International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 6, Number 4 (2013), pp. 541-556

http://www.irphouse.com

Decision-Making Scenario towards Supply Chain Performance Assessment in Fuzzy Context

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Abstract

Supply chain management (SCM) has been viewed as one of the most powerful tool for enhancing organizational competitiveness both in manufacturing as well as services. SCM often encounters a variety of decision-making situations. The process becomes complicated due subjectivity of qualitative evaluation criterions/attributes. For proper understanding and controlling on key performance elements in a SCM and for successful implementation of SCM in an entire organizational context, supply chain performance extent need to be assessed. Supply chain performance appraisement is basically a multi-criteria decision-making (MCDM) process subjected to numerous evaluation indices, both qualitative as well as quantitative. Difficulty is faced in dealing with qualitative performance indices. This requires expert opinion to be obtained by an experienced decision-making group. In the real word, decision-making problems are very vague and uncertain in a number of ways. Expert data are often incomplete, imprecise as well as inconsistent. Most of the criteria being interdependent and having interactive features; data cannot be evaluated by conventional methods. Therefore, it requires exploration of the fuzzy multi-criteria decision making (FMCDM) tools and techniques. Fuzzy logic has the capability of efficiently dealing with vague human judgment; thereby, facilitating the said decision-making process. To this end, this paper describes development of a fuzzy decision support system (DSS) towards performance evaluation of an organizational supply chain. The research has been extended to identify ill-performing areas of the entire organizational supply chain, which require future improvement.

Keywords: Supply Chain Management; multi-criteria decision making; Decision Support System (DSS).

1. Introduction

Supply chains comprise all activities associated with the flow and transformation of goods from the raw material stage through to the end user (Handfield and Nichols, 1999). A range of benefits has been attributed to supply chain management, including reduced costs, increased market share and sales, and solid customer relations (Ferguson, 2000).

Market globalization, intensifying competition and an increasing emphasis on customer orientation are regularly cited as catalyzing the surge in interest in supply chain management (e.g. Gunasekaran et al., 2001; Webster, 2002). Against this backdrop, effective supply chain management is treated as key to building a sustainable competitive edge through improved inter and intra-firm relationships (Ellinger, 2000). In order to analyze the efficiency and benefits of SC scientifically and objectively, the performance evaluation system and method of SC should be established accordingly (Ma, 2005).

Beamon (1999) provided an overview and evaluation of the performance measures used in supply chain models. The author presented a framework for the selection of performance measurement systems for manufacturing supply chains. The author also proposed a new flexibility measures for supply chains. Gunasekaran et al. (2004) developed a framework to promote a better understanding of the importance of SCM performance measurement and metrics. Hervani et al. (2005) provided an integrative framework for study, design and evaluation of green supply chain management performance tools.

Shepherd and Günter (2006) provided taxonomy of performance measures followed by a critical evaluation of measurement systems designed to evaluate the performance of supply chains. Bhagwat and Sharma (2007) developed a balanced scorecard for supply chain management (SCM) that measured and evaluated day-to-day business operations from following four perspectives: finance, customer, internal business process, and learning and growth. Varma et al. (2008) used a combination of analytical hierarchy process (AHP) and balanced scorecard (BSC) for evaluating performance of the petroleum supply chain. Yang (2009) analyzed the efficiency and benefits of supply chain (SC) scientifically and validated the usability of methods on performance evaluation index system.

Cai et al. (2009) proposed a framework towards improving the iterative key performance indicators (KPIs) accomplishment in a supply chain context. The proposed framework quantitatively analyzed the interdependent relationships among a set of KPIs. It could identify crucial KPI accomplishment costs and proposed performance improvement strategies for decision-makers in a supply chain. Trkman, et al. (2010) investigated the relationship between analytical capabilities in the plan, source, make and deliver area of the supply chain and its performance using information system support and business process orientation as moderators.

