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Application of FUZZY Methods for Measuring Leanness of Manufacturing Industries

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Abstract: - Manufacturing plays a vital role in the growth of any economy. In India also the manufacturing is growing rapidly and passing through transforming stage. To maintain the customer demands, quality, profitability, and sustainability it is necessary to adapt good manufacturing practices. This paper emphasizes the adaptation of lean manufacturing and development of model for assessing the lean status of different manufacturing sectors. For assessing leanness, manufacturing sectors are evaluated on 29 lean criterions by using Fuzzy TOPSIS. Fuzzy TOPSIS can deal with a variety of questions. Lean criterions are identified, linguistic ratings for different criterion are selected and scores are assigned, and finally lean status is compared, and it is found that automobile sector is leaner as compared to textile and heavy industries. This paper will help the industry, academia and lean practitioners to assess the lean status of their industry and to strengthen their knowledge towards various benefits of lean manufacturing in the industry.

Keywords: Lean manufacturing, Fuzzy TOPSIS, Automobile sector, textile Sector.

1 INTRODUCTION

For the sustainable development of any nation manufacturing industries are vital and essential. Manufacturing helps the economy through many sectors such as mining, trading, finance, marketing etc. [12] and [9][10]. From employment point of view also manufacturing is the most promising field. Micro Small and Medium enterprises (MSMEs) are equally important for the economic development of the nation along with large and small enterprises, because these are related to the core of the economy.

Efficiency and effectiveness of system are two performance measurement criteria for last many years. But in recent time performance measurement is business management and performance improvement [3]. Sink and Tuttle claims, whatever can be measured can be managed. Performance measurement helps in identifying key areas and framing management strategies for the improvement. Re-aligning goals and business process is also guided through performance indicators [4].

For enhancing the quality and efficiency of manufacturing system, feedback or information about customer satisfaction and strategic objectives are also related to performance measurement [4].

Now a days manufacturing growth and competition encourage all industries to deliver better performance by optimizing the resources. Therefore, industries are going with the philosophy of lean and implementing concepts of lean manufacturing which results in optimum human resources, time, space and waste with fewer defects by eliminating nonvalue added activities [7].

In recent years, researchers have found that why lean manufacturing is not adopted in all industries is (i) it is objective based (ii) non availability of holistic measurement model [2]. Therefore, it is a requirement of time to have the assessment model for measuring leanness of any manufacturing system.

There are many common approaches available for assessment such as Life Cycle Analysis (LCA), Cost Benefit Analysis (CBA), Environment Impact Analysis (EIA), optimization models, system dynamics models and Multi Criteria Decision Analysis (MCDA).

For evaluating multiple conflicting criteria MCDM (Multi criteria decision making) methods are generally used [8]. But in fuzzy environment where criteria are conflicting and not properly defined inclusion of artificial intelligence is suggested [7]. In this paper MCDM with fuzzy TOPSIS is used for assessment purposes.

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2. LITERATURE REVIEW:

Contemporary literature related to lean manufacturing and models for performance measurement related to assessment of leanness and other parameters are reviewed.

2.1 Lean Manufacturing:

Lean manufacturing means to improve performance in production systems by eliminating waste and delivering value to customers. It is to minimize waste which prevents the smooth flow of products and services. Toyota Production System (TPS) identified unnecessary transportation, overproduction, over processing, inventory, unnecessary motion, defects, and waiting time as seven wastes. Lean methods enable the accomplishment of just in time (JIT), total preventive maintenance (TPM), value stream mapping (VSM) and continuous improvement (kaizen).

As per [2], leanness in manufacturing can be taken as methodology to get better achievement of organization goals with less input. On reviewing further about lean manufacturing, it is observed that leanness focuses mainly on minimization of wastes means optimum resource utilization. The purpose of lean manufacturing is to reduce waste and non – value added activities.

Lean manufacturing principles are still not well accepted and understood by Indian industries [11]. Indian MSMEs are still showing resistance to change from management side and employees' side as well. The pace of implementation of lean principles is very slow due to slackness in upgradation of technology [13] and skilled work force. The current status of lean in India is just started and some quantitative benefits are perceived [6] and for speedy acceptance of lean principles assessment of leanness is essential. Now a days lean assessment is also one of the research agenda. [2] focused on some specific components of lean to measure the leanness such as JIT, KAIZEN and quality control and concluded that Ford Motors in comparison to General Motors is 17 % lean. In literature, 20 criteria based lean assessment model was suggested by (Vinod and Chintha, 2009). Comprehensiveness of this model was achieved with 30 criteria model suggested by (Vinod and Vimal,2012) and a leanness index has been identified.

Assessment of lean status is essential for the improvement of any manufacturing system. For the purpose of assessment three different sectors automobile industries (A1), textile industries (A2) and heavy engineering industries (A3) are chosen.

2.2 Automotive Industries: In the development and growth of any economy the automotive sector plays an important role. Automotive industries are the world leading in advance manufacturing technology producing complex products and require large capital, equipment and workforce. Automobile industries in India also have grown and transforming rapidly. India has become manufacturing hub for global automotive manufacturer and advancement in terms of technology and manufacturing system has taken place. Automotive industries are classified in four categories vehicles for passenger, commercial, three wheels and two wheels.

2.3 Textile Industries: Textile industries sector in any country provides livelihood to maximum people through organized and unorganized sector. Textile and apparel industry contributes 5 % to India's GDP, 7% of industry output in value terms, and 12% of the country's export earnings. India is among the top exporter of textiles and apparel in the world. This industry is very diversified and has a wide range of products including traditional handloom, handicrafts, wool, and silk products to the organized textile industry. Spinning, weaving, processing, and apparel manufacturing requires technology needs large capital for mass production of textile products characterizes organized textile industry.

In the recent past it has also gone through many changes in terms of quality and technology. The textile industry's aim is not only to produce quality fabric but also run a balance plant therefore this sector can be treated as potential for lean principles.

2.4 Heavy Engineering Industries: Heavy Industry in India means, heavy engineering, machine tool, electrical, industrial machinery, and auto-industry. These industries are essential for all sectors of the economy as provide goods and services to power, rail, and road transport. These companies are indirect players, not dealing with direct customers but with other companies who are producing these goods.

Heavy industry also requires high capital investment, high barriers to entry, and low transportability. The term "heavy" means that the goods produced by "heavy industry" are such as iron, coal, oil, ships, etc. Today, the reference also refers to industries that disturb the environment in the form of pollution, deforestation, etc.

