PERFORMANCE APPRAISEMENT OF A BRICK INDUSTRY UNDER SUPPLY CHAIN METRICS: VAGUE BASED MODELING

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Abstract
In last decade, Brick Industry has begun to establish the production with rapid rate in compensating the high demand of bricks with rich-quality of service level. In order to respond these, many brick firm perceived the necessity to balance the production chain. In the presented research work, a 2nd second level hierarchical supply chain module structure has been constructed for measuring performance of a brick industry, where Fuzzy Performance Index model has been applied to assess the overall performance of brick industry firm.
Key Words: Benchmarking, Supply Chain, Performance Measurement (PM), Fuzzy Performance Index (FPI), Brick Industry

1. Introduction

Supply Chain Management (SCM) is described as the procedure of planning and executing, and at the same time managing the supply chain by the mainly efficient potential way. Supply chain management involves controlling of finished products from the source of origin the consumption level. The conventional supply chain concerned with two or more firms, which were enabled the connection among the consumers and the vendors. In this conventional technique, therefore the finished products are delivered to the purchasers through a chain of warehouses. SC is a system of business that are involved, through upstream and downstream connection, in the dissimilar procedure and actions, which create worth in the term of goods and services in the hands of the final purchasers. 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. Performance measurement is counted as vital constituent of effective forecast and controlling as well as decision making. It provides essential criticisms or information to expose growth, augment in enthusiasm and identify problems. 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. Supply chain management networking is shown in Fig.1.

Fig.1. Supply chain management networking

2. Fuzzy set theory

Prof. Zadeh 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 (Sahu et al., 2015a, b, Sahu et al., 2016c, Sahu et al., 2017b).

Fuzzy logic deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets. Fuzzy logic variables may have a truth value that ranges in degree between 0 and 1.

3. Research Objectives

It is observed that, many philosophies were introduced in loop of supply chain management in order to solve various problems of industrial sectors i.e. assessment of resiliency of supplier against disasters, waste management equipments availability in evaluated manufacturing firms, green performance, responses of firms towards their clients etc. Amongst proposed SC strategies. The decision support tool, can measure performances of a brick industry under fuzzy data has been proposed so less.

It is realized to propose a 2nd second level hierarchical supply chain module structure with Fuzzy Performance Index model to assess the overall performance of brick industry firm.

4. FPI modeling

Considering an L-A, 2nd level appraisement hierarchical module, included criterion at 1st and 2nd level followed below said notations to compute the performances of brick manufacturing/supplier firm.

C_i = i^{th} 1st level assessment index; $i = 1,2,\ldots,m$.

C_{ij} = j^{th} 2nd level assessment index which is under i^{th} 1st level assessment index C_i; $j = 1,2,\ldots,n$.

The calculated fuzzy rating of individual 1st level assessment criterion-attribute can be computed as, (Lin et al., 2006, Sahu et al., 2014).

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

Here U_{ij} represents aggregated fuzzy performance (rating) of core derivers and w_{ij} represent aggregated fuzzy importance grade with respect to attributes C_{ij} at 2nd level. Also, U_i represents the calculated fuzzy performance (rating) of core derivers with respect to the index C_i at 1st level.

Also the single numerical value of the fuzzy number $\tilde{A} = (a_1, a_2, a_3, a_4)$ based on Center of Area (COA) technique can be articulated by following relation:

$$defuzz(\bar{A}) = \frac{\int x \cdot \mu(x)dx}{\int \mu(x)dx} \quad \ldots\ldots(2)$$

$$= \frac{\int_{a_1}^{a_2}\left(x - a_1 \big/ a_2 - a_1\right)\cdot x dx + \int_{a_2}^{a_3} x dx + \int_{a_3}^{a_4}\left(a_4 - x \big/ a_4 - a_3\right)\cdot x dx}{\int_{a_1}^{a_2}\left(x - a_1 \big/ a_2 - a_1\right) dx + \int_{a_2}^{a_3} dx + \int_{a_3}^{a_4}\left(a_4 - x \big/ a_4 - a_3\right) dx}$$

$$= \frac{-a_1a_2 + a_3a_4 + \frac{1}{3}(a_4 - a_3)^2 - \frac{1}{3}(a_2 - a_1)^2}{-a_1 - a_2 + a_3 + a_4}.$$

5. Empirical Case research

A case research of brick manufacturing/supplier firm is carried out, where supply chain based appraisement module is constructed in purpose to measure the performance of brick manufacturing/supplier. 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 brick manufacturing/supplier under supply chain management strategies. In proposed module, Lean (L) and Agile (A) has considered as

strategy, while Technology leanness, (C_1), Employee leanness, (C_2), Production management, (C_3), Marketing Capability, (C_4), Human resource management, (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, ($C_{3,4}$), Customer demanded changes, ($C_{4,1}$),Experience with customers, ($C_{4,2}$),Working Culture for its partners, ($C_{4,3}$),Firm representative's attitude, ($C_{4,4}$),Learning ability, ($C_{5,1}$),Market expertise, ($C_{5,2}$),Organizational leadership, ($C_{5,3}$),Quality of management team, ($C_{5,4}$), have considered as metrics have considered as metrics.

The multi level hierarchical appraisement module, shown in Table 1. An appropriate linguistic scale is elected, 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, is formed to express priority weight (significances) and appropriateness ratings in terms of linguistic variables against 2nd level indices, shown in Tables 2-3 for of brick manufacturing/supplier firm.

