | (0.757,0.810,0.906,0.939;1.000) | (0.648,0.702,0.804,0.841;1.000) |
| $C_{3116}$ | (0.825,0.869,0.948,0.974;1.000) | (0.667,0.719,0.830,0.870;1.000) |
| $C_{3117}$ | (0.708,0.760,0.874,0.914;1.000) | (0.669,0.719,0.816,0.852;1.000) |
| $C_{3121}$ | (0.811,0.854,0.936,0.963;1.000) | (0.759,0.810,0.892,0.921;1.000) |
| $C_{3122}$ | (0.860,0.890,0.960,0.985;1.000) | (0.783,0.832,0.928,0.960;1.000) |
| $C_{3123}$ | (0.769,0.806,0.904,0.938;1.000) | (0.694,0.753,0.878,0.922;1.000) |
| $C_{3124}$ | (0.769,0.806,0.904,0.938;1.000) | (0.645,0.703,0.846,0.897;1.000) |
| $C_{411}$ | (0.769,0.814,0.920,0.957;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{412}$ | (0.722,0.775,0.886,0.925;1.000) | (0.699,0.755,0.892,0.940;1.000) |
| $C_{413}$ | (0.825,0.866,0.952,0.982;1.000) | (0.694,0.753,0.878,0.922;1.000) |
| $C_{414}$ | (0.874,0.908,0.968,0.988;1.000) | (0.641,0.697,0.808,0.849;1.000) |
| $C_{421}$ | (0.741,0.795,0.908,0.946;1.000) | (0.825,0.869,0.948,0.974;1.000) |
| $C_{422}$ | (0.797,0.836,0.928,0.960;1.000) | (0.735,0.778,0.872,0.905;1.000) |
| $C_{423}$ | (0.734,0.790,0.912,0.954;1.000) | (0.742,0.788,0.888,0.924;1.000) |
| $C_{431}$ | (0.764,0.809,0.910,0.947;1.000) | (0.804,0.849,0.940,0.971;1.000) |
| $C_{432}$ | (0.846,0.889,0.956,0.977;1.000) | (0.708,0.760,0.874,0.914;1.000) |
| $C_{433}$ | (0.741,0.784,0.896,0.935;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{434}$ | (0.853,0.891,0.956,0.977;1.000) | (0.673,0.725,0.854,0.900;1.000) |
| $C_{441}$ | (0.715,0.762,0.874,0.914;1.000) | (0.622,0.677,0.786,0.828;1.000) |
| $C_{442}$ | (0.790,0.834,0.928,0.960;1.000) | (0.743,0.792,0.898,0.936;1.000) |
| $C_{443}$ | (0.720,0.775,0.900,0.943;1.000) | (0.668,0.731,0.856,0.901;1.000) |

**Table VII.**

(*continued*)