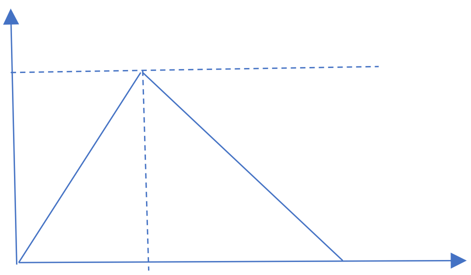
2.5 Fuzzy TOPSIS method:

MCDM approach has a wide range of applications and has common multiple objectives and criteria which are in conflict with each other. In real world situation decision making is subjected to many constraints so fusion of fuzzy and MCDM is preferred. In many assessments and judgements natural language where words do not have specific meaning. Whenever in any system uncertainty and vagueness exist and things can be represented in linguistic terms fuzzy set theory is suggested to do the decision making [1].

Fuzzy TOPSIS was introduced to fit human thinking in actual environment by Chen [5]. Many authors have successfully used this method for plant location selection, supplier evaluation, supply chain selection, manufacturing system justification etc [7].

To solve the decision problem where information is vague, subjective, and incomplete triangular fuzzy numbers are advantageous. Triangular fuzzy number $\bar{a}$ can be defined as triplet (a_1,a_2,a_3) shown in figure 1 and to transform linguistic terms into fuzzy numbers a conversion scale is used and membership function

$$\mu_{\bar{a}}(x) = \begin{cases} \frac{x-a1}{a2-a1}, & a_1 \leq x \leq a_2 \\ \frac{a2-x}{a3-a2}, & a_2 \leq x \leq a_3 \\ 0, & \text{else} \end{cases} \quad \text{.....................................1}$$



For applying Fuzzy TOPSIS following steps has to be followed.

Step 1: Assigning ratings to the criteria and alternatives.

For J possible alternatives D = {D_1, D_2, …D_j} evaluated against M criteria C = {C_1, C_2, …C_j}. The criteria weights are denoted by w_i (i = 1,2, ….m). The performance ratings of each decision maker D_k (k = 1,2,…..K) for each alternative D_j (j = 1,2,…..n) with respect to criteria C_i (i = 1,2,…..m) are denoted by $\bar{R}_k = X_{ijk}$(i = 1,2,....,m; j= 1,2,.....,n; k = 1,2,....,K) with membership function $\mu_{\bar{R}k}(x)$.s

Step 2: Compute aggregate fuzzy ratings for criteria and alternatives.

If the fuzzy ratings of all the decision makers are described as triangular fuzzy members

$\bar{R}_k = (a_k,b_k,c_k)$, k 1,2,...,K, then aggregated fuzzy rating is given by $\bar{R}$ = (a,b,c), k = 1,2,...,K where

$$a = \min_k\{a_k\}, b = \frac{1}{k}\sum_{k=1}^{k} b_k , c = \max_k\{c_k\}$$

If the fuzzy rating and importance weight of kth decision maker are $\overline{x}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk})$ and $\overline{w}_{ijk} = (w_{jk1}, w_{jk2}, w_{jk3})$, i = 1,2,…..,m; j = 1,2,….,n respectively then the aggregated fuzzy ratings $\overline{(x_{ij})}$ of alternatives with respect to each criteria are given by $\overline{x}_{ijk} = (a_{ij}, b_{ij}, c_{ij})$ where

$a_{ij} = \min_k\{a_{ijk}\}, b_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ijk}, c_{ij} = \max_k\{c_{ijk}\}$ ……………………………………………2

The fuzzy weights $(\overline{w}_{ij})$ of each criterion are calculated as $\overline{w}_j = (w_{j1}, w_{j2}, w_{j3})$ where

$w_{j1} = \min_k\{w_{jk1}\}\, w_{j2} = \frac{1}{k}\sum_{k=1}^{k} w_{jk2}, w_{j3} = \max_k\{w_{jk3}\}$ ……………………………………………………3

Step 3: Compute the fuzzy decision matrix.

The fuzzy decision matrix for the alternatives $(\overline{D})$ and criteria $(\overline{W})$ is constructed as follows

$\overline{D} = \begin{matrix} A_1 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} \overline{x}_{11} & \cdots & \overline{x}_{1n} \\ \vdots & \ddots & \vdots \\ \overline{x}_{m1} & \cdots & \overline{x}_{mn} \end{bmatrix}$…………………………………………4 i = 1, 2,…..,m; j = 1,2,……,n

$\overline{W} = (\overline{w}_1, \overline{w}_2, \ldots\ldots, \overline{w}_n)$………………………………………………5

Step 4: Normalize the fuzzy decision matrix

Normalization of raw data using a linear scale transformation to make the various criteria scales onto a comparable scale. The normalized fuzzy decision matrix $\overline{R}$ is given by

$$\overline{R} = [\overline{r}_{ij}]m * n \qquad \text{i = 1, 2,….,m; j = 1,2,…..,n} \quad \text{…………6}$$

where,

$\overline{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right)$ and $c_j^* = max_i\{c_{ij}\}$ benefit or importance criteria …………..7

$\overline{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right)$ and $a_j^- = min_i\{a_{ij}\}$ cost criteria ………………………………8

Step 5: Compute the weighted normalized matrix.

The weighted normalized matrix $\overline{V}$ for criteria is computed by multiplying the weights $\overline{w}_j$ of evaluation criteria with the normalized fuzzy decision matrix $\overline{r}_{ij}$

$$\overline{V} = [\overline{v}_{ij}]m * n \quad \text{i = 1, 2,….,m; j = 1,2,…..,n} \quad \text{…………….9}$$

where, $\overline{v}_{ij} = \overline{r}_{ij} * \overline{w}_j$

Step 6 : Compute the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS)

The FPIS and FNIS of the alternatives are computed as follows $A^* = (\overline{v}_1^*, \overline{v}_2^*, \ldots\ldots, \overline{v}_n^*)$ ………………………………………………………..10

where, $\overline{v}_j^* = max_i\{v_{ij3}\}$

i = 1,2,…,m; j = 1,2,….,n

$A^- = (\overline{v}_1^-, \overline{v}_2^-, \ldots\ldots, \overline{v}_n^-)$ ……………………………………………………………11

where, $\overline{v}_j^- = min_i\{v_{ij3}\}$

i = 1,2,…,m; j = 1,2,….,n

Step 7 : Compute the distance of each alternative form FPIS and FNIS

The distance between triangular fuzzy numbers $\overline{a}$ = (a_1;a_2;a_3) and $\overline{b}$ = (b_1;b_2;b_3)

using the vertex method is given by

$$d\,(\overline{a},\overline{b}) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \quad \text{……………………..12}$$

