www.ijemr.net ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

Volume-7, Issue-3, May-June 2017

International Journal of Engineering and Management Research

Page Number: 765-771

Intelligent DSS towards Identifying the Ill and Strong Drivers of Individual Firm by using Fuzzy-in Centre Method

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ABSTRACT

In the presented research work, a 2nd second level hierarchical Lean-Resilient supply chain module structure has been constructed, where Fuzzy Performance Index model has been applied to assess the overall performance of crank and shaft vendor firm.

Apart from this, a 'In centre of Centroid' method merged with generalized trapezoidal fuzzy set has been applied on module structure for identifying an ill and strong chief drivers under Lean-Resilient (L-R) SC strategies, so that managers could hike the firm's performance up to standard level in case of non wanted performance. An empirical case research of assumed of crank and shaft vendor firm is presented. Proposed an intelligent DSS is active for tracing the L-R supply chain's ill and strong chief drivers.

Keywords-- Multi-Criteria Decision Making (MCDM), L-R (Leanness-Resilient) Supply Chain, Performance Measurement (PM)

I. INTRODUCTION

These instructions give you guidelines for SCM integrate vendors, goods producers, warehouses and stores, in order that goods / services are produced and distributed to the consumers at right quantity, at right site, at right time, at right price by removing the system wide price while fulfilling the service level requirement of customers. SCM is concerned to incorporate its logistic, procurement, process and advertising functions with other supply chain members so as to stuffs, information, component / parts and finished goods may run from point of origin to final purchasers at the low unit price and high level services.

Performance measurement is consider as a part of methods, metrics, courses and systems , used in firms to explain strategies into tactics, observe implementation, and supply insight to get better financial and operations. It reflects the tactical, incorporated development of commerce cleverness to hold up the organization courses. Performance measurement is considered as rigorous procedure of materializing the efficiency and effectiveness of subjects.

II. FUZZY SET THEORY

(Prof. Zadeh 1965) proposed the concept of fuzzy logic in 1965. Fuzzy logic theory is a control tool and technique, which encompasses the data by allowing partial set membership rather than crisp set membership or non-membership.

Fuzzy logic deals with the concept of partial truth, where the truth value may range between completely true and completely false. Fuzzy logic found their application where the valuable information is neither completely true nor completely false, or which are partly true and partly false.

Fuzzy logic deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets (where variables may take on true or false values) fuzzy logic variables may have a truth value that ranges in degree between 0 and 1.

III. RESEARCH OBJECTIVES

A multi criterion decision making performance appraisement hierarchical module (constituted by mixing the segregated Lean-Resilient L-R 2nd layers of SC measures / drivers and their corresponding interrelated metrics has been developed conjunctive with Fuzzy Performance Index model in purpose to estimation the ill and strong drivers of individual firm.

IV. RANKING OF FUZZY NUMBERS

ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

Fuzzy logic is a tool, which is used to transform the oral information into mathematical data (Thorani et al., 2012). Fig. 1, showed the In center trapezoidal fuzzy number.

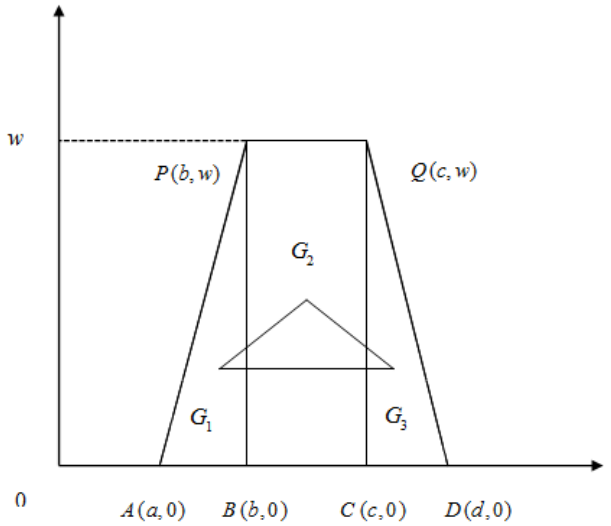

Fig.1. Incenter trapezoidal fuzzy number

A Fuzzy Performance Importance Index (FPII) is employed to recognize these ill-performing drivers / sub-criterion or metrics. FPII merges the criterion's performance ratings and weight of various 1st level sub-criterion / drivers. The higher the FPII of a aspect, the higher is the contribution. The idea of FPII was introduced by (Lin et al., 2006, Sahu et al., 2014, Sahu et al., 2015a, b, Sahu et al., 2016c, Sahu et al., 2017b, e).
Here,

$$W_i' = \lfloor \lfloor (1,1,1,1,1) \rfloor - w_i \rfloor$$

$$FPII_i = W'_i \otimes U_i \quad \text{.....(1)}$$

U_{ij} is the rating and w_{ij} is the importance weight of j_{th} index (at 2nd level).