Chen and Yan (2011) constructed an alternative network DEA model that embodied the internal structure for supply chain performance evaluation. Ip et al. (2011) proposed an integrated approach towards modeling and measuring supply chain performance and stability using system dynamics (SD) and the autoregressive integrated moving average (ARIMA). Effectiveness and efficiency, with six corresponding indicators (product reliability, employee fulfillment, customer fulfillment, on-time delivery, profit growth, and working efficiency), were found to be the most significant factors in the performance of the supply chain.

Cho et al. (2012) developed a framework of service supply chain performance measurement. Based on the strategic, tactical and operational level performance in a service supply chain, measures and metrics were discussed in this reporting. The emphasis was on performance measures dealing with service supply chain processes such as demand management, customer relationship management, supplier relationship management, capacity and resource management, service performance, information and technology management and service supply chain finance.

Elgazzar et al. (2012) developed a performance measurement method which links supply chain (SC) processes' performance to a company's financial strategy through demonstrating and utilizing the relationship between SC processes' performance and a company's financial performance. Olugu and Wong (2012) developed an expert fuzzy rule-based system for closed-loop supply chain performance assessment in the automotive industry. Uysal (2012) applied the Decision Making Trial and Evaluation Laboratory (DEMATEL) Method to deal with the importance and causal relationships between the sustainable performances measurements criteria by considering the interrelationships among them.

Vaidya and Hudnurkar (2013) proposed an approach to evaluate the performance of supply chain using multiple criteria. A multi-criteria decision making tool (like analytic hierarchy process) was developed for performance evaluation. The said methodology was also elucidated with an illustration and a case from Indian chemical company. Supply chain performance number was computed, indicating the present performance status of the supply chain. The methodology also helped rank the various links according to its performance. The analysis proposed on computation of supply chain performance number (SCPN).

According to (Gunasekaran et al., 2004), the literature on SCM focus strategies and technologies for effectively managing a supply chain is quite vast. In recent years, organizational performance measurement and metrics have received much attention from researchers and practitioners. The role of these measures and metrics in the success of an organization cannot be overstated because they affect strategic, tactical and operational planning and control. Performance measurement and metrics have an important role to play in setting objectives, evaluating performance, and determining future courses of actions. Performance measurement and metrics pertaining to SCM have not received adequate attention from researchers or practitioners.

Issues related to performance assessment and related aspects have been attempted by pioneer researchers to a remarkable extent. Different SC performance evaluation index systems have been documented in literature. It has been found that in most of the cases, SC performance evaluation criteria/attribute hierarchy consists of a variety of subjective evaluation indices. Subjective attributes are difficult to analyze due to the incompleteness as well as inconsistency in the evaluation information. Expert opinions are often expressed in linguistic variables which are basically vague in nature. Unless and until linguistic data are transformed into a mathematic base, it is difficult to analyze. Conceptually, SC performance indicates existence of an evaluation index to be represented by a number. Such evaluation or appraisement index can be treated as an indicator to reflect existing SC performance extent; basis for comparing performance of different organizations (running under similar SC architecture i.e. benchmarking).

In order to explore the extent of research in supply chain performance measurement and establish the gap in knowledge in supply chain performance measurement using fuzzy logic; the present work aims to develop an efficient DSS to facilitate supply chain performance appraisement in an organizational context. Empirical data has been analyzed for better understanding on the methodology of analysis towards estimating SC performance index.

2. Procedural Hierarchy for SC Performance Appraisement

A fuzzy based performance appraisement module proposed in this paper has been present below. It utilizes the concept of Generalized Triangular Fuzzy Numbers (GTFNs) set. General Hierarchy Criteria (GHC) for evaluating supply chain performance extent generally involves various criterions as well as sub-criterions at different levels. Let us assume that GHC consists of two-level index system; which aims at achieving the target to evaluate overall appraisement index (Table 1). Tables 2.1-2.2 represent seven-member linguistic terms (and their corresponding generalized triangular fuzzy numbers) for analyzing decision-making information (attribute weights as well as appropriateness rating). 1st level consists of eight main criterions (C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8): Customer Service, Purchasing Management, Administration/Financial Management, Process, Cross Functional Measures, Manufacturing Management, Marketing Management, Extended Enterprise Measures, Logistics Performance.