The distance (d_i^+, d_i^-) of each weighted alternative i = 1,2,……,m from the FPIS and FNIS is computed as follows

$$d_i^+ = \sum_{j=1}^{n} d_v(\overline{v}_{ij}, \overline{v}_j^*), i = 1,2, \dots, m \quad \text{…………………………………………...13}$$

$$d_i^- = \sum_{j=1}^{n} d_v(\overline{v}_{ij}, \overline{v}_j^*), i = 1,2, \dots, n \quad \text{…………………………………………...14}$$

Step 8 : Calculate the closeness coefficient (CC_i) of each alternative

The CC_i means distances to the FPIS (A^*) simultaneously. Closeness coefficient of each alternative is calculated as

$$CC_i = \frac{d_i^-}{(d_i^+ + d_i^-)}, i = 1,2, \dots., m \quad \text{…………………………………………………..15}$$

Step 9 : Alternatives ranking

Ranking of alternatives are performed on the basis of the closeness coefficient CC_i in decreasing order and ranked first with the highest closeness coefficient. Closest to the FPIS and farthest from FNIS is considered the best alternative.

3. APPLICATION OF FUZZY TOPSIS FOR EVALUATING LEAN STATUS

1. First select criteria of evaluation for lean status and decide attributes for each criterion.

2. Select some experts from industries and academia to assign linguistic terms to criteria.

Table 1 and Table 2 categorize linguistic terms and membership functions.

Table 1 : Linguistic terms for alternative rating

Linguistic term	Membership function
Very poor [VP]	(1,1,3)
Poor [P]	(1,3,5)
Fair [F]	(3,5,7)
Good [G]	(5,7,9)
Very Good [VG]	(7,9,9)

Table 2 : Linguistic terms for criteria rating

Linguistic term	Membership function
Very low [VL]	(1,1,3)
Low [L]	(1,3,5)
Medium [M]	(3,5,7)
High [H]	(5,7,9)
Very High [VH]	(7,9,9)

To assess the lean status of industry a total of 29 criteria are selected from literature. For the rating a scale of 1 – 9 is applied. A team of three experts who are decision makers are consulted and they assign linguistic ratings. Experts are given a set of questionnaires to get the relative importance of drivers and alternatives. These criteria are categorized, and linguistic terms are assigned. Some criteria are cost related (C) and some related to benefit (B). All these are tabulated in Table 3.

Table 3: Criteria for lean assessment

LEANNESS ENABLERS	**LEAN CRITERIA**		**LEANNESS ATTRIBUTES**	**CATEGORY**
MANAGEMENT RESPONSIBILITY	ORGANISATIONAL CULTURE	C1	SMOOTH INFORMATION FLOW	B
			TEAM MANAGEMENT FOR DECISION MAKING	
			CROSS FUNCTIONAL TEAM	
			INTERCHANGABILITY OF PERSONNEL	
	NATURE OF MANAGEMENT	C2	CLEAR MANAGEMENT GOALS	B
			MANAGEMENT INVOLVEMENT	
			TRANSPERENCY IN INFORMATION SHARING	
MANUFACTURING MANAGEMENT LEANNESS	JIT/CONTINUOUS FLOW PRODUCTION	C3	PRODUCE SMALL LOT SIZE	C
			JIT DELIVERY TO CUSTOMERS	
			CYCLE TIME REDUCTION	
			OPTIMISATION OF PROCESSING SEQUENCE AND FLOW	
	PULL SYSTEM/KANBAN	C4	DEMAND DRIVEN PRODUCTION	B
			LIMITED WIP INVENTORY	
			MINIMUM EQUIPMENT IDLE TIME	
	CUSTOMER RESPONSE ADAPTATION	C5	PREVALENCE TO CONTINUOUS IMPROVEMENT CULTURE	B
			EMPOWERMENT OF PERSONNEL TO RESOLVE CUSTOMER PROBLEMS	

	SUPPLIER DEVELOPMENT	C6	PROVIDING TECHNOLOGICAL SUPPORT TO SUPPLIERS	B
			PROVIDING TRAINING TO SUPPLIERS	
			PROVIDING FINANCIAL ASSISTANCE	
	QUICK CHANGEOVER TECHNIQUE	C7	TIME TO MARKET	C
	CELLULAR MANUFACTURING	C8	ORGANISATION OF MANUFACTURING AROUND SIMILAR PART FAMILIES	C
			UTILISATION OF MANUFACTURING CELLS	
	CONTINUOUS IMPROVEMENT PROGRAM	C9	KAIZEN	B
	WASTE QUANTIFICATION	C10	IDENTIFICATION OF WASTE	C
			SCOPE FOR WASTE ELIMINATION	
	AUTONOMATION	C11	SELF REGULATION	B
WORKFORCE LEANNESS	EMPLOYEE INVOLVEMENT	C12	EMPLOYEE EMPOWERMENT	B
			STRONG EMPLOYEE SPIRIT AND COPERATION	
	EMPLOYEE STATUS	C13	FLEXIBLE WORKFORCE FOR ADAPTATIION OF NEW TECHNOLOGIES	B
			MULTI SKILLED WORKERS	
			IMPLEMENTATION OF JOB ROTATION SYSTEM	
TECHNOLOGY LEANNESS	MANUFACTURING SET UPS	C14	FLEXIBLE SETUPS	C
			USE OF AUTOMATED TOOLS TO ENHANCE PRODUCTION	
			LESS TIME TO CHANGE THE MACHINE SETUP	
			ACTIVITY POLICY TO KEEP WORK AREA CLEAN AND TIDY	