U_{ij} is the rating and w_{ij} is the importance weight of j_{th} index (at 2nd level).

Consider a generalized trapezoidal fuzzy number $\tilde{A} = (a,b,c,d;w)$. The Centroid of the three flat figures are respectively.

$$G_1 = \frac{(a+2b)}{3}, \frac{W}{3} \quad \text{.....(2)}$$

$$G_2 = \frac{(b+c)}{2}, \frac{W}{2} \quad \text{.....(3)}$$

$$G_3 = \frac{(2c+d)}{3}, \frac{W}{3} \quad \text{.....(4)}$$

Equation of the line $\overleftrightarrow{G_1G_3}$ is $y = \frac{w}{3}$ and G_2 does not lie on the line $\overleftrightarrow{G_1G_3}$. Therefore G_1, G_2 and G_3 are non-collinear and in form a triangle. The centre can be defined as $I_{\tilde{A}}(\bar{x}_0, \bar{y}_0)$ of the triangle with vertices G_1, G_2 and G_3 of the generalized trapezoidal fuzzy number set as $\tilde{A} = (a,b,c,d;w)$

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

.....(5)

Where

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

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

As a particular case, for triangular fuzzy number $\tilde{A} = (a,b,c,d;w)$ i.e. c = b the in centre of centroid is shown by

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

..... (6)

Where

$$x = \frac{\sqrt{(2d-2b)^2 + w^2}}{6}, y = \frac{\sqrt{(d-a)^2 + w^2}}{3},$$

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

The preference function of the generalized trapezoidal

fuzzy number $\tilde{A} = (a,b,c,d;w)$, which measures the set of all fuzzy numbers to a set of actual numbers

$$R(\tilde{A}) = (\bar{x}_0 \times \bar{y}_0) = \left(\frac{x\left(\frac{a+2b}{3}\right) + yb + z\left(\frac{2b+d}{3}\right)}{x+y+z}, \frac{x\left(\frac{w}{3}\right) + y\left(\frac{w}{2}\right) + z\left(\frac{w}{3}\right)}{x+y+z} \right)$$

……………………………………………… (7)

V. PROPOSED LEAN-RESILIENT (L-R) SUPPLY CHAIN EVALUATION MODEL: EMPIRICAL CASE RESEARCH

The practical steps for measuring the performance of a crank and shaft manufacturing firm under Lean-Resilient (L-R) supply chain actions are presented.

Step 1: Construction of a cluster of expert's panel for assessing the overall Lean-Resilient (L-R) performances of supply chain management of crank and shaft manufacturing firm.

Step 2: Evaluation of suitable linguistic scale in terms of appropriateness ratings and importance weight against evaluation criterion.

Step 3: Evaluation of performance ratings as well as weights against criterion associated with module up to 2nd level hierarchy and weight of 1st level hierarchy.

Step4: Transform the linguistic variables into generalized trapezoidal fuzzy number set (GTFNs) and then aggregated the assigned linguistic terms (as rating and weights) converts into single responses.

Step 5: Applied fuzzy performance index model to calculate the ratings of 1st level criterion.

Step 6: Recognition of ill-performing drivers, which require future improvement.