| Leagile criterions ($C_{ijk}$) | Aggregated priority weight ($w_{ijk}$) | Aggregated rating ($U_{ijk}$) |
|---|---|---|
| $C_{444}$ | (0.748,0.805,0.924,0.965;1.000) | (0.653,0.701,0.822,0.867;1.000) |
| $C_{445}$ | (0.750,0.797,0.894,0.928;1.000) | (0.666,0.720,0.858,0.908;1.000) |
| $C_{451}$ | (0.811,0.854,0.936,0.963;1.000) | (0.759,0.810,0.892,0.921;1.000) |
| $C_{452}$ | (0.860,0.890,0.960,0.985;1.000) | (0.783,0.832,0.928,0.960;1.000) |
| $C_{453}$ | (0.769,0.806,0.904,0.938;1.000) | (0.694,0.753,0.878,0.922;1.000) |
| $C_{454}$ | (0.769,0.806,0.904,0.938;1.000) | (0.645,0.703,0.846,0.897;1.000) |
| $C_{455}$ | (0.769,0.814,0.920,0.957;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{456}$ | (0.722,0.775,0.886,0.925;1.000) | (0.699,0.755,0.892,0.940;1.000) |
| $C_{457}$ | (0.825,0.866,0.952,0.982;1.000) | (0.694,0.753,0.878,0.922;1.000) |
| $C_{458}$ | (0.874,0.908,0.968,0.988;1.000) | (0.641,0.697,0.808,0.849;1.000) |
| $C_{461}$ | (0.741,0.795,0.908,0.946;1.000) | (0.825,0.869,0.948,0.974;1.000) |
| $C_{462}$ | (0.797,0.836,0.928,0.960;1.000) | (0.735,0.778,0.872,0.905;1.000) |
| $C_{463}$ | (0.755,0.810,0.920,0.957;1.000) | (0.742,0.788,0.888,0.924;1.000) |
| $C_{464}$ | (0.722,0.772,0.890,0.933;1.000) | (0.804,0.849,0.940,0.971;1.000) |
| $C_{471}$ | (0.867,0.909,0.964,0.980;1.000) | (0.708,0.760,0.874,0.914;1.000) |
| $C_{472}$ | (0.713,0.762,0.888,0.932;1.000) | (0.696,0.753,0.864,0.904;1.000) |
| $C_{473}$ | (0.853,0.891,0.956,0.977;1.000) | (0.673,0.725,0.854,0.900;1.000) |
| $C_{474}$ | (0.715,0.762,0.874,0.914;1.000) | (0.622,0.677,0.786,0.828;1.000) |
| $C_{475}$ | (0.769,0.814,0.920,0.957;1.000) | (0.743,0.792,0.898,0.936;1.000) |
| $C_{476}$ | (0.720,0.775,0.900,0.943;1.000) | (0.668,0.731,0.856,0.901;1.000) |
| $C_{511}$ | (0.748,0.805,0.924,0.965;1.000) | (0.653,0.701,0.822,0.867;1.000) |
| $C_{512}$ | (0.750,0.797,0.894,0.928;1.000) | (0.666,0.720,0.858,0.908;1.000) |
| $C_{513}$ | (0.762,0.801,0.908,0.946;1.000) | (0.673,0.725,0.854,0.900;1.000) |
| $C_{521}$ | (0.832,0.871,0.948,0.974;1.000) | (0.710,0.768,0.876,0.915;1.000) |
| $C_{522}$ | (0.790,0.834,0.928,0.960;1.000) | (0.715,0.773,0.886,0.925;1.000) |
| $C_{523}$ | (0.755,0.799,0.908,0.946;1.000) | (0.650,0.705,0.860,0.915;1.000) |
| $C_{531}$ | (0.790,0.842,0.944,0.979;1.000) | (0.629,0.682,0.782,0.820;1.000) |
| $C_{532}$ | (0.764,0.815,0.902,0.931;1.000) | (0.804,0.849,0.940,0.971;1.000) |
| $C_{533}$ | (0.769,0.814,0.920,0.957;1.000) | (0.764,0.809,0.910,0.947;1.000) |
| $C_{541}$ | (0.895,0.928,0.976,0.991;1.000) | (0.674,0.732,0.842,0.881;1.000) |
| $C_{542}$ | (0.720,0.775,0.900,0.943;1.000) | (0.666,0.720,0.858,0.908;1.000) |
| $C_{543}$ | (0.825,0.869,0.948,0.974;1.000) | (0.675,0.725,0.840,0.882;1.000) |
| $C_{551}$ | (0.692,0.742,0.880,0.929;1.000) | (0.743,0.795,0.894,0.928;1.000) |
| $C_{552}$ | (0.748,0.802,0.928,0.973;1.000) | (0.759,0.799,0.880,0.910;1.000) |
| $C_{553}$ | (0.881,0.924,0.976,0.991;1.000) | (0.647,0.711,0.848,0.898;1.000) |
| $C_{561}$ | (0.741,0.795,0.908,0.946;1.000) | (0.578,0.640,0.780,0.832;1.000) |
| $C_{562}$ | (0.783,0.832,0.928,0.960;1.000) | (0.688,0.739,0.838,0.873;1.000) |
| $C_{563}$ | (0.832,0.874,0.944,0.966;1.000) | (0.609,0.666,0.784,0.829;1.000) |

**Table VII.**

aimed to present an integrated fuzzy-based performance appraisement module in an organizational leagile supply chain.

This paper proposes a FOPI to assess the combined agility and leanness measure (leagility) of the organizational supply chain. This evaluation module helps to assess existing organizational leagility degree; it can be considered as a ready reference to compare performance of different leagile organization (running under similar supply chain architecture) and to benchmark candidate leagile enterprises; so that best practices can be transmitted to the less-performing organizations. Moreover, there is scope to identify ill-performing areas (barriers of leagility) which require special managerial attention for future improvement.