Table 1: Evaluation Index System of Supply Chain Performance.

Goal	1st level indices (Attributes)	2nd level indices (Criterions)
Evaluation Index of	Customer Service, C1	Order Fill Rate, C11
		Line Item Fill Rate, C12

Supply Chain Performance, C		Quantity Fill Rate, C13
		Backorders/Stock outs, C14
		Customer Satisfaction, C15
		%Resolution of first customer call, C16
		Customer Returns, C17
		Order Track and Trace Performance, C18
		Customer Disputes, C19
		Order Entry Accuracy, C1,10
		Order Entry Times, C1,11
	Purchasing Management, C2	Material Inventories, C21
		Supplier Delivery Performance, C22
		Material/Component Quality, C23
		Material Stock Outs, C24
		Unit Purchase Costs, C25
		Material Acquisition Costs, C26
		Expediting Activities, C27
	Administration/Financial Management, C3	Cash Flow, C31
		Revenue, C32
		Return on Capital Employed, C33
		Cash-to-Cash Cycle, C34
		Return on Investment, C35
		Revenue Per Employee, C36
		Invoice Errors, C37
		Return on Assets, C38
	Process, Cross Functional Measures, C4	Forecast Accuracy, C41
		Percent Perfect Orders, C42
		New Product-Time-To-Market, C43
		New Product-Time-To-First-Make, C44
		Planning Process Cycle Time, C45
		Schedule Changes, C46
	Manufacturing Management, C5	Product Quality, C51
		WIP Inventories, C52
		Adherence to Schedule, C53
		Cost Per Unit Produced, C54
		Setups/Changeovers, C55
		Setup/Changeover Costs, C56
		Unplanned Stockroom Issues, C57
		Bill-of-Materials Accuracy, C58
		Routing Accuracy, C59
		Plant Space Utilization, C5,10
		Line Breakdowns, C5,11
		Warranty Costs, C5,12

		Source-to-make-Cycle Time, C5,13
		Percent Scrap/Rework, C5,14
		Material Usage Variance, C5,15
		Overtime Usage, C5,16
		Production Cycle Time, C5,17
		Manufacturing Productivity, C5,18
		Master Schedule Stability, C5,19
	Marketing Management, C6	Market Share, C61
		Percent of Sales from New Products, C62
		Time-To-Market, C63
		Repeat versus New Customer Sales, C64
	Extended Enterprise Measures, C7	Total Landed Cost, C71
		Point of Consumption Product Availability, C72
		Total Supply Chain Inventory, C73
		Retail Shelf Display, C74
		Channel Inventories, C75
		EDI Transactions, C76
		Percent of Demand/Supply on VMI/CRP, C77
		Percent of Customers Sharing Forecasts, C78
		Percent of Suppliers Getting Shared Forecast, C79
		Supplier Inventories, C7,10
		Internet Activity to Suppliers/Customers, C7,11
		Percent Automated Tendering, C7,12
	Logistics Performance, C8	Finished Goods Inventory Turns, C81
		Finished Goods Inventory Days of Supply, C82
		On-Time Delivery, C83
		Lines Picked/Hour, C84
		Damaged Shipments, C85
		Inventory Accuracy, C86
		Pick Accuracy, C87
		Logistics Cost, C88
		Shipment Accuracy, C89
		On-Time Shipment, C8,10
		Delivery Times, C8,11
		Warehouse Space Utilization, C8,12
		End-of-Life Inventory, C8,13

		Obsolete Inventory, C8,14
		Inventory Shrinkage, C8,15
		Cost of Carrying/Holding Inventory, C8,16
		Documentation Accuracy, C8,17
		Transportation Cost, C8,18
		Warehousing Costs, C8,19
		Container Utilization, C8,20
		Truck Cube Utilization, C8,21
		In-Transit Inventories, C8,22
		Premium Freight Charges, C8,23
		Warehouse Receipts, C8,24