VI. AN EMPIRICAL CASE RESEARCH OF CRANK AND SHAFT MANUFACTURING FIRM

In the conducted research work, research of crank and shaft manufacturing firm is carried out, where Lean-Resilient (L-R) supply chain based appraisement module is constructed in purpose to measure the performance of an crank and shaft manufacturing firm. In the presented work, a decision support system (consist of multi criterion hierarchical module coupled with fuzzy performance index model) is proposed to calculate the performance of said firm under lean-resilient supply chain management strategies. In proposed module, Lean (L) and Resilient (R) has considered as strategy, while Technology leanness, (C_1), Work force leanness, (C_2), Manufacturing management, (C_3), Collaborative planning, (C_4), Resiliency, (C_5) have counted as 1st level drivers. Apart from that, Systematic process control, ($C_{1,1}$), Use of TQM tools, ($C_{1,2}$), Maintenance of machines, ($C_{1,3}$), Reduction of non-value adding cost via techniques, ($C_{1,4}$), Identification and prioritization of critical machines, ($C_{1,5}$), Products designed for easy manufacturing, ($C_{1,6}$), Flexible workforce for adaptation of new technologies, ($C_{2,1}$), Multi-skilled personnel, ($C_{2,2}$), Strong employee spirit and cooperation, ($C_{2,3}$), Employee empowerment, ($C_{2,4}$), Improvement culture, ($C_{3,1}$), JIT delivery to customers, ($C_{3,2}$), Optimization of processing sequence and flow in shop floor, ($C_{3,3}$), Overall Manufacturing waste reduction, ($C_{3,4}$), Material planning, ($C_{4,1}$), Production planning, ($C_{4,2}$), Supplier planning, ($C_{4,3}$), Distributor inventory planning, ($C_{4,4}$), Effective handling of question and answer, ($C_{5,1}$), Information discovery, ($C_{5,2}$), Decision-coordination, ($C_{5,3}$), Business intelligence, ($C_{5,4}$) have considered as core drivers.

The multi level hierarchical appraisement module, shown in Table 1. An appropriate linguistic scale is elected, shown in Table 2, which facilitated the experts to state their oral opinions in the terms of priority weight (significances) and appropriateness ratings against evaluation criterion. For computing importance and ratings of criterion, available at different hierarchical levels, a committee of six expert's panel, DM_1, DM_2, DM_3 DM_4, DM_5 and DM_6 is formed to express priority weight (significances) and appropriateness ratings in terms of linguistic variables against 2nd level indices, shown in Tables 3-4 for crank and shaft manufacturing firm.

Similarly, Expert's panel (E) expressed their importance in linguistic terms against 1st level criterion for alternative, shown in Tables 5. Table. 6 depicted importance against individual 1st level criterion. Considering a Lean-Resilient (L-R) supply chain activities 2nd level appraisement hierarchical module, included criterion at 1st and 2nd level. Equation 8 is used to calculate rating for first level, shown in Table. 6

The FPII is calculated by Equation 1. Then equation 7 is used to identify strong and ill measures.

VII. FPI (FUZZY PERFORMANCE INDEX)

$$U_i = \frac{\sum_{j=1}^{n} \left(w_{ij} \otimes U_{ij} \right)}{\sum_{j=1}^{n} w_{ij}}$$

…………………………………………………………..(8)

Fuzzy Performance Importance Index (FPII) has been calculated against 1st level drivers. After estimating the FPII values, the crisp scores with respect to FPII of sole 1st level drivers has been computed by exploring the concept of in centre of centroid method Equ. 7, ranking order has been shown in Table 7, where high crisp value doesn't require improvement.

Table: 1 L-R SC performance appraisement module

Goal		1st level driver	2nd level indices /metrics	Sources
Fuzzy-Performance measurement of a firm under L-R supply chain, (C)	Lean (L) strategy,C1	Technology leanness, (C_1)	Systematic process control, ($C_{1,1}$)	Matawale, 2016
			Use of TQM tools, ($C_{1,2}$)	Matawale, 2016
			Maintenance of machines, ($C_{1,3}$)	Matawale, 2016
			Reduction of non-value adding cost via techniques, ($C_{1,4}$)	Matawale, 2016
			Identification and prioritization of critical machines, ($C_{1,5}$)	Matawale, 2016
			Products designed for easy manufacturing, ($C_{1,6}$)	Matawale, 2016
		Work force leanness, (C_2)	Flexible workforce for adaptation of new technologies, ($C_{2,1}$)	Sahu et al., 2015a,b
			Multi-skilled personnel, ($C_{2,2}$)	Srivastava, 2007
			Strong employee spirit and cooperation, ($C_{2,3}$)	Srivastava, 2007
			Employee empowerment, ($C_{2,4}$)	Green et al., 1998
		Manufacturing management, (C_3)	Improvement culture, ($C_{3,1}$)	Sahu et al., 2016a,b
			JIT delivery to customers, ($C_{3,2}$)	Sahu et al., 2016a,b
			Optimization of processing sequence and flow in shop floor, ($C_{3,3}$)	Sahu et al., 2017a,c,d
			Overall Manufacturing waste reduction, ($C_{3,4}$)	Sahu et al., 2017a,c,d,f,g
	Resilient (R) staregy,C_2	Collaborative planning, (C_4)	Material planning, ($C_{4,1}$)	Sahu et al., 2017a,c,d,f,g
			Production planning, ($C_{4,2}$)	Green et al., 1998
			Supplier planning, ($C_{4,3}$)	Sahu et al., 2017a,b,c,d,e,f,g
			Distributor inventory planning, ($C_{4,4}$)	Sahu et al., 2017a,b,c,d,e,f,g
		Resiliency, (C_5)	Effective handling of question and answer, ($C_{5,1}$)	Sahu et al., 2017a
			Information discovery, ($C_{5,2}$)	Sahu et al., 2017c
			Decision-coordination, ($C_{5,3}$)	Kainumaa and Tawara 2006
			Business intelligence, ($C_{5,4}$)	Kainumaa and Tawara 2006