| Leagile attributes ($C_{ij}$) | Aggregated priority weight ($w_{ij}$) | Computed fuzzy rating ($U_{ij}$) |
|---|---|---|
| $C_{11}$ | (0.804,0.841,0.924,0.952;1.000) | (0.579,0.684,0.979,1.122;1.000) |
| $C_{12}$ | (0.846,0.875,0.948,0.974;1.000) | (0.590,0.695,1.002,1.152;1.000) |
| $C_{13}$ | (0.755,0.791,0.892,0.927;1.000) | (0.557,0.655,0.946,1.085;1.000) |
| $C_{14}$ | (0.762,0.801,0.908,0.946;1.000) | (0.508,0.620,0.968,1.149;1.000) |
| $C_{15}$ | (0.769,0.814,0.920,0.957;1.000) | (0.555,0.658,0.974,1.125;1.000) |
| $C_{16}$ | (0.736,0.782,0.882,0.917;1.000) | (0.572,0.675,0.968,1.112;1.000) |
| $C_{17}$ | (0.769,0.814,0.920,0.957;1.000) | (0.518,0.622,0.920,1.070;1.000) |
| $C_{18}$ | (0.839,0.873,0.948,0.974;1.000) | (0.558,0.660,0.935,1.073;1.000) |
| $C_{19}$ | (0.741,0.795,0.908,0.946;1.000) | (0.595,0.691,0.979,1.106;1.000) |
| $C_{110}$ | (0.783,0.821,0.916,0.949;1.000) | (0.564,0.666,0.952,1.091;1.000) |
| $C_{21}$ | (0.734,0.790,0.912,0.954;1.000) | (0.599,0.705,1.017,1.168;1.000) |
| $C_{22}$ | (0.708,0.757,0.878,0.922;1.000) | (0.547,0.652,0.965,1.120;1.000) |
| $C_{23}$ | (0.839,0.876,0.944,0.966;1.000) | (0.579,0.681,0.983,1.123;1.000) |
| $C_{24}$ | (0.741,0.784,0.896,0.935;1.000) | (0.582,0.684,0.973,1.113;1.000) |
| $C_{25}$ | (0.867,0.906,0.968,0.988;1.000) | (0.535,0.644,0.988,1.160;1.000) |
| $C_{31}$ | (0.715,0.762,0.874,0.914;1.000) | (0.569,0.671,0.967,1.108;1.000) |
| $C_{32}$ | (0.797,0.836,0.928,0.960;1.000) | (0.578,0.679,0.963,1.102;1.000) |
| $C_{33}$ | (0.748,0.797,0.908,0.946;1.000) | (0.554,0.661,0.996,1.162;1.000) |
| $C_{34}$ | (0.748,0.805,0.924,0.965;1.000) | (0.529,0.629,0.892,1.024;1.000) |
| $C_{35}$ | (0.750,0.797,0.894,0.928;1.000) | (0.540,0.643,0.932,1.079;1.000) |
| $C_{36}$ | (0.748,0.786,0.896,0.935;1.000) | (0.562,0.665,0.955,1.094;1.000) |
| $C_{37}$ | (0.804,0.838,0.928,0.960;1.000) | (0.571,0.676,0.988,1.142;1.000) |
| $C_{38}$ | (0.790,0.834,0.928,0.960;1.000) | (0.569,0.671,0.967,1.108;1.000) |
| $C_{39}$ | (0.769,0.814,0.920,0.957;1.000) | (0.574,0.677,0.980,1.130;1.000) |
| $C_{310}$ | (0.762,0.812,0.920,0.957;1.000) | (0.566,0.668,0.958,1.100;1.000) |
| $C_{311}$ | (0.764,0.815,0.902,0.931;1.000) | (0.528,0.630,0.914,1.057;1.000) |
| $C_{312}$ | (0.839,0.873,0.948,0.974;1.000) | (0.606,0.703,0.979,1.103;1.000) |
| $C_{41}$ | (0.895,0.928,0.976,0.991;1.000) | (0.564,0.666,0.952,1.091;1.000) |
| $C_{42}$ | (0.720,0.775,0.900,0.943;1.000) | (0.609,0.715,1.024,1.176;1.000) |
| $C_{43}$ | (0.811,0.854,0.936,0.963;1.000) | (0.600,0.699,0.973,1.104;1.000) |
| $C_{44}$ | (0.678,0.727,0.868,0.918;1.000) | (0.531,0.637,0.961,1.124;1.000) |
| $C_{45}$ | (0.692,0.742,0.880,0.929;1.000) | (0.585,0.685,0.966,1.097;1.000) |
| $C_{46}$ | (0.909,0.946,0.984,0.994;1.000) | (0.616,0.723,1.034,1.188;1.000) |
| $C_{47}$ | (0.741,0.795,0.908,0.946;1.000) | (0.558,0.661,0.959,1.104;1.000) |
| $C_{51}$ | (0.769,0.817,0.916,0.949;1.000) | (0.529,0.631,0.958,1.120;1.000) |
| $C_{52}$ | (0.818,0.859,0.932,0.955;1.000) | (0.572,0.674,0.972,1.113;1.000) |
| $C_{53}$ | (0.755,0.799,0.908,0.946;1.000) | (0.592,0.696,0.981,1.125;1.000) |
| $C_{54}$ | (0.722,0.775,0.886,0.925;1.000) | (0.564,0.661,0.929,1.061;1.000) |
| $C_{55}$ | (0.825,0.869,0.948,0.974;1.000) | (0.571,0.678,0.985,1.136;1.000) |
| $C_{56}$ | (0.708,0.760,0.874,0.914;1.000) | (0.513,0.614,0.890,1.030;1.000) |

**Table VIII.**
Aggregated fuzzy priority weight and computed fuzzy rating of leagile attributes

| Leagile enablers ($C_i$) | Aggregated weight ($w_i$) | Computed rating ($U_i$) |
|---|---|---|
| $C_1$ | (0.881,0.913,0.964,0.980;1.000) | (0.460,0.594,1.075,1.349;1.000) |
| $C_2$ | (0.895,0.931,0.972,0.983;1.000) | (0.463,0.602,1.101,1.393;1.000) |
| $C_3$ | (0.853,0.891,0.956,0.977;1.000) | (0.456,0.592,1.076,1.358;1.000) |
| $C_4$ | (0.790,0.834,0.928,0.960;1.000) | (0.474,0.612,1.098,1.382;1.000) |
| $C_5$ | (0.776,0.819,0.916,0.949;1.000) | (0.453,0.589,1.068,1.353;1.000) |