	MAINTAINANCE OPTIMISATION	C15	IDENTIFICATION AND PRIORTISATION OF CRITICAL MACHINES	C
			IMPEMENTATION OF TPM	
			MAINTAINANCE OF INSTALLED MACHINE	
	VISUAL CONTROL	C16	IMPLEMENTATION OF POKA-YOKE	B
			USING ANDON DEVICE	
			INTRODUCTION OF CARD SYSTEM (KANBAN)	
	PRODUCT SERVICING	C17	PRODUCT DESIGNED FOR EASY SERVICABILITY	C
			SERVICE CENTERS EQUIPPED WITH ALL THE SPARES	
			USAGE OF DFMA PRINCIPLES	
			JOB ROTATION BETWEEN DESIGN AND MANUFACTURING PERSONS	
	INTEGRATED PRODUCT DESIGN	C18	USAGE OF PDM (PRODUCT DATA MANAGEMENT)	B
			CORDINATION BETWEEN DESIGN AND MANUFACTURING ISSUES	
	IN HOUSE TECHNOLOGY	C19	DESIGN AND DEVELOPMENT OF PROPRITERY ITEMS	B
			IMPROVE PRESENT EQUIPMENT BEFORE NEW EQUIPMENT	
			DEVELOP SPECIFIC TECHNOLOGIES FOR PRODUCTS	
	PRODUCTION METHODOLOGY	C20	MANAGEMENT INTEREST TOWARDS FMS	C
			FOR MINIMISATION OF WASTES	
			FOR BETTER SUPPLIER AND VENDOR MANAGEMENT	
		C21	ELIMINATION OF UNNECESSARY TOOLS	B

	WORK PLACE ORGANISATION(5S)		SUSTAINABILITY OF IMPROVEMENTS	
			PROPER ALLOCATIONS OF TOOLS	
	MANUFACTURING PLANNING	C22	MRP II SYSTEM	C
			ERP SYSTEM	
			PROCUREMENT POLICY AS PER PRODUCTION SCHEDULE	
			SCM POLICIES	
MANUFACTURING STRATEGY LEANNESS	STANDARDISATION AND SIMPLIFICATION	C23	STANDARDISATION OF COMPONENTS	C
			SYSTEMATISATION OF PROCESS	
			SIMPLIFICATION OF PROCESS	
	STATUS OF QUALITY	C24	PRODUCT EXCEEDING CUSTOMER EXPECTATION	B
			TQM IMPLEMENTATION	
			CONDUCT SURVEY FOR QUALITY STATUS	
	STATUS OF PRODUCTIVITY	C25	PRODUCTIVITY LINKED TO PERSONNEL PROSPERITY	C
			REDUCTION OF NON VALUE ADDED COST	
			APPLICATION OF TOTALITY IN ACIEVING PRODUCTIVITY	
	COST MANAGEMENT	C26	KAIZEN FOR PRODUCT PRICING	C
			IDENTIFICATION OF VALUE ADDED AND NON VALUE ADDED ACTIVITIES	
	TIME MANAGEMENT	C27	SCHEDULED ACTIVITIES	B
			IT BASED COMMUNICATION SYSTEM	
	RESOURCE UTILISATION	C28	PLANNING OF RESOURCES	C
			USE OF OPTIMISATION TOOLS	
			RETROFITTING OF MACHINE TOOLS	

	FLEXIBLE BUSINESS PROCESS	C29	EXPLORATION OF MACHINE TOOL AUTOMATION	B
			FLEXIBILITY IN LAYOUT	

In next step ratings are allocated to linguistic terms for each criteria and alternatives referring Table 1 and Table 2 with the help of decision makers team and shown in Table 4 and Table 5. Then, the aggregate fuzzy weights for each criteria and alternatives are calculated as per equation 3.

$$w_{j1} = \min_k\{5,5,7\}, w_{j2} = \frac{1}{3}\sum_{k=1}^{k}(7+7+9)\,, w_{j3} = \max_k\{9,9,9\}$$

$$w_j = (5,7.67,9)$$

Similarly, aggregate weights can be calculated for other criteria presented in Table 4.

TABLE 4 : LINGUISTIC ASSESSMENT FOR THE CRITERIA

CRITERIA	DM1	DM2	DM3	DM1	DM2	DM3	AGG. FUZZY WEIGHTS
C1	H	H	VH	5,7,9	5,7,9	7,9,9	5,7.67,9
C2	VH	H	H	7,9,9	5,7,9	5,7,9	5,7.67,9
C3	VH	VH	VH	7,9,9	7,9,9	7,9,9	7,9,9
C4	VH	VH	H	7,9,9	7,9,9	5,7,9	5,7.67,9
C5	H	H	VH	5,7,9	5,7,9	7,9,9	5,7.67,9
C6	H	H	H	5,7,9	5,7,9	5,7,9	5,7,9
C7	H	VH	H	5,7,9	7,9,9	5,7,9	5,7.67,9
C8	H	H	VH	5,7,9	5,7,9	7,9,9	5,7.67,9
C9	H	H	H	5,7,9	5,7,9	5,7,9	5,7,9
C10	H	VH	VH	5,7,9	7,9,9	7,9,9	5,8.33,9
C11	H	H	H	5,7,9	5,7,9	5,7,9	5,7,9
C12	VH	H	H	7,9,9	5,7,9	5,7,9	5,7.67,9
C13	H	H	H	5,7,9	5,7,9	5,7,9	5,7,9
C14	H	VH	H	5,7,9	7,9,9	5,7,9	5,7.67,9
C15	H	H	VH	5,7,9	5,7,9	7,9,9	5,7.67,9
C16	H	VH	VH	5,7,9	7,9,9	7,9,9	5,8.33,9
C17	VH	VH	H	7,9,9	7,9,9	5,7,9	5,8.33,9
C18	H	VH	H	5,7,9	7,9,9	5,7,9	5,7.67,9
C19	H	H	H	5,7,9	5,7,9	5,7,9	5,7,9
C20	H	H	H	5,7,9	5,7,9	5,7,9	5,7,9
C21	H	VH	H	5,7,9	7,9,9	5,7,9	5,7.67,9
C22	VH	VH	H	7,9,9	7,9,9	5,7,9	5,8.33,9
C23	VH	H	H	7,9,9	5,7,9	5,7,9	5,7.67,9

C24	H	H	H	5,7,9	5,7,9	5,7,9	5,7,9
C25	H	H	VH	5,7,9	5,7,9	7,9,9	5,7.67,9
C26	H	VH	H	5,7,9	7,9,9	5,7,9	5,7.67,9
C27	H	H	H	5,7,9	5,7,9	5,7,9	5,7,9
C28	H	H	VH	5,7,9	5,7,9	7,9,9	5,7.67,9
C29	H	H	H	5,7,9	5,7,9	5,7,9	5,7,9

Aggregate weights for alternatives can also be calculated in similar manner as weights for criterias are calculated by using equation 2 and presented in Table 5.