The 2nd level encompasses different sub-criterions under each of the 1st level main criterion. Performance evaluation is to be started at the 2nd level and then extended to the 1st level; and finally the overall performance extent is to be computed. In order to tackle ambiguity and vagueness arising from subjective decision-making information; linguistic data has been converted into fuzzy numbers to provide a strong mathematic basis of the performance evaluation forum thus facilitating clear understanding of the performing supply chain scenario towards effective decision-making. The procedural steps of performance appraisement have been listed below.

1. Form a committee of decision-makers for evaluating and appraising supply chain performance.
2. Choose appropriate linguistic variable towards expressing subjective preference of the decision-makers' against importance weight as well as ratings of individual evaluation indices.
3. Representing decision-makers' linguistic judgments using appropriate fuzzy numbers set. Convert linguistic weights and ratings into appropriate fuzzy numbers for the analysis purpose.
4. Use of fuzzy operational rules towards estimating aggregated fuzzy weight as well as aggregated fuzzy rating (pulled opinion of the decision-makers) for each of the evaluation criterion.
5. Calculation of computed performance rating of 1st level attributes and finally SC overall performance index called Fuzzy Performance Index (FPI).

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

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

In this expression (Eq. 1) U_{ij} is denoted as the aggregated fuzzy appropriateness rating against j_{th} evaluation index (at 2nd level) which is under i_{th} main criterion in the 1st level. w_{ij} is the aggregated fuzzy weight against j_{th} attribute (at 2nd level) which is under i_{th} main criterion in 1st level. Also m is the total number of criterions which are under i_{th} 1st level attributes.

The Fuzzy Performance Index (FPI) has been computed as:

$$U(FPI) = \frac{\sum_{i=1}^{n} U_i \otimes w_i}{\sum_{i=1}^{n} w_i} \tag{2}$$

In this expression (Eq. 2) U_i is denoted as the computed fuzzy appropriateness rating (obtained using Eq. 2) against i_{th} evaluation index at 1st level. w_i is the aggregated fuzzy priority weight against i_{th} evaluation index in 1st level. n is the total number of SC attributes in 1st level.

1. Investigation for identifying ill-performing areas those seek for future improvement. Calculate Fuzzy Performance Importance Index (FPII) of the 2nd level evaluation indices for indentifying ill-performing areas of the SC.

After evaluating FPI, simultaneously it is felt indeed necessary to identify and analyze weak (ill-performing) areas in which organizational SC may require future improvement. Fuzzy Performance Importance Index *(FPII)* may be used to identify these ill-performing areas. FPII combines the performance rating and importance weight of various 2nd level indices. The higher the FPII of a factor, the higher is the contribution. The concept of FPII was introduced by (Lin et al., 2006) for agility extent measurement in supply chain.

$$FPII_{ij} = w'_{ij} \otimes U_{ij} \tag{3}$$

$$\text{Here, } w'_{ij} = \left[\left[(1,1,1;1),(1,1,1;1)\right] - w_{ij}\right] \tag{4}$$

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

2. Calculate performance ranking order (of individual 2nd level evaluation indices) based on crisp value. The concept of ranking method introduced by (Thorani et al., 2012) has been adapted here to rank FPIIs of individual 2nd level evaluation indices.