**Table IX.**
Aggregated fuzzy priority weight and computed fuzzy rating of leagile enablers

| Leagile criterions ($C_{ijk}$) | FPII $= U_{ij} \times [(1,1,1,1,1) - w_{ij}]$ | $I_{\bar{A}}(\bar{x}_0, \bar{y}_0)$ | $R(\overline{A}) = x_0 \times y_0$ | Ranking order |
|---|---|---|---|---|
| $C_{111}$ | (0.038,0.069,0.174,0.221;1.000) | (0.1232,0.3779) | 0.0466 | 23 |
| $C_{112}$ | (0.052,0.086,0.201,0.261;1.000) | (0.1461,0.3811) | 0.0557 | 9 |
| $C_{113}$ | (0.020,0.045,0.131,0.174;1.000) | (0.0901,0.3727) | 0.0336 | 40 |
| $C_{114}$ | (0.008,0.022,0.074,0.107;1.000) | (0.0507,0.3610) | 0.0183 | 56 |
| $C_{115}$ | (0.045,0.080,0.194,0.252;1.000) | (0.1394,0.3810) | 0.0531 | 13 |
| $C_{121}$ | (0.029,0.056,0.143,0.184;1.000) | (0.1011,0.3730) | 0.0377 | 35 |
| $C_{122}$ | (0.034,0.069,0.186,0.246;1.000) | (0.1303,0.3816) | 0.0497 | 17 |
| $C_{123}$ | (0.054,0.093,0.214,0.270;1.000) | (0.1554,0.3823) | 0.0594 | 4 |
| $C_{124}$ | (0.016,0.033,0.097,0.141;1.000) | (0.0686,0.3660) | 0.0251 | 52 |
| $C_{125}$ | (0.047,0.084,0.206,0.259;1.000) | (0.1466,0.3821) | 0.0560 | 7 |
| $C_{131}$ | (0.015,0.032,0.093,0.132;1.000) | (0.0654,0.3648) | 0.0239 | 53 |
| $C_{132}$ | (0.053,0.085,0.187,0.236;1.000) | (0.1380,0.3775) | 0.0521 | 14 |
| $C_{133}$ | (0.040,0.073,0.180,0.229;1.000) | (0.1284,0.3788) | 0.0486 | 20 |
| $C_{141}$ | (0.038,0.073,0.193,0.252;1.000) | (0.1353,0.3820) | 0.0517 | 15 |
| $C_{142}$ | (0.023,0.053,0.160,0.218;1.000) | (0.1097,0.3791) | 0.0416 | 32 |
| $C_{151}$ | (0.057,0.091,0.206,0.265;1.000) | (0.1509,0.3811) | 0.0575 | 6 |
| $C_{152}$ | (0.036,0.067,0.170,0.214;1.000) | (0.1198,0.3773) | 0.0452 | 26 |
| $C_{153}$ | (0.018,0.040,0.113,0.154;1.000) | (0.0788,0.3689) | 0.0291 | 47 |
| $C_{154}$ | (0.029,0.056,0.147,0.194;1.000) | (0.1036,0.3746) | 0.0388 | 34 |
| $C_{155}$ | (0.035,0.065,0.173,0.224;1.000) | (0.1211,0.3788) | 0.0459 | 25 |
| $C_{161}$ | (0.013,0.038,0.124,0.172;1.000) | (0.0836,0.3731) | 0.0312 | 43 |
| $C_{162}$ | (0.067,0.100,0.207,0.263;1.000) | (0.1559,0.3791) | 0.0591 | 5 |
| $C_{163}$ | (0.033,0.065,0.169,0.219;1.000) | (0.1188,0.3781) | 0.0449 | 27 |