TABLE 5 : LINGUISTIC ASSESSMENT AND FUZZY RATINGS FOR ALTERNATIVES

	ALTERNATIVES(LINGUISTIC ASSESMENT)									ALTERNATIVES											
	A1			A2			A3			A1				A2				A3			
CRITERIA	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	**FUZZY RATINGS**	DM1	DM2	DM3	**FUZZY RATINGS**	DM1	DM2	DM3	**FUZZY RATINGS**
C1	H	VH	H	H	H	VH	H	H	M	5,7,9	7,9,9	5,7,9	**5,7.67,9**	5,7,9	5,7,9	7,9,9	**5,7.67,9**	5,7,9	5,7,9	3,5,7	**3,6.33,9**
C2	H	M	M	M	L	L	L	L	L	5,7,9	3,5,7	3,5,7	**3,5.67,9**	3,5,7	1,3,5	1,3,5	**1,3.67,7**	1,3,5	1,3,5	1,3,5	**1,3,5**
C3	H	VH	M	H	M	M	M	M	M	5,7,9	7,9,9	3,5,7	**3,7,9**	5,7,9	3,5,7	3,5,7	**3,5.67,9**	3,5,7	3,5,7	3,5,7	**3,5,7**
C4	H	H	M	M	M	H	M	M	M	5,7,9	5,7,9	3,5,7	**3,6.33,9**	3,5,7	3,5,7	5,7,9	**3,5.67,9**	3,5,7	3,5,7	3,5,7	**3,5,7**
C5	L	M	M	M	M	M	M	M	M	1,3,5	3,5,7	3,5,7	**1,4.33,7**	3,5,7	3,5,7	3,5,7	**3,5,7**	3,5,7	3,5,7	3,5,7	**3,5,7**
C6	M	M	H	M	L	M	M	L	M	3,5,7	3,5,7	5,7,9	**3,5.67,9**	3,5,7	1,3,5	3,5,7	**1,4.33,7**	3,5,7	1,3,5	3,5,7	**1,4.33,7**
C7	M	M	M	M	L	VL	L	L	VL	3,5,7	3,5,7	3,5,7	**3,5,7**	3,5,7	1,3,5	1,1,3	**1,3,7**	1,3,5	1,3,5	1,1,3	**1,2.33,5**
C8	VH	H	H	M	H	H	M	M	L	7,9,9	5,7,9	5,7,9	**5,7.67,9**	3,5,7	5,7,9	5,7,9	**3,6.33,9**	3,5,7	3,5,7	1,3,5	**1,4.33,7**
C9	H	H	M	H	H	M	M	H	M	5,7,9	5,7,9	3,5,7	**3,6.33,9**	5,7,9	5,7,9	3,5,7	**3,6.33,9**	3,5,7	5,7,9	3,5,7	**3,5.67,9**
C10	H	M	L	H	L	L	H	L	L	5,7,9	3,5,7	1,3,5	**1,5,9**	5,7,9	1,3,5	1,3,5	**1,4.33,9**	5,7,9	1,3,5	1,3,5	**1,4.33,9**
C11	M	M	M	M	M	M	M	M	M	3,5,7	3,5,7	3,5,7	**3,5,7**	3,5,7	3,5,7	3,5,7	**3,5,7**	3,5,7	3,5,7	3,5,7	**3,5,7**
C12	M	M	L	M	M	VL	L	M	VL	3,5,7	3,5,7	1,3,5	**1,4.33,7**	3,5,7	3,5,7	1,1,3	**1,3.67,7**	1,3,5	3,5,7	1,1,3	**1,3,7**
C13	M	M	M	M	H	H	M	H	M	3,5,7	3,5,7	3,5,7	**3,5,7**	3,5,7	5,7,9	5,7,9	**3,6.33,9**	3,5,7	5,7,9	3,5,7	**3,5.67,9**
C14	M	M	H	H	M	M	M	M	M	3,5,7	3,5,7	5,7,9	**3,5.67,9**	5,7,9	3,5,7	3,5,7	**3,5.67,9**	3,5,7	3,5,7	3,5,7	**3,5,7**
C15	H	H	VH	M	H	H	M	M	H	5,7,9	5,7,9	7,9,9	**5,7.67,9**	3,5,7	5,7,9	5,7,9	**3,6.33,9**	3,5,7	3,5,7	5,7,9	**3,5.67,9**
C16	VH	H	H	H	H	H	H	M	H	7,9,9	5,7,9	5,7,9	**5,7.67,9**	5,7,9	5,7,9	5,7,9	**5,7,9**	5,7,9	3,5,7	5,7,9	**3,6.33,9**
C17	H	H	H	M	M	H	M	L	L	5,7,9	5,7,9	5,7,9	**5,7,9**	3,5,7	3,5,7	5,7,9	**3,5.67,9**	3,5,7	1,3,5	1,3,5	**1,3.67,7**
C18	H	M	H	M	H	M	M	M	M	5,7,9	3,5,7	5,7,9	**3,6.33,9**	3,5,7	5,7,9	3,5,7	**3,5.67,9**	3,5,7	3,5,7	3,5,7	**3,5,7**
C19	M	M	L	M	M	H	M	M	H	3,5,7	3,5,7	1,3,5	**1,4.33,7**	3,5,7	3,5,7	5,7,9	**3,5.67,9**	3,5,7	3,5,7	5,7,9	**3,5.67,9**
C20	VH	H	H	H	H	H	M	M	M	7,9,9	5,7,9	5,7,9	**5,7.67,9**	5,7,9	5,7,9	5,7,9	**5,7,9**	3,5,7	3,5,7	3,5,7	**3,5,7**
C21	VH	H	H	H	VH	H	H	H	H	7,9,9	5,7,9	5,7,9	**5,7.67,9**	5,7,9	7,9,9	5,7,9	**5,7.67,9**	5,7,9	5,7,9	5,7,9	**5,7,9**
C22	VH	VH	H	H	H	H	H	M	M	7,9,9	7,9,9	5,7,9	**5,8.33,9**	5,7,9	5,7,9	5,7,9	**5,7,9**	5,7,9	3,5,7	3,5,7	**3,5.67,9**
C23	VH	VH	VH	VH	H	H	L	L	M	7,9,9	7,9,9	7,9,9	**7,9,9**	7,9,9	5,7,9	5,7,9	**5,7.67,9**	1,3,5	1,3,5	3,5,7	**1,3.67,7**
C24	H	VH	H	H	H	VH	H	H	H	5,7,9	7,9,9	5,7,9	**5,7.67,9**	5,7,9	5,7,9	7,9,9	**5,7.67,9**	5,7,9	5,7,9	5,7,9	**5,7,9**
C25	H	H	H	H	H	H	M	M	M	5,7,9	5,7,9	5,7,9	**5,7,9**	5,7,9	5,7,9	5,7,9	**5,7,9**	3,5,7	3,5,7	3,5,7	**3,5,7**
C26	VH	H	H	H	VH	H	M	H	H	7,9,9	5,7,9	5,7,9	**5,7.67,9**	5,7,9	7,9,9	5,7,9	**5,7.67,9**	3,5,7	5,7,9	5,7,9	**3,6.33,9**
C27	H	H	H	H	H	M	H	H	M	5,7,9	5,7,9	5,7,9	**5,7,9**	5,7,9	5,7,9	3,5,7	**3,6.33,9**	5,7,9	5,7,9	3,5,7	**3,6.33,9**
C28	H	H	M	H	H	H	M	M	M	5,7,9	5,7,9	3,5,7	**3,6.33,9**	5,7,9	5,7,9	5,7,9	**5,7,9**	3,5,7	3,5,7	3,5,7	**3,5,7**
C29	M	H	H	H	H	M	M	H	M	3,5,7	5,7,9	5,7,9	**3,6.33,9**	5,7,9	5,7,9	3,5,7	**3,6.33,9**	3,5,7	5,7,9	3,5,7	**3,5.67,9**