Table 2: Nine-member linguistic terms and their corresponding fuzzy representations

Linguistic terms for weights	Linguistic terms for performance ratings	Fuzzy representation
DL: Definitely low	DL: Definitely low	(0.0, 0.0, 0.0, 0.0; 1.0)
VL: Very low	VL: Very low	(0.0, 0.0, 0.02, 0.07; 1.0)
L: Low	L: Low	(0.04, 0.10, 0.18, 0.23; 1.0)
ML: More or less low	ML: More or less low	(0.17, 0.22, 0.36, 0.42; 1.0)
M: Middle	M: Middle	(0.32, 0.41, 0.58, 0.65; 1.0)
MH: More or less high	MH: More or less high	(0.58, 0.63, 0.80, 0.86; 1.0)
H: High	H: High	(0.72, 0.78, 0.92, 0.97; 1.0)

VH: Very high	VH: Very high	(0.93, 0.98, 1.0, 1.0; 1.0)
DH: Definitely high	DH: Definitely high	(1.0, 1.0, 1.0, 1.0; 1.0)

Table 3: Weights of 2nd level indices assigned by DMs

2nd level indices	Weights of 2nd level indices assigned by DMs					
	DM1	DM2	DM3	DM4	DM5	DM6
C_{11}	H	H	VH	H	H	VH
C_{12}	MH	H	H	MH	H	H
C_{13}	H	MH	MH	H	MH	MH
C_{14}	MH	MH	MH	MH	MH	MH
C_{15}	MH	MH	MH	MH	MH	MH
C_{16}	MH	MH	MH	MH	MH	MH
C_{21}	VH	VH	DH	VH	VH	DH
C_{22}	H	VH	DH	H	VH	DH
C_{23}	VH	H	VH	VH	H	VH
C_{24}	DH	H	H	DH	H	H
C_{31}	MH	H	MH	MH	H	MH
C_{32}	H	MH	H	H	MH	H
C_{33}	MH	M	MH	MH	M	MH
C_{34}	MH	M	H	MH	M	H
C_{41}	H	MH	ML	H	MH	ML
C_{42}	MH	M	M	MH	M	M
C_{43}	M	MH	ML	M	MH	ML
C_{44}	MH	MH	L	MH	MH	L
C_{51}	L	ML	L	L	ML	L
C_{52}	VL	ML	ML	VL	ML	ML
C_{53}	ML	L	ML	ML	L	ML
C_{54}	DL	L	L	DL	L	L

Table 4: Rating of 2nd level indices assigned by DMs

2nd level indices	Rating of 2nd level indices assigned by DMs					
	DM1	DM2	DM3	DM4	DM5	DM6
C_{11}	VH	H	MH	VH	H	MH
C_{12}	H	M	MH	H	M	MH
C_{13}	M	H	VH	M	H	VH
C_{14}	VH	VH	VH	VH	VH	VH
C_{15}	VH	VH	VH	VH	VH	VH
C_{16}	VH	VH	VH	VH	VH	VH
C_{21}	H	VH	VH	H	VH	VH
C_{22}	VH	VH	H	VH	VH	H
C_{23}	H	M	NH	H	M	NH
C_{24}	H	M	MH	H	M	MH
C_{31}	VH	H	DH	VH	H	DH
C_{32}	VH	H	DH	VH	H	DH
C_{33}	H	VH	VH	H	VH	VH
C_{34}	DH	VH	VH	DH	VH	VH
C_{41}	VH	VH	H	VH	VH	H
C_{42}	H	H	DH	H	H	DH
C_{43}	VH	M	H	VH	M	H
C_{44}	DH	M	VH	DH	M	VH
C_{51}	H	MH	H	H	MH	H
C_{52}	VH	MH	H	VH	MH	H
C_{53}	MH	H	VH	MH	H	VH