| $C_{164}$ | (0.006,0.018,0.061,0.093;1.000) | (0.0419,0.3576) | 0.0150 | 58 |
| $C_{165}$ | (0.038,0.072,0.193,0.254;1.000) | (0.1352,0.3823) | 0.0517 | 15 |
| $C_{166}$ | (0.018,0.038,0.110,0.154;1.000) | (0.0768,0.3689) | 0.0283 | 48 |
| $C_{167}$ | (0.053,0.095,0.231,0.286;1.000) | (0.1642,0.3850) | 0.0632 | 1 |
| $C_{168}$ | (0.037,0.077,0.201,0.255;1.000) | (0.1401,0.3828) | 0.0536 | 12 |
| $C_{169}$ | (0.006,0.017,0.064,0.107;1.000) | (0.0450,0.3602) | 0.0162 | 57 |
| $C_{171}$ | (0.031,0.059,0.160,0.215;1.000) | (0.1124,0.3775) | 0.0424 | 30 |
| $C_{172}$ | (0.028,0.053,0.141,0.189;1.000) | (0.0996,0.3737) | 0.0372 | 36 |
| $C_{173}$ | (0.029,0.051,0.128,0.174;1.000) | (0.0922,0.3705) | 0.0341 | 39 |
| $C_{174}$ | (0.033,0.067,0.179,0.232;1.000) | (0.1248,0.3801) | 0.0474 | 22 |
| $C_{181}$ | (0.040,0.066,0.153,0.204;1.000) | (0.1122,0.3738) | 0.0419 | 31 |
| $C_{182}$ | (0.027,0.052,0.138,0.183;1.000) | (0.0970,0.3729) | 0.0362 | 37 |
| $C_{183}$ | (0.058,0.091,0.196,0.249;1.000) | (0.1453,0.3786) | 0.0550 | 10 |
| $C_{184}$ | (0.028,0.052,0.130,0.174;1.000) | (0.0934,0.3708) | 0.0346 | 38 |
| $C_{191}$ | (0.012,0.033,0.102,0.134;1.000) | (0.0690,0.3669) | 0.0253 | 51 |
| $C_{192}$ | (0.043,0.072,0.170,0.213;1.000) | (0.1228,0.3760) | 0.0462 | 24 |
| $C_{193}$ | (0.040,0.067,0.164,0.207;1.000) | (0.1175,0.3755) | 0.0441 | 29 |
| $C_{1101}$ | (0.030,0.060,0.161,0.209;1.000) | (0.1124,0.3770) | 0.0424 | 30 |
| $C_{1102}$ | (0.052,0.086,0.201,0.261;1.000) | (0.1461,0.3811) | 0.0557 | 9 |
| $C_{1103}$ | (0.012,0.036,0.118,0.161;1.000) | (0.0792,0.3716) | 0.0294 | 45 |
| $C_{1104}$ | (0.008,0.022,0.074,0.107;1.000) | (0.0507,0.3610) | 0.0183 | 56 |
| $C_{211}$ | (0.045,0.080,0.194,0.252;1.000) | (0.1394,0.3810) | 0.0531 | 13 |
| $C_{212}$ | (0.029,0.056,0.143,0.184;1.000) | (0.1011,0.3730) | 0.0377 | 35 |
| $C_{213}$ | (0.034,0.069,0.186,0.246;1.000) | (0.1303,0.3816) | 0.0497 | 17 |
| $C_{214}$ | (0.054,0.093,0.214,0.270;1.000) | (0.1554,0.3823) | 0.0594 | 4 |
| $C_{215}$ | (0.024,0.043,0.110,0.154;1.000) | (0.0794,0.3673) | 0.0292 | 46 |