In next step normalized fuzzy decision matrix for all the alternatives is developed by using equations 6 to 8. For example normalized ratings for alternative 1 which is categorized as benefit

$$c_j^* = max_i\{9,9,9\} = 9$$

$$\overline{r}_{ij} = \left(\frac{5}{9}, \frac{7.67}{9}, \frac{9}{9}\right) = (0.55,0.85,1)$$

If the criteria is categorized as cost then for criteria 3 of alternative 1 can be computed as

$$a_j^- = min_i\{5,7,3\} = 3$$

$$\overline{r}_{ij} = \left(\frac{3}{9}, \frac{3}{7}, \frac{3}{3}\right) = (0.99,0.428,1)$$

Similarly, it can be calculated for other alternatives and criterias and represented as Table 6.

TABLE 6 : NORMALISED FUZZY DECISION MATRIX

CRITERIA	**A1**	**A2**	**A3**
C1	**0.55,0.85,1**	**0.55,0.85,1**	**0.33,0.7,1**
C2	**0.11,0.17,0.33**	**0.14,0.27,1**	**0.2,0.33,1**
C3	**0.33,0.77,1**	**0.33,0.63,1**	**0.33,0.55,0.77**
C4	**0.33,0.70,1**	**0.33,0.63,1**	**0.33,0.55,0.77**
C5	**0.11,0.48,0.77**	**0.33,0.55,0.77**	**0.33,0.55,0.77**
C6	**0.11,.17,0.33**	**0.14,0.231,1**	**0.14,0.23,1**
C7	**0.14,0.2,0.33**	**0.14,0.33,1**	**0.2,0.43,1**
C8	**0.55,0.85,1**	**0.33,0.70,1**	**0.11,0.48,0.77**
C9	**0.11,0.157,0.33**	**0.11,0.157,0.33**	**0.11,0.17,0.33**
C10	**0.11,0.55,1**	**0.11,0.48,1**	**0.11,0.48,1**
C11	**0.33,0.55,0.77**	**0.33,0.55,0.77**	**0.33,0.55,0.77**
C12	**0.11,0.48,0.77**	**0.11,0.407,0.77**	**0.11,0.33,0.77**
C13	**0.14,0.2,0.33**	**0.11,0.157,0.33**	**0.33,0.63,1**
C14	**0.11,0.176,0.33**	**0.11,0.17,0.33**	**0.14,0.2,0.33**
C15	**0.55,0.85,1**	**0.33,0.70,1**	**0.33,0.63,1**
C16	**0.11,0.14,0.2**	**0.11,0.14,0.2**	**0.11,0.16,0.33**
C17	**0.55,0.77,1**	**0.33,0.63,1**	**0.11,0.41,0.77**
C18	**0.33,0.70,1**	**0.33,0.63,1**	**0.33,0.55,0.77**
C19	**0.14,0.231,1**	**0.11,0.17,0.33**	**0.11,0.17,0.33**
C20	**0.55,0.85,1**	**0.55,0.77,1**	**0.33,0.55,0.77**
C21	**0.11,0.13,0.2**	**0.11,0.13,0.2**	**0.11,0.14,0.2**
C22	**0.11,0.12,0.2**	**0.11,0.14,0.2**	**0.11,0.17,0.33**
C23	**0.11,0.11,0.14**	**0.11,0.13,0.2**	**0.14,0.27,1**
C24	**0.55,0.85,1**	**0.55,0.85,1**	**0.55,0.77,1**
C25	**0.11,0.14,0.2**	**0.11,0.14,0.2**	**0.14,0.2,0.33**

C26	**0.11,0.13,0.2**	**0.11,0.14,0.2**	**0.11,0.16,0.33**
C27	**0.55,0.77,1**	**0.33,0.70,1**	**0.33,0.7,1**
C28	**0.11,0.157,0.33**	**0.11,0.14,0.2**	**0.14,0.2,0.33**
C29	**0.33,0.70,1**	**0.33,0.70,1**	**0.33,0.63,1**

For finding out weighted normalized alternatives, weighted criterias and normalized weights for various alternatives can be multiplied and are represented as Table 7. Then, fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) are computed e.g. for criteria 1 FNIS (1.65,1.65,1.65) and FPIS (9,9,9) by using equation 10 and 11 are also presented in Table 7.