3. Empirical Research

The two-level criteria hierarchy for supply chain performance evaluation adopted in this study has been furnished in Table 1. Table 2.1-2.2 represents seven-member linguistic terms (and their corresponding generalized triangular fuzzy numbers) for analyzing decision-making information. In order to provide priority weight against various attributes (1st level) as well as criteria (2nd level); the decision-making group has been instructed to use the following linguistic terms: **Very Low (VL)**, **Low (L)**, **Medium Low (ML)**, **Medium (M)**, **Medium High (H), High (H)**, and **Very High (VH)**. The following linguistic scale has been utilized to assign performance appropriateness rating against 2nd level criterions: **Very Poor (VP)**, **Poor (P)**, **Medium Poor (MP)**, **Medium (M)**, **Medium Good (MG)**, **Good (G)** and **Very Good (VG)**. Assuming a decision-making group consists of five decision-makers (DMs): DM1, DM2, DM3, DM4, and DM5. Assume that appropriateness rating (in linguistic scale) of 2nd level criterions has been assigned by DMs. Priority weights (in linguistic scale) of 2nd level indices and 1st level indices assigned by DMs have also been given. Linguistic decision-making information has been transformed into triangular fuzzy numbers. Aggregated fuzzy appropriateness rating and aggregated fuzzy priority weight of 2nd level criterions have been computed. Computed fuzzy appropriateness rating and aggregated fuzzy priority weight of 1st level indices have been computed next.

Table 2.1: The scale of attribute weights.

Scale	$\otimes w$
Very Low (VL)	(0, 0.05, 0.15)
Low (L)	(0.1, 0.2, 0.3)
Medium Low (ML)	(0.2, 0.35, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium High (MH)	(0.5, 0.65, 0.8)
High (H)	(0.7, 0.8, 0.9)
Very High (VH)	(0.85, 0.95, 1.0)

Table 2.2: The scale of attribute ratings.

Scale	$\otimes R$
Very Poor (VP)	(0, 0.05, 0.15)
Poor (P)	(0.1, 0.2, 0.3)
Medium Poor (MP)	(0.2, 0.35, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium Good (MG)	(0.5, 0.65, 0.8)
Good (G)	(0.7, 0.8, 0.9)
Very Good (VG)	(0.85, 0.95, 1.0)

Overall SC performance extent (Fuzzy Performance Index) thus becomes: **(0.32, 0.66, 1.20)**

After evaluating FPI, the next step is to rank different 2nd level indices in accordance with their FPII (Eq. 3). Thus, ill-performing areas can easily be sorted out and future improvement opportunities can be identified. Computed values of FPII (with corresponding crisp score) against individual 2nd level criterions have been shown in Table 3. Ranking order (based on crisp score) facilitates in realizing ill-performing areas of the said supply chain.

Table 3: Ranking order of 2nd level indices.

2nd level indices	FPII	Crisp Value	Ranking Order
C11	(0.049, 0.054, 0.037)	0.017	78
C12	(0.102, 0.115, 0.115)	0.036	43
C13	(0.162, 0.136, 0.082)	0.044	31
C14	(0.158, 0.108, 0.053)	0.036	44
C15	(0.096, 0.078, 0.043)	0.025	66
C16	(0.178, 0.131, 0.070)	0.043	32
C17	(0.238, 0.184, 0.108)	0.060	9
C18	(0.160, 0.095, 0.038)	0.032	51
C19	(0.168, 0.112, 0.054)	0.037	40
C1,10	(0.054, 0.067, 0.050)	0.021	71
C1,11	(0.090, 0.100, 0.070)	0.031	55
C21	(0.139, 0.099, 0.050)	0.033	49
C22	(0.147, 0.088, 0.036)	0.030	59
C23	(0.119, 0.100, 0.059)	0.032	52
C24	(0.224, 0.177, 0.106)	0.058	12
C25	(0.147, 0.088, 0.036)	0.030	60
C26	(0.182, 0.120, 0.056)	0.040	35
C27	(0.054, 0.067, 0.050)	0.021	72
C31	(0.228, 0.172, 0.094)	0.056	14
C32	(0.043, 0.049, 0.034)	0.015	81
C33	(0.063, 0.055, 0.028)	0.017	79
C34	(0.186, 0.148, 0.086)	0.048	23
C35	(0.238, 0.184, 0.108)	0.060	10
C36	(0.101, 0.068, 0.030)	0.022	69
C37	(0.158, 0.108, 0.053)	0.036	45
C38	(0.238, 0.184, 0.108)	0.060	11
C41	(0.228, 0.172, 0.094)	0.056	15
C42	(0.038, 0.044, 0.030)	0.014	83