(*continued*)

**Table X.**
Computation of FPII and ranking order of leagile criterions

| Leagile criterions ($C_{ijk}$) | FPII $= U_{ij} \times [(1,1,1,1,1) - w_{ij}]$ | $I_{\tilde{A}}(\bar{x}_0, \bar{y}_0)$ | $R(\overline{A}) = x_0 \times y_0$ | Ranking order |
|---|---|---|---|---|
| $C_{216}$ | (0.047,0.084,0.206,0.259;1.000) | (0.1466,0.3821) | 0.0560 | 7 |
| $C_{221}$ | (0.025,0.046,0.123,0.164;1.000) | (0.0870,0.3698) | 0.0322 | 42 |
| $C_{222}$ | (0.053,0.085,0.187,0.236;1.000) | (0.1380,0.3775) | 0.0521 | 14 |
| $C_{223}$ | (0.032,0.063,0.167,0.216;1.000) | (0.1171,0.3779) | 0.0442 | 28 |
| $C_{224}$ | (0.038,0.073,0.193,0.252;1.000) | (0.1353,0.3820) | 0.0517 | 15 |
| $C_{225}$ | (0.023,0.053,0.160,0.218;1.000) | (0.1097,0.3791) | 0.0416 | 32 |
| $C_{226}$ | (0.057,0.091,0.206,0.265;1.000) | (0.1509,0.3811) | 0.0575 | 6 |
| $C_{227}$ | (0.028,0.052,0.130,0.174;1.000) | (0.0934,0.3708) | 0.0346 | 38 |
| $C_{231}$ | (0.012,0.033,0.102,0.134;1.000) | (0.0690,0.3669) | 0.0253 | 51 |
| $C_{232}$ | (0.043,0.072,0.170,0.213;1.000) | (0.1228,0.3760) | 0.0462 | 24 |
| $C_{233}$ | (0.040,0.067,0.164,0.207;1.000) | (0.1175,0.3755) | 0.0441 | 29 |
| $C_{234}$ | (0.030,0.060,0.161,0.209;1.000) | (0.1124,0.3770) | 0.0424 | 30 |
| $C_{235}$ | (0.052,0.086,0.201,0.261;1.000) | (0.1461,0.3811) | 0.0557 | 9 |
| $C_{236}$ | (0.012,0.036,0.118,0.161;1.000) | (0.0792,0.3716) | 0.0294 | 45 |
| $C_{241}$ | (0.008,0.022,0.074,0.107;1.000) | (0.0507,0.3610) | 0.0183 | 56 |
| $C_{242}$ | (0.045,0.080,0.194,0.252;1.000) | (0.1394,0.3810) | 0.0531 | 13 |
| $C_{243}$ | (0.029,0.056,0.143,0.184;1.000) | (0.1011,0.3730) | 0.0377 | 35 |
| $C_{244}$ | (0.034,0.069,0.186,0.246;1.000) | (0.1303,0.3816) | 0.0497 | 17 |
| $C_{245}$ | (0.045,0.083,0.200,0.256;1.000) | (0.1435,0.3815) | 0.0547 | 11 |
| $C_{246}$ | (0.024,0.043,0.110,0.154;1.000) | (0.0794,0.3673) | 0.0292 | 46 |
| $C_{247}$ | (0.047,0.084,0.206,0.259;1.000) | (0.1466,0.3821) | 0.0560 | 7 |
| $C_{248}$ | (0.015,0.032,0.093,0.132;1.000) | (0.0654,0.3648) | 0.0239 | 53 |
| $C_{249}$ | (0.053,0.085,0.187,0.236;1.000) | (0.1380,0.3775) | 0.0521 | 14 |
| $C_{251}$ | (0.040,0.073,0.180,0.229;1.000) | (0.1284,0.3788) | 0.0486 | 20 |
| $C_{252}$ | (0.045,0.082,0.205,0.265;1.000) | (0.1459,0.3829) | 0.0558 | 8 |
| $C_{253}$ | (0.023,0.053,0.160,0.218;1.000) | (0.1097,0.3791) | 0.0416 | 32 |
| $C_{311}$ | (0.048,0.076,0.174,0.227;1.000) | (0.1279,0.3766) | 0.0482 | 21 |
| $C_{312}$ | (0.036,0.067,0.170,0.214;1.000) | (0.1198,0.3773) | 0.0452 | 26 |
| $C_{313}$ | (0.018,0.040,0.113,0.154;1.000) | (0.0788,0.3689) | 0.0291 | 47 |
| $C_{314}$ | (0.029,0.056,0.147,0.194;1.000) | (0.1036,0.3746) | 0.0388 | 34 |
| $C_{321}$ | (0.035,0.065,0.173,0.224;1.000) | (0.1211,0.3788) | 0.0459 | 25 |
| $C_{322}$ | (0.013,0.038,0.124,0.172;1.000) | (0.0836,0.3731) | 0.0312 | 43 |
| $C_{323}$ | (0.055,0.083,0.174,0.229;1.000) | (0.1316,0.3751) | 0.0494 | 18 |
| $C_{324}$ | (0.033,0.065,0.169,0.219;1.000) | (0.1188,0.3781) | 0.0449 | 27 |
| $C_{325}$ | (0.016,0.032,0.090,0.123;1.000) | (0.0633,0.3632) | 0.0230 | 54 |
| $C_{331}$ | (0.038,0.072,0.193,0.254;1.000) | (0.1352,0.3823) | 0.0517 | 15 |
| $C_{332}$ | (0.025,0.046,0.123,0.167;1.000) | (0.0872,0.3700) | 0.0323 | 41 |
| $C_{333}$ | (0.053,0.095,0.231,0.286;1.000) | (0.1642,0.3850) | 0.0632 | 1 |
| $C_{334}$ | (0.020,0.058,0.174,0.229;1.000) | (0.1177,0.3813) | 0.0449 | 27 |
| $C_{341}$ | (0.006,0.017,0.064,0.107;1.000) | (0.0450,0.3602) | 0.0162 | 57 |
| $C_{342}$ | (0.031,0.059,0.160,0.215;1.000) | (0.1124,0.3775) | 0.0424 | 30 |
| $C_{343}$ | (0.028,0.053,0.141,0.189;1.000) | (0.0996,0.3737) | 0.0372 | 36 |
| $C_{344}$ | (0.021,0.037,0.099,0.139;1.000) | (0.0711,0.3650) | 0.0259 | 50 |
| $C_{351}$ | (0.033,0.067,0.179,0.232;1.000) | (0.1248,0.3801) | 0.0474 | 22 |
| $C_{352}$ | (0.040,0.066,0.153,0.204;1.000) | (0.1122,0.3738) | 0.0419 | 31 |
| $C_{353}$ | (0.017,0.037,0.109,0.152;1.000) | (0.0759,0.3685) | 0.0280 | 49 |
| $C_{354}$ | (0.058,0.091,0.196,0.249;1.000) | (0.1453,0.3786) | 0.0550 | 10 |
| $C_{361}$ | (0.030,0.060,0.161,0.209;1.000) | (0.1124,0.3770) | 0.0424 | 30 |
| $C_{362}$ | (0.060,0.095,0.214,0.274;1.000) | (0.1571,0.3820) | 0.0600 | 3 |