TABLE 7 : WEIGGHTED NORMALISED, FPIS AND FNIS

CRITERIA	**WEIGHTED NORMALISED(A1)**			**WEIGHTED NORMALISED(A2)**			**WEIGHTED NORMALISED(A3)**			**FNIS**	**FPIS**
C1	2.75	6.5195	9	2.75	6.5195	9	1.65	5.369	9	(1.65,1.65,1.65)	(9,9,9)
C2	0.55	1.3039	2.97	1.65	4.8321	9	1	2.5311	9	(0.55,0.55,0.55)	(9,9,9)
C3	2.31	6.93	9	2.31	5.67	9	2.31	4.95	6.93	(2.31,2.31,2.31)	(9,9,9)
C4	1.65	5.369	9	1.65	4.8321	9	1.65	4.2185	6.93	(1.65,1.65,1.65)	(9,9,9)
C5	0.55	3.6816	6.93	1.65	4.2185	6.93	1.65	4.2185	6.93	(0.55,0.55,0.55)	(6.93,6.93,6.93)
C6	0.55	1.19	2.97	0.7	1.617	9	0.7	1.61	9	(0.55,0.55,0.55)	(9,9,9)
C7	0.7	1.534	2.97	0.7	2.5311	9	1	3.2981	9	(0.7,0.7,0.7)	(9,9,9)
C8	2.75	6.5195	9	1.65	5.369	9	0.55	3.6816	6.93	(0.55,0.55,0.55)	(9,9,9)
C9	0.55	1.099	2.97	0.55	1.099	2.97	0.55	1.19	2.97	(0.55,0.55,0.55)	(2.97,2.97,2.97)
C10	0.55	4.5815	9	0.55	3.9984	9	0.55	3.9984	9	(0.55,0.55,0.55)	(9,9,9)
C11	1.65	3.85	6.93	1.65	3.85	6.93	1.65	3.85	6.93	(1.65,1.65,1.65)	(6.93,6.93,6.93)
C12	0.55	3.6816	6.93	0.55	3.12169	6.93	0.55	2.5311	6.93	(0.55,0.55,0.55)	(6.93,6.93,6.93)
C13	0.7	1.4	2.97	0.55	1.099	2.97	1.65	4.41	9	(0.55,0.55,0.55)	(9,9,9)
C14	0.55	1.34992	2.97	0.55	1.3039	2.97	0.7	1.534	2.97	(0.55,0.55,0.55)	(2.97,2.97,2.97)
C15	2.75	6.5195	9	1.65	5.369	9	1.65	4.8321	9	(1.65,1.65,1.65)	(9,9,9)
C16	0.55	1.1662	1.8	0.55	1.1662	1.8	0.55	1.3328	2.97	(0.55,0.55,0.55)	(2.97,2.97,2.97)
C17	2.75	6.4141	9	1.65	5.2479	9	0.55	3.4153	6.93	(0.55,0.55,0.55)	(9,9,9)
C18	1.65	5.369	9	1.65	4.8321	9	1.65	4.2185	6.93	(1.65,1.65,1.65)	(9,9,9)
C19	0.7	1.617	9	0.55	1.19	2.97	0.55	1.19	2.97	(0.55,0.55,0.55)	(9,9,9)
C20	2.75	5.95	9	2.75	5.39	9	1.65	3.85	6.93	(1.65,1.65,1.65)	(9,9,9)
C21	0.55	0.9971	1.8	0.55	0.9971	1.8	0.55	1.0738	1.8	(0.55,0.55,0.55)	(1.8,1.8,1.8)
C22	0.55	0.9996	1.8	0.55	1.1662	1.8	0.55	1.4161	2.97	(0.55,0.55,0.55)	(2.97,2.97,2.97)
C23	0.55	0.8437	1.26	0.55	0.9971	1.8	0.7	2.0709	9	(0.55,0.55,0.55)	(9,9,9)
C24	2.75	5.95	9	2.75	5.95	9	2.75	5.39	9	(2.75,2.75,2.75)	(9,9,9)
C25	0.55	1.0738	1.8	0.55	1.0738	1.8	0.7	1.534	2.97	(0.55,0.55,0.55)	(2.97,2.97,2.97)
C26	0.55	0.9971	1.8	0.55	1.0738	1.8	0.55	1.2272	2.97	(0.55,0.55,0.55)	(2.97,2.97,2.97)
C27	2.75	5.39	9	1.65	4.9	9	1.65	4.9	9	(1.65,1.65,1.65)	(9,9,9)
C28	0.55	1.20419	2.97	0.55	1.0738	1.8	0.7	1.534	2.97	(0.55,0.55,0.55)	(2.97,2.97,2.97)
C29	1.65	4.9	9	1.65	4.9	9	1.65	4.41	9	(1.65,1.65,1.65)	(9,9,9)

The distance of each alternative from FPIS and FNIS can be calculated by using equations 12 to 14.

$$d\ (A_1, A^+) = \sqrt{\frac{1}{3}[(2.75-1.65)^2 + (6.59-1.65)^2 + (9-1.65)^2]}$$

$$d\ (A_1, A^-) = \sqrt{\frac{1}{3}[(2.75-9)^2 + (6.59-9)^2 + (9-9)^2]}$$

Similarly, distance for each alternative is calculated and presented in Table 8.