C_{54}	MH	H	DH	MH	H	DH

Table 5: Weights of 1st level drivers assigned by DMs

1st level indices	Weights of 1st level indices assigned by DMs					
	DM1	DM2	DM3	DM4	DM5	DM6
C_1	VH	DH	H	VH	DH	H
C_2	H	H	H	H	H	H
C_3	DH	VH	DH	DH	VH	DH
C_4	MH	H	MH	MH	H	MH
C_5	MH	M	MH	MH	M	MH

Table 6: Aggregated fuzzy importance weights and calculated fuzzy ratings of 1st level drivers

1st level indices	Aggregated fuzzy importance grade, w_i	Computed fuzzy rating, U_i
C_1	[0.638, 0.691, 0.8323, 0.898;1]	[0.518, 0.642, 1.050, 1.250;1]
C_2	[0.720, 0.780, 0.920, 0.970;1]	[0.627, 0.808, 0.923, 1.025;1]
C_3	[0.976, 0.993, 1.000, 1.000;1]	[0.605, 0.748, 1.223, 1.466;1]
C_4	[0.626, 0.680, 0.840, 0.896;1]	[0.467, 0.624, 1.203, 1.554;1]
C_5	[0.493, 0.556, 0.726, 0.790;1]	[0.229, 0.458, 1.531, 2.986;1]

Table 7: Preference orders of 1st level measures

2nd level indices	FPII	Crisp Value $R(\tilde{A})$	Ranking Order
C_1	[0.0610, 0.0515, 0.0284, 0.0135; 1]	0.0130	4.00
C_2	[0.1788, 0.1785, 0.0742, 0.0318; 1]	0.0430	3.00
C_3	[0.0149, 0.0058, 0.0000, 0.0000; 1]	0.0010	5.00
C_4	[0.1708, 0.2008, 0.1939, 0.1622; 1]	0.0630	2.00
C_5	[0.1154, 0.2035, 0.4204,0. 6279; 1]	0.1200	1.00

VIII. RESULTS

Fuzzy performance importance index with 'In centre of Centroid Method' is applied to identify the ill and strong drivers. A conduit to recognize the ill driven is exhibited. It is found that manufacturing management (C_3) must be improved preliminary than all.

IX. CONCLUSIONS

In case of poor performance, the drivers /measures i.e. Lean-Resilient (L-R) performance can be hiked by applying fuzzy performance importance index with 'In centre of Centroid Method' to identify the ill and strong drivers. The drivers raking, Manufacturing Management (C_3) must be improved preliminary than all. Fig: 2 showed the bar chart, displayed ranking order of drivers.

The presented work aids the novel / forthcoming perusals and researchers to solve their own personal and Professional problems under linguistic information. The proposed chapter has aptitude to overcome the problems in relation to appraise the overall performance of many firm simultaneously under considered module.

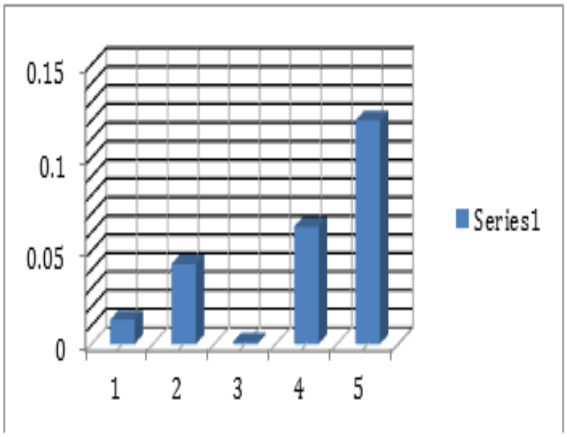

Fig: 2. Bar chart, displayed ranking order of drivers

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