C43	(0.153, 0.091, 0.037)	0.031	56
C44	(0.189, 0.136, 0.072)	0.045	27
C45	(0.048, 0.060, 0.046)	0.018	76
C46	(0.072, 0.070, 0.042)	0.022	70
C51	(0.139, 0.099, 0.050)	0.033	50
C52	(0.266, 0.208, 0.126)	0.068	2
C53	(0.132, 0.118, 0.074)	0.038	39
C54	(0.178, 0.131, 0.070)	0.043	33
C55	(0.147, 0.088, 0.036)	0.030	61
C56	(0.197, 0.141, 0.074)	0.046	26
C57	(0.048, 0.060, 0.046)	0.018	77
C58	(0.160, 0.095, 0.038)	0.032	53
C59	(0.038, 0.041, 0.025)	0.013	85
C5,10	(0.102, 0.115, 0.084)	0.036	46
C5,11	(0.198, 0.154, 0.088)	0.050	21
C5,12	(0.189, 0.136, 0.072)	0.045	28
C5,13	(0.160, 0.095, 0.038)	0.032	54
C5,14	(0.189, 0.136, 0.072)	0.045	29
C5,15	(0.061, 0.074, 0.055)	0.023	68
C5,16	(0.088, 0.062, 0.028)	0.020	74
C5,17	(0.178, 0.131, 0.070)	0.043	34
C5,18	(0.266, 0.208, 0.126)	0.068	3
C5,19	(0.219, 0.166, 0.092)	0.054	16
C61	(0.034, 0.036, 0.023)	0.011	87
C62	(0.153, 0.091, 0.037)	0.031	57
C63	(0.038, 0.044, 0.030)	0.014	84
C64	(0.102, 0.115, 0.084)	0.036	47
C71	(0.139, 0.085, 0.035)	0.028	64
C72	(0.168, 0.112, 0.054)	0.037	41
C73	(0.248, 0.191, 0.110)	0.063	6
C74	(0.210, 0.160, 0.090)	0.052	17
C75	(0.034, 0.036, 0.023)	0.011	88
C76	(0.130, 0.081, 0.034)	0.027	65
C77	(0.189, 0.136, 0.072)	0.045	30
C78	(0.269, 0.205, 0.115)	0.067	5
C79	(0.147, 0.088, 0.036)	0.030	62
C7,10	(0.038, 0.041, 0.025)	0.013	86
C7,11	(0.160, 0.146, 0.098)	0.047	25
C7,12	(0.198, 0.154, 0.088)	0.050	22
C81	(0.175, 0.116, 0.055)	0.039	36
C82	(0.153, 0.091, 0.037)	0.031	58
C83	(0.049, 0.054, 0.037)	0.017	80

C84	(0.248, 0.191, 0.110)	0.063	7
C85	(0.029, 0.029, 0.015)	0.009	90
C86	(0.067, 0.066, 0.040)	0.021	73
C87	(0.224, 0.177, 0.106)	0.058	13
C88	(0.210, 0.160, 0.090)	0.052	18
C89	(0.205, 0.146, 0.075)	0.048	24
C8,10	(0.147, 0.088, 0.036)	0.030	63
C8,11	(0.043, 0.049, 0.034)	0.015	82
C8,12	(0.126, 0.112, 0.070)	0.036	48
C8,13	(0.156, 0.112, 0.054)	0.037	42
C8,14	(0.175, 0.116, 0.055)	0.039	37
C8,15	(0.289, 0.224, 0.132)	0.073	1
C8,16	(0.054, 0.064, 0.046)	0.020	75
C8,17	(0.175, 0.116, 0.055)	0.039	38
C8,18	(0.034, 0.036, 0.023)	0.011	89
C8,19	(0.246, 0.184, 0.098)	0.060	12
C8,20	(0.248, 0.191, 0.110)	0.063	8
C8,21	(0.029, 0.029, 0.015)	0.009	91
C8,22	(0.101, 0.078, 0.042)	0.025	67
C8,23	(0.266, 0.208, 0.126)	0.068	3
C8,24	(0.210, 0.160, 0.090)	0.052	19