TABLE 8 : DISTANCE d(-) AND d(+) FOR ALTERNATIVES

		d(+)				d(-)		
CRITERIA	**FNIS**	**A1**	**A2**	**A3**	**FPIS**	**A1**	**A2**	**A3**
C1	(1.65,1.65,1.65)	**5.13**	**5.13**	**4.76**	(9,9,9)	**3.88**	**3.88**	**4.73**
C2	(0.55,0.55,0.55)	**1.46**	**5.51**	**5.02**	(9,9,9)	**7.46**	**4.88**	**5.94**
C3	(2.31,2.31,2.31)	**4.69**	**4.32**	**3.07**	(9,9,9)	**4.04**	**4.31**	**4.67**
C4	(0.55,0.55,0.55)	**4.76**	4.62	3.39	(9,9,9)	**4.73**	**4.88**	**5.20**
C5	(0.55,0.55,0.55)	**4.10**	**4.30**	**4.30**	(6.93,6.93,6.93)	**4.13**	**3.43**	**3.43**
C6	(0.55,0.55,0.55)	**1.45**	**4.92**	**4.92**	(9,9,9)	**7.50**	**6.41**	**6.42**
C7	(0.7,0.7,0.7)	**1.40**	**4.91**	**5.02**	(9,9,9)	**7.33**	**6.08**	**5.67**
C8	(0.55,0.55,0.55)	**6.11**	**5.65**	**4.10**	(9,9,9)	**3.88**	**4.73**	**5.89**
C9	(0.55,0.55,0.55)	**1.43**	**1.43**	**1.45**	(2.97,2.97,2.97)	**1.77**	**1.77**	**1.73**
C10	(0.55,0.55,0.55)	**5.41**	**5.27**	**5.27**	(9,9,9)	**5.51**	**5.67**	**5.67**
C11	(1.65,1.65,1.65)	**3.30**	**3.30**	**3.30**	(6.93,6.93,6.93)	**3.53**	**3.53**	**3.53**
C12	(0.55,0.55,0.55)	**4.10**	**3.97**	**3.86**	(6.93,6.93,6.93)	**4.13**	**4.29**	**4.47**
C13	(0.55,0.55,0.55)	**1.48**	**1.43**	**5.40**	(9,9,9)	**7.37**	**7.53**	**5.00**
C14	(0.55,0.55,0.55)	**1.47**	**1.46**	**1.51**	(2.97,2.97,2.97)	**1.68**	**1.70**	**1.55**
C15	(1.65,1.65,1.65)	**5.13**	**4.76**	**4.62**	(9,9,9)	**3.88**	**4.73**	**4.88**
C16	(0.55,0.55,0.55)	**0.80**	**0.80**	**1.47**	(2.97,2.97,2.97)	**1.80**	**1.80**	**1.63**
C17	(0.55,0.55,0.55)	**6.07**	**5.62**	**4.04**	(9,9,9)	**3.91**	**4.76**	**5.97**
C18	(1.65,1.65,1.65)	**4.76**	**4.62**	**3.39**	(9,9,9)	**4.73**	**4.88**	**5.20**
C19	(0.55,0.55,0.55)	**4.92**	**1.45**	**1.45**	(9,9,9)	**6.41**	**7.50**	**7.50**
C20	(1.65,1.65,1.65)	**4.96**	**4.80**	**3.30**	(9,9,9)	**4.02**	**4.17**	**5.32**
C21	(0.55,0.55,0.55)	**0.77**	**0.77**	**0.78**	(1.8,1.8,1.8)	**0.86**	**0.86**	**0.83**
C22	(0.55,0.55,0.55)	**0.77**	**0.80**	**1.48**	(2.97,2.97,2.97)	**1.92**	**1.87**	**1.66**
C23	(0.55,0.55,0.55)	**0.44**	**0.77**	**4.96**	(9,9,9)	**8.12**	**7.90**	**6.24**
C24	(2.75,2.75,2.75)	**4.05**	**4.05**	**3.92**	(9,9,9)	**4.02**	**4.02**	**4.17**
C25	(0.55,0.55,0.55)	**0.78**	**0.78**	**1.51**	(2.97,2.97,2.97)	**1.90**	**1.90**	**1.55**
C26	(0.55,0.55,0.55)	**0.77**	**0.78**	**1.45**	(2.97,2.97,2.97)	**1.93**	**1.90**	**1.72**
C27	(1.65,1.65,1.65)	**4.80**	**4.64**	**4.64**	(9,9,9)	**4.17**	**4.86**	**4.86**
C28	(0.55,0.55,0.55)	**1.45**	**0.78**	**1.51**	(2.97,2.97,2.97)	**1.73**	**1.90**	**1.55**
C29	(1.65,1.65,1.65)	**4.64**	**4.64**	**4.53**	(9,9,9)	**4.86**	**4.86**	**5.00**

After calculating distances for each alternative, coefficient of closeness is calculated by using equation 15, results presented in Table 9.

TABLE 9 : CLOSENESS COEFFICIENT FOR ALTERNATIVES			
	A1	A2	A3
d(-)	121.2	120.99	122
d(+)	91.4	96.3	98.42
CCi	0.570084666	0.556813475	0.553488794

Results presented in Table 9 conclude that alternate A1 which represents automobile sector is closer to lean status as compared to other two sectors.

4. RESULT AND OUTCOME:

In this paper we developed a mathematical model through which we can compare lean status of different systems, sectors, and industries by using Fuzzy TOPSIS method. In our studies we compared three manufacturing sectors automobile, textile and heavy engineering industries named A1, A2 and A3 respectively.

It is observed that the lean status in automobile sector is better than other two sectors. In automobile industries production is accompanied with the latest technology and the system is customer driven. Automobile industries are also reducing the inventory level by implementing the concepts of JIT. Automobile industries also have good sales and marketing network, so their customer connect is better than other sectors and flow of information is smooth.

Lean status in heavy engineering industries is weakest among three sectors because of their resistance in technology upgradation. Customers connect of heavy engineering industries is not strong as in automobile industries so the information flow is slow.

REFERENCES

1. Awasthi A,Chauhan SS, Omrani H(2011) Application of fuzzy TOPSIS in evaluating sustainable
2. Bayou M E, Korvin A de (2008), Measuring the leanness of manufacturing systems – A case study of Ford motor company and General motors. Journal Engineering Technology Management 25: 287-304
3. Chan FTS (2003), Performance measurement in supply chain. International Journal of Advance Manufacturing Technology 21:534 – 548
4. Chen M, Tzeng G, Liu D (2003), Multi – criteria task assignment in workflow management systems, In IEEE Proceedings of 36th Hawai international conference on system sciences
5. Chen, C. T. (2000). Extensions of the TOPSIS for group decision-making under fuzzy environment. Fuzzy sets and systems, 114(1), 1-9.
6. Eswaramoorthi, M., Kathiresan, G. R., Prasad, P. S. S., & Mohanram, P. V. (2011). A survey on lean practices in Indian machine tool industries. The International Journal of Advanced Manufacturing Technology, 52(9-12), 1091-1101.
7. Gandhi Nevil S, Shashank J Thanki, Thakkar Jitesh J (2017) Ranking of drivers for integrated Lean – Green manufacturing for Indian SMEs. Journal of cleaner production
8. Mittal, V. K., & Sangwan, K. S. (2015). Ranking of Drivers for Green Manufacturing Implementation Using Fuzzy Technique for Order of Preference by Similarity to Ideal Solution Method. Journal of Multi-Criteria Decision Analysis, 22(1-2), 119-130.
9. Sarkis J(2003) A strategic decision framework for green supply chain management. Journal of Cleaner Production 11(4):397-409
10. Sarkis J (2001) Manufacturing's role in corporate environmental sustainability – Concerns for the new millennium. International Journal of Operations & Production Management 21(5/6):666-686
11. Singh Bhim, Garg S.K.,Sharma S.K., (2010) Lean implementation and it's benefits to production industry. International Journal of Lean Six Sigma 1(2):157 – 168
12. Thurner T, Roud V (2016) Greening strategies in Russia's manufacturing – from compliance to opportunity. Journal of Cleaner Production 112:2851-2860
13. Upadhye, N., Deshmukh, S. G., & Garg, S. (2010). Lean manufacturing system for medium size manufacturing enterprises: an Indian case. International Journal of Management Science and Engineering Management, 5(5), 362-375.