**Table X.** (*continued*)

| Leagile criterions ($C_{ijk}$) | FPII $= U_{ij} \times [(1,1,1,1,1) - w_{ij}]$ | $I_{\tilde{A}}(\bar{x}_0, \bar{y}_0)$ | $R(\overline{A}) = x_0 \times y_0$ | Ranking order |
|---|---|---|---|---|
| $C_{363}$ | (0.020,0.045,0.131,0.174;1.000) | (0.0901,0.3727) | 0.0336 | 40 |
| $C_{364}$ | (0.008,0.022,0.074,0.107;1.000) | (0.0507,0.3610) | 0.0183 | 56 |
| $C_{371}$ | (0.045,0.080,0.194,0.252;1.000) | (0.1394,0.3810) | 0.0531 | 13 |
| $C_{372}$ | (0.029,0.056,0.143,0.184;1.000) | (0.1011,0.3730) | 0.0377 | 35 |
| $C_{373}$ | (0.034,0.069,0.186,0.246;1.000) | (0.1303,0.3816) | 0.0497 | 17 |
| $C_{374}$ | (0.054,0.093,0.214,0.270;1.000) | (0.1554,0.3823) | 0.0594 | 4 |
| $C_{375}$ | (0.016,0.033,0.097,0.141;1.000) | (0.0686,0.3660) | 0.0251 | 52 |
| $C_{376}$ | (0.055,0.093,0.219,0.272;1.000) | (0.1574,0.3829) | 0.0603 | 2 |
| $C_{377}$ | (0.015,0.032,0.093,0.132;1.000) | (0.0654,0.3648) | 0.0239 | 53 |
| $C_{378}$ | (0.053,0.085,0.187,0.236;1.000) | (0.1380,0.3775) | 0.0521 | 14 |
| $C_{379}$ | (0.032,0.063,0.167,0.216;1.000) | (0.1171,0.3779) | 0.0442 | 28 |
| $C_{3710}$ | (0.045,0.082,0.205,0.265;1.000) | (0.1459,0.3829) | 0.0558 | 8 |
| $C_{3711}$ | (0.023,0.053,0.160,0.218;1.000) | (0.1097,0.3791) | 0.0416 | 32 |
| $C_{381}$ | (0.048,0.076,0.174,0.227;1.000) | (0.1279,0.3766) | 0.0482 | 21 |
| $C_{382}$ | (0.036,0.067,0.170,0.214;1.000) | (0.1198,0.3773) | 0.0452 | 26 |
| $C_{383}$ | (0.018,0.040,0.113,0.154;1.000) | (0.0788,0.3689) | 0.0291 | 47 |
| $C_{384}$ | (0.029,0.056,0.147,0.194;1.000) | (0.1036,0.3746) | 0.0388 | 34 |
| $C_{391}$ | (0.035,0.065,0.173,0.224;1.000) | (0.1211,0.3788) | 0.0459 | 25 |
| $C_{392}$ | (0.013,0.038,0.124,0.172;1.000) | (0.0836,0.3731) | 0.0312 | 43 |
| $C_{393}$ | (0.055,0.083,0.174,0.229;1.000) | (0.1316,0.3751) | 0.0494 | 18 |
| $C_{394}$ | (0.033,0.065,0.169,0.219;1.000) | (0.1188,0.3781) | 0.0449 | 27 |
| $C_{3101}$ | (0.006,0.018,0.061,0.093;1.000) | (0.0419,0.3576) | 0.0150 | 58 |
| $C_{3102}$ | (0.038,0.072,0.193,0.254;1.000) | (0.1352,0.3823) | 0.0517 | 15 |
| $C_{3103}$ | (0.018,0.038,0.110,0.154;1.000) | (0.0768,0.3689) | 0.0283 | 48 |
| $C_{3104}$ | (0.053,0.095,0.231,0.286;1.000) | (0.1642,0.3850) | 0.0632 | 1 |
| $C_{3105}$ | (0.037,0.077,0.201,0.255;1.000) | (0.1401,0.3828) | 0.0536 | 12 |
| $C_{3106}$ | (0.006,0.017,0.064,0.107;1.000) | (0.0450,0.3602) | 0.0162 | 57 |
| $C_{3111}$ | (0.031,0.059,0.160,0.215;1.000) | (0.1124,.3775) | 0.0424 | 30 |
| $C_{3112}$ | (0.028,0.053,0.141,0.189;1.000) | (0.0996,0.3737) | 0.0372 | 36 |
| $C_{3113}$ | (0.021,0.037,0.099,0.139;1.000) | (0.0711,0.3650) | 0.0259 | 50 |
| $C_{3114}$ | (0.033,0.067,0.179,0.232;1.000) | (0.1248,0.3801) | 0.0474 | 22 |
| $C_{3115}$ | (0.040,0.066,0.153,0.204;1.000) | (0.1122,0.3738) | 0.0419 | 31 |
| $C_{3116}$ | (0.017,0.037,0.109,0.152;1.000) | (0.0759,0.3685) | 0.0280 | 49 |
| $C_{3117}$ | (0.058,0.091,0.196,0.249;1.000) | (0.1453,0.3786) | 0.0550 | 10 |
| $C_{3121}$ | (0.028,0.052,0.130,0.174;1.000) | (0.0934,0.3708) | 0.0346 | 38 |
| $C_{3122}$ | (0.012,0.033,0.102,0.134;1.000) | (0.0690,0.3669) | 0.0253 | 51 |
| $C_{3123}$ | (0.043,0.072,0.170,0.213;1.000) | (0.1228,0.3760) | 0.0462 | 24 |
| $C_{3124}$ | (0.040,0.067,0.164,0.207;1.000) | (0.1175,0.3755) | 0.0441 | 29 |
| $C_{411}$ | (0.030,0.060,0.161,0.209;1.000) | (0.1124,0.3770) | 0.0424 | 30 |
| $C_{412}$ | (0.052,0.086,0.201,0.261;1.000) | (0.1461,0.3811) | 0.0557 | 9 |
| $C_{413}$ | (0.012,0.036,0.118,0.161;1.000) | (0.0792,0.3716) | 0.0294 | 45 |
| $C_{414}$ | (0.008,0.022,0.074,0.107;1.000) | (0.0507,0.3610) | 0.0183 | 56 |
| $C_{421}$ | (0.045,0.080,0.194,0.252;1.000) | (0.1394,0.3810) | 0.0531 | 13 |
| $C_{422}$ | (0.029,0.056,0.143,0.184;1.000) | (0.1011,0.3730) | 0.0377 | 35 |
| $C_{423}$ | (0.034,0.069,0.186,0.246;1.000) | (0.1303,0.3816) | 0.0497 | 17 |
| $C_{431}$ | (0.043,0.076,0.180,0.229;1.000) | (0.1296,0.3780) | 0.0490 | 19 |
| $C_{432}$ | (0.016,0.033,0.097,0.141;1.000) | (0.0686,0.3660) | 0.0251 | 52 |
| $C_{433}$ | (0.045,0.078,0.187,0.234;1.000) | (0.1340,0.3789) | 0.0508 | 16 |
| $C_{434}$ | (0.015,0.032,0.093,0.132;1.000) | (0.0654,0.3648) | 0.0239 | 53 |

(*continued*)