4. Conclusion

In recent years, supply chain management has been viewed a major component of competitive strategy to enhance organizational productivity and profitability. Supply chain management creates value for companies, customers and stakeholders interacting throughout a supply chain. The strategic dimension of supply chains makes it paramount that their performances are measured (Estampe et al., 2010). The proposed methodology of using fuzzy logic in monitoring performance of a supply chain network has been highlighted in this paper. An efficient fuzzy based Decision-Support System (DSS) for supply chain performance measurement has been reported in this paper. By using the above methodology, the managers can easily indentify ill-performing areas which need future attention to enhance supply chain performance extent.

References

[1] A. A. Hervani,M.M. Helmsand J. Sarkis(2005), Performance measurement for green supply chain management", *Benchmarking: An International Journal*, **12**, *4*, pp. 330-353.

[2] A. Gunasekaran, C. Patel and E. Tirtiroglu(2001) Performance measures and metrics in a supply chain environment, *International Journal of Operations & Production Management*, **21**, *1-2*, pp. 71-87.

[3] A. Gunasekaran, C. Patel and E.R.McGaughey(2004), A framework for supply chain performance measurement", *International Journal of Production Economics*, **87**, pp. 333–347.

[4] A. Kaufmann and M.M. Gupta (1991), Introduction to Fuzzy Arithmetic: Theory and Applications. Van Nostrand Reinhold Electrical/Computer Science and Engineering Series, New York.

[5] A.E.Ellinger(2000), Improving marketing/logistics cross functional collaboration in the supply chain, Industrial Marketing Management, **29**, pp. 85-96.

[6] B.M. Beamon(1999),Measuring supply chain Performance, *International Journal of Operations & Production Management*, **19**, *3*, pp. 275-292.

[7] B.R. Ferguson, (2000), Implementing supply chain management, *Production and Inventory Management Journal,* March, pp. 64-7.

[8] C. Chen and H. Yan (2011), Network DEA model for supply chain performance evaluation, *EuropeanJournal of Operational Research*, **213**, pp. 147–155.

[9] C. Shepherdand H. Günter (2006), Measuring supply chain performance: current research and future directions, *International Journal of Productivity and Performance Management*, **55**, *3-4*, pp. 242-258.

[10] D.Estampe, S. Lamouri, Paris, Jean-Luc and, S. Brahim-Djelloul(2010), A framework for analysing supply chain performance evaluation models", *International Journal of Production Economics*, doi:10.1016/j.ijpe.2010.11.024.

[11] D.S. Negi (1989), Fuzzy analysis and optimization, Ph.D. Dissertation, Department of Industrial Engineering, Kansas State University.

[12] D.W. Cho, Y.H Lee, S.H.Ahnand M.K. Hwang (2012), A framework for measuring the performance of service supply chain management, *Computers & Industrial Engineering*, **62**, pp. 801-818.

[13] E.U. Olugu, and K.Y. Wong (2012), An expert fuzzy rule-based system for closed-loop supply chain performance assessment in the automotive industry, *Expert Systems with Applications*, **39**, pp. 375-384.

[14] F. Uysal(2012), An integrated model for sustainable performance measurement in supply chain, *Procedia-Social and Behavioral Sciences*, **62**, pp. 689-694.

[15] G.J. Klir and B. Yuan (1995), Fuzzy Sets and Fuzzy Logic: Theory and Applications, Prentice-Hall Inc., USA.

[16] H.J. Zimmermann (1991), Fuzzy Set Theory and its Applications, second eds. Kluwer Academic Publishers, Boston, Dordrecht, London.