Similarly, Expert's panel (E) expressed their importance in linguistic terms against 1st level criterion for alternative, shown in Tables 4. By using trapezoidal fuzzy operators given by (Arbos 2002), (Beamon 1999), the fuzzy importance and ratings against individual 2nd level criterion for alternative is aggregated. Next same trapezoidal fuzzy operators given by (Arbos 2002), (Beamon 1999), is used to compute 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, followed, Equation 1 is used to compute the rating performances of 1st level and Equation 1 for computing overall FPI, which computed as (0.5108179, 0.6319028, 1.0085557; 1.3156745; 1) for brick manufacturing/supplier firm. The crisp score has computed as 0.88 by exploring (Equ. 2)

6. Step for evaluating results

Step 1: Construction of a cluster of expert's panel for assessing the overall Lean-Agile (L-A) performances of supply chain management of brick manufacturing/supplier 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.

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.

Step6: Estimation of overall performance index

Table: 1 SC performance appraisement module for brick industry

Goal		1st level driver	2nd level indices /metrics
Fuzzy-Performance measurement of a firm under le-agile supply chain, (C)	Lean (L) strategy,C1	Technology leanness, (C_1)	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, ($C_{1,6}$)
		Employee leanness, (C_2)	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, ($C_{2,4}$)
		Production management, (C_3)	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, ($C_{3,4}$)
	Resilient (A) staregy,C_2	Marketing Capability, (C_4)	Customer demanded changes, ($C_{4,1}$)
			Experience with customers, ($C_{4,2}$)
			Working Culture for its partners, ($C_{4,3}$)
			Firm representative's attitude, ($C_{4,4}$)
		Human resource management, (C_5)	Learning ability, ($C_{5,1}$)
			Market expertise,, ($C_{5,2}$)
			Organizational leadership, ($C_{5,3}$)
			Quality of management team, ($C_{5,4}$)

Table 2: Weights of 2nd level indices assigned by Ps

2nd level indices	Weights of 2nd level indices assigned by Ps					
	P1	P2	P3	P4	P5	P6
C_{11}	H	VH	VH	H	H	H
C_{12}	H	H	H	MH	MH	H
C_{13}	MH	MH	MH	H	H	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	DH	DH	VH	VH	VH
C_{22}	VH	DH	DH	H	H	VH
C_{23}	H	VH	VH	VH	VH	H
C_{24}	H	H	H	DH	DH	H
C_{31}	H	MH	MH	MH	MH	H
C_{32}	MH	H	H	H	H	MH
C_{33}	M	MH	MH	MH	MH	M
C_{34}	M	H	H	MH	MH	M

C_{41}	MH	ML	ML	H	H	MH
C_{42}	M	M	M	MH	MH	M
C_{43}	MH	ML	ML	M	M	MH
C_{44}	MH	L	L	MH	MH	MH
C_{51}	ML	L	L	L	L	ML
C_{52}	ML	ML	ML	VL	VL	ML
C_{53}	L	ML	ML	ML	ML	L
C_{54}	L	L	L	DL	DL	L

Table 3: Rating of 2nd level indices assigned by Ps

2nd level indices	Rating of 2nd level indices assigned by Ps					
	P1	P2	P3	P4	P5	P6
C_{11}	H	MH	MH	VH	VH	H
C_{12}	M	MH	MH	H	H	M
C_{13}	H	VH	VH	M	M	H
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}	VH	VH	VH	H	H	VH
C_{22}	VH	H	H	VH	VH	VH
C_{23}	M	NH	NH	H	H	M
C_{24}	M	MH	MH	H	H	M
C_{31}	H	DH	DH	VH	VH	H
C_{32}	H	DH	DH	VH	VH	H
C_{33}	VH	VH	VH	H	H	VH
C_{34}	VH	VH	VH	DH	DH	VH
C_{41}	VH	H	H	VH	VH	VH
C_{42}	H	DH	DH	H	H	H
C_{43}	M	H	H	VH	VH	M
C_{44}	M	VH	VH	DH	DH	M
C_{51}	MH	H	H	H	H	MH
C_{52}	MH	H	H	VH	VH	MH
C_{53}	H	VH	VH	MH	MH	H
C_{54}	H	DH	DH	MH	MH	H

Table 4: Weights of 1st level drivers assigned by Ps

1st level indices	Weights of 1st level indices assigned by Ps					
	P1	P2	P3	P4	P5	P6
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

7. Results

The result has shown that evaluated fuzzy performance is (0.5108179, 0.6319028, 1.0085557; 1.3156745; 1) in term of fuzzy scale and 0.88 in crisp value, can be compared with the actual/standard performance of firm. Performance can be escalated by enchaining the performance of measures.

8. Conclusions

In the presented work, the constructed multi criterion decision making performance appraisement module (constituted by mixing the segregated the Lean-Agile (L-A) SC strategy and their corresponding five (5) core drivers and twenty two (22) interrelated metrics) conjunctive with Fuzzy Performance Index model called DSS (Decision Support System) has been practical implemented on brick manufacturing/supplier firm to estimation the overall performance of a organization. The evaluated fuzzy performance is (0.5108179, 0.6319028, 1.0085557; 1.3156745; 1) in term of fuzzy scale and 0.88 in crisp value, which can be compared with the actual performance of firm. Performance can be hiked by enchaining the performance of criterion.

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