**Table X.**

| Leagile criterions ($C_{ijk}$) | FPII $= U_{ij} \times [(1,1,1,1,1) - w_{ij}]$ | $I_{\tilde{A}}(\bar{x}_0, \bar{y}_0)$ | $R(\overline{A}) = x_0 \times y_0$ | Ranking order |
|---|---|---|---|---|
| $C_{441}$ | (0.053,0.085,0.187,0.236;1.000) | (0.1380,0.3775) | 0.0521 | 14 |
| $C_{442}$ | (0.030,0.057,0.149,0.197;1.000) | (0.1053,0.3748) | 0.0395 | 33 |
| $C_{443}$ | (0.038,0.073,0.193,0.252;1.000) | (0.1353,0.3820) | 0.0517 | 15 |
| $C_{444}$ | (0.023,0.053,0.160,0.218;1.000) | (0.1097,0.3791) | 0.0416 | 32 |
| $C_{445}$ | (0.048,0.076,0.174,0.227;1.000) | (0.1279,0.3766) | 0.0482 | 21 |
| $C_{451}$ | (0.028,0.052,0.130,0.174;1.000) | (0.0934,0.3708) | 0.0346 | 38 |
| $C_{452}$ | (0.012,0.033,0.102,0.134;1.000) | (0.0690,0.3669) | 0.0253 | 51 |
| $C_{453}$ | (0.043,0.072,0.170,0.213;1.000) | (0.1228,0.3760) | 0.0462 | 24 |
| $C_{454}$ | (0.040,0.067,0.164,0.207;1.000) | (0.1175,0.3755) | 0.0441 | 29 |
| $C_{455}$ | (0.030,0.060,0.161,0.209;1.000) | (0.1124,0.3770) | 0.0424 | 30 |
| $C_{456}$ | (0.052,0.086,0.201,0.261;1.000) | (0.1461,0.3811) | 0.0557 | 9 |
| $C_{457}$ | (0.012,0.036,0.118,0.161;1.000) | (0.0792,0.3716) | 0.0294 | 45 |
| $C_{458}$ | (0.008,0.022,0.074,0.107;1.000) | (0.0507,0.3610) | 0.0183 | 56 |
| $C_{461}$ | (0.045,0.080,0.194,0.252;1.000) | (0.1394,0.3810) | 0.0531 | 13 |
| $C_{462}$ | (0.029,0.056,0.143,0.184;1.000) | (0.1011,0.3730) | 0.0377 | 35 |
| $C_{463}$ | (0.032,0.063,0.169,0.226;1.000) | (0.1186,0.3789) | 0.0449 | 27 |
| $C_{464}$ | (0.054,0.093,0.214,0.270;1.000) | (0.1554,0.3823) | 0.0594 | 4 |
| $C_{471}$ | (0.014,0.027,0.080,0.122;1.000) | (0.0573,0.3619) | 0.0207 | 55 |
| $C_{472}$ | (0.047,0.084,0.206,0.259;1.000) | (0.1466,0.3821) | 0.0560 | 7 |
| $C_{473}$ | (0.015,0.032,0.093,0.132;1.000) | (0.0654,0.3648) | 0.0239 | 53 |
| $C_{474}$ | (0.053,0.085,0.187,0.236;1.000) | (0.1380,0.3775) | 0.0521 | 14 |
| $C_{475}$ | (0.032,0.063,0.167,0.216;1.000) | (0.1171,0.3779) | 0.0442 | 28 |
| $C_{476}$ | (0.038,0.073,0.193,0.252;1.000) | (0.1353,0.3820) | 0.0517 | 15 |
| $C_{511}$ | (0.023,0.053,0.160,0.218;1.000) | (0.1097,0.3791) | 0.0416 | 32 |
| $C_{512}$ | (0.048,0.076,0.174,0.227;1.000) | (0.1279,0.3766) | 0.0482 | 21 |
| $C_{513}$ | (0.036,0.067,0.170,0.214;1.000) | (0.1198,0.3773) | 0.0452 | 26 |
| $C_{521}$ | (0.018,0.040,0.113,0.154;1.000) | (0.0788,0.3689) | 0.0291 | 47 |
| $C_{522}$ | (0.029,0.056,0.147,0.194;1.000) | (0.1036,0.3746) | 0.0388 | 34 |
| $C_{523}$ | (0.035,0.065,0.173,0.224;1.000) | (0.1211,0.3788) | 0.0459 | 25 |
| $C_{531}$ | (0.013,0.038,0.124,0.172;1.000) | (0.0836,0.3731) | 0.0312 | 43 |
| $C_{532}$ | (0.055,0.083,0.174,0.229;1.000) | (0.1316,0.3751) | 0.0494 | 18 |
| $C_{533}$ | (0.033,0.065,0.169,0.219;1.000) | (0.1188,0.3781) | 0.0449 | 27 |
| $C_{541}$ | (0.006,0.018,0.061,0.093;1.000) | (0.0419,0.3576) | 0.0150 | 58 |
| $C_{542}$ | (0.038,0.072,0.193,0.254;1.000) | (0.1352,0.3823) | 0.0517 | 15 |
| $C_{543}$ | (0.018,0.038,0.110,0.154;1.000) | (0.0768,0.3689) | 0.0283 | 48 |
| $C_{551}$ | (0.053,0.095,0.231,0.286;1.000) | (0.1642,0.3850) | 0.0632 | 1 |
| $C_{552}$ | (0.020,0.058,0.174,0.229;1.000) | (0.1177,0.3813) | 0.0449 | 27 |
| $C_{553}$ | (0.006,0.017,0.064,0.107;1.000) | (0.0450,0.3602) | 0.0162 | 57 |
| $C_{561}$ | (0.031,0.059,0.160,0.215;1.000) | (0.1124,0.3775) | 0.0424 | 30 |
| $C_{562}$ | (0.028,0.053,0.141,0.189;1.000) | (0.0996,0.3737) | 0.0372 | 36 |
| $C_{563}$ | (0.021,0.037,0.099,0.139;1.000) | (0.0711,0.3650) | 0.0259 | 50 |

**Table X.**

## References

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