[17] J. Cai, X. Liu, Z. Xiao and J. Liu (2009), Improving supply chain performance management: A systematic approach to analyzing iterative KPI accomplishment, *Decision Support Systems*, **46**, pp. 512–521.

[18] J. Yang(2009) Integrative performance evaluation for supply chain system based on logarithm triangular fuzzy number-AHP method, *Kybernetes*, **38**, *10*, pp. 1760-1770.

[19] J.J. Buckley (1985), Fuzzy hierarchical analysis, *Fuzzy Sets and Systems*, **17**, *3*, pp. 233–247.

[20] L. Ching-Torng, H. Chiuand Chu Po-Young (1996), Agility index in the supply chain, *International Journal of Production Economics*, **100**, *2*, pp. 285-299.

[21] L.A. Zadeh (1965), "Fuzzy sets, Information and Control", **8**, *3*, pp. 338-353

[22] L.A. Zadeh(1975), The concept of a linguistic variable and its application to approximate reasoning-I and II, *Information Sciences*, **8**, *3(I) 4(II)*, pp. 199-249(I) 301-357(II).

[23] L.J. Ma (2005), Supply Chain Management, High Education Press, Beijing, pp. 6.

[24] M. Webster (2002), Supply system structure, management and performance: a conceptual model, International Journal of Management Reviews, **4,** *4*, pp. 353-69.

[25] O. Vaidya, M. and Hudnurkar (2013), Multi-criteria supply chain performance evaluation, An Indian chemical industry case study, *International Journal of Productivity and Performance Management*, **62**, *3*, pp. 293-316.

[26] P. Moeinzadeh, and A. Hajfathaliha (2010), A combined fuzzy decision making approach to supply chain risk assessment, *International Journal of Human and Social Sciences*, **5**, *13*, pp. 859-875.

[27] P. Trkman, K. McCormack, M.P.V. Oliveira and M.B.L. Ladeira (2010), The impact of business analytics on supply chain performance, *Decision Support Systems*, doi:10.1016/j.dss.2010.03.007.

[28] R. Bhagwat and M.K. Sharma (2007), Performance measurement of supply chain management: A balanced scorecard approach, *Computers & Industrial Engineering*, **53**, pp. 43–62.

[29] R.B.Handfield and E.L.Nichols (1999), Introduction to Supply Chain Management, Prentice-Hall, Englewood Cliffs, NJ.

[30] S. Varma, S. Wadhwaand S.G. Deshmukh (2008), Evaluating petroleum supply chain performance Application of analytical hierarchy process to balanced scorecard, *Asia Pacific Journal of Marketing and Logistics*, **20**, *3*, pp. 343-356.

[31] S.H. Chen(1985), Ranking fuzzy numbers with maximizing set and minimizing set, *Fuzzy Sets and Systems*, **17**, *2*, pp. 113-129.

[32] S.H.Elgazzar, N.S. Tipi, N.J. Hubbard D.Z. Leach, (2012), Linking supply chain processes performance to a company's financial strategic objectives, *European Journal of Operational Research*, **223**, pp. 276–289.

[33] S.J. Chen, and S.M. Chen(2003), A new method for handing multi-criteria fuzzy decision-making problems using FN-IOWA operators", *Cybernetics and Systems*, **34**, *2*, pp. 109-137.

[34] S.M. Chen, and J.H. Chen (2009), Fuzzy risk analysis based on ranking generalized fuzzy numbers with different heights and different spreads, *Expert Systems with Applications*, **36**, *3*, pp. 6833-6842.

[35] W.H. Ip, S.L. Chan and C.Y Lam (2011), Modeling supply chain performance and stability, *Industrial Management & Data Systems*, **111**, 8, pp. 1332-1354.

[36] Y. L. P. Thorani, P.P.B.Raoand N. Ravi Shankar (2012), Ordering generalized trapezoidal fuzzy numbers, *International Journal of Contemporary Mathematical Sciences*, **7**, *12*, pp. 555-573.