Improve the 5s Performance in an Assembly Plant Using Fuzzy Logic Based Modeling

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Abstract— Nowadays in this dynamic and technological world, the secret of surviving for any kind of organization is to be competitive and pioneer in its products or services. One of the main ways to succeed is continuous improvement and increasing the quality of product or service. However, there is lack of knowledge in some improving methods and tools like 5S and the challenge is much greater. This 5S system which is a component of lean manufacturing helps organize a workplace efficiently. A 5S audit was designed which enabled each zone head to identify the potential level of quality improvement and at the same time analyze the ability and weakness of each zone in the division. Most measures of 5S are described subjectively by linguistic terms which are characterised by ambiguity and multi-possibility, thus, using the conventional approaches to 5S assessment is not effective whereas fuzzy logic provides a useful tool for dealing with decisions in which the phenomena are imprecise and vague. A 5S assessment model was designed and evaluated, followed by, weighing up the same using fuzzy logics. After determining the 5S level at the 5 zones, the importance indexes of various 5S attributes were found. Various proposals for 5S improvement were suggested based on the experiences of the conduct of the project. These proposals after implementation lead to enhancement of quality and thereby increase in the efficiency of the organisation.

Keywords: 5S, Fuzzy Logic Approach, 5S Audit, Performance ratings, Importance weights.

I. INTRODUCTION

In recent years, researchers and practitioners are paying increasing attention to the phenomenon of new management systems and their impact on company’s performance. There is a real need for empirical studies in this field. However, there is lack of knowledge in some improving methods and tools like 5S and the challenge is much greater.

The practice of 5S is commonly used among the Japanese firms in order to enhance human capability and productivity. Since it was introduced by Takashi Osada in the early 1980s, it is believed that applying the 5S techniques could considerably raise the environmental performance in production line including housekeeping, health and safety.

Poor performance is an issue that worries managers and employees alike. It is of concern to senior managers because it is a measure of how effectively the organization is led. Dealing with poor performance is an emotive issue for managers and organizations, therefore, that many organizations fail to address it. In our research, five different zone heads shared their perspectives on the issue.

This study would like to show that 5S is a good management practice to create a performance improvement plan and a great work environment for employees where the companies are deal with poor performance problems.

There is a need to follow the method according to its framework to be easy to use and allow a practical and comprehensive measurement and also to cover most aspects of total quality management. It also allows a meaningful and practical analysis in the sense of being usable for total quality management approach and being applicable to an organization.

II. RESEARCH METHODOLOGY

The methodology followed during the project is shown in Fig.1. The project begins with a literature review on the 5S evaluation. Then a conceptual model for 5S evaluation has been developed. The performance rating and weights of 5S attributes are assessed using Linguistic terms. This is followed by approximation of Linguistic terms by fuzzy numbers. Next, the 5S effective index of each zone has been determined. Then, the importance index of various 5S attributes has been found. Finally, the proposals have been derived an implemented for 5S improvement.

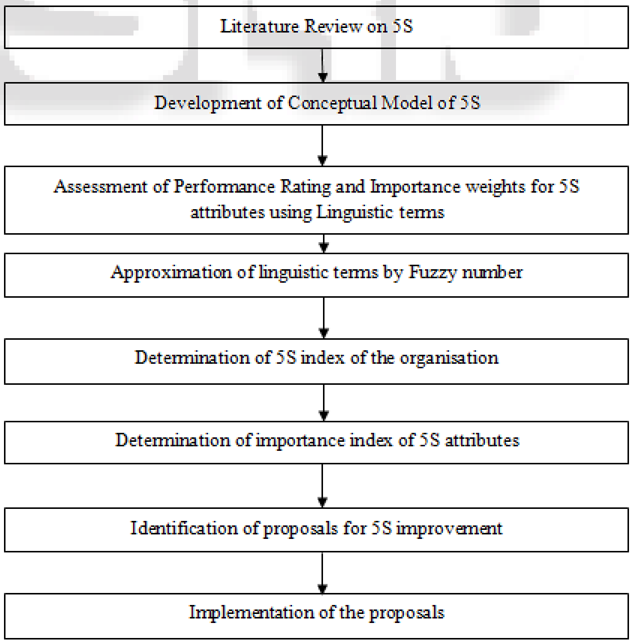

Fig. 1: Research Methodology

III. CONCEPTUAL MODEL FOR 5S EVALUATION

The conceptual method for 5S evaluation model has been shown in Table I. The model consists of five 5S enablers, 25 5S criteria and 59 5S attributes. The model is comprehensive as it has been developed from literature by referring to various peer reviewed journal papers. 5S enablers present the first level; 5S criteria formed the second level and 5S attributes formed the third level.

Table 1 An Excerpt Of 5s Evaluation Model

5S Enablers	5S Criteria	5S Attributes
SORT ($5SE_1$)	Parts or materials($5SC_1$)	No unnecessary stock items. ($5SA_{1,1}$)
		Excess WIP is eliminated. ($5SA_{1,2}$)
	Machines and equipments ($5SC_2$)	All machines and equipments are in regular use. ($5SA_{2,1}$)
		Accessories are used frequently. ($5SA_{2,2}$)
	Jigs, fixtures, measuring instruments and tools. ($5SC_3$)	All jigs, fixtures and cutting tools are in regular use. ($5SA_{3,1}$)
		Measuring instruments are in good working condition. ($5SA_{3,2}$)
	Documents($5SC_4$)	All unnecessary old drawings/ old job cards are removed from shop and moved to an identified location for storage. ($5SA_{4,1}$)
		Check if there is not a single NCR related with wrong drawing revision used in this zone in the last month. ($5SA_{4,2}$)
	Awareness about "Red Tagging" ($5SC_5$)	Red tagging has been done as per plan. ($5SA_{5,1}$)
		Check the data/ records of Red Tagging. ($52A_{5,2}$)

IV. Determination Of Approximate Linguistic Terms For Assessing Performance Rating And Important Weights Of 5s Attributes

The linguistic terms are used to assess the performance rating and important weights of 5S attributes. In order to assist in assigning the performance rating of 5S attributes, the linguistic variables (Excellent (E), Very Good (VG), Good (G), Fair (F), Poor (P), Very Poor (VP) and Worst (W)) are used. In order to assess the importance weights of 5S attributes, the linguistic variables (Very High (VH), High (H), Medium (M), Fairly Low (FL), Low (L) and Very Low (VL)) are used. The linguistic variables and fuzzy numbers used in this project are shown in the table.

Table 2 Linguistic Variables And Fuzzy Numbers Used

Performance-Rating		**Importance-Weights**	
Linguistic Variables	**Fuzzy Number**	**Linguistic Ariables**	**Fuzzy Number**
Worst (W)	(0.0,0.5,1.5)	Very Low (Vl)	(0.00,0.05,0.15)
Very Poor (Vp)	(1.0,2.0,3.0)	Low (L)	(0.10,0.20,0.30)
Poor (P)	(2.0,3.5,5.0)	Fairly Low (Fl)	(0.20,0.35,0.50)
Fair (F)	(3.0,5.0,7.0)	Medium (M)	(0.30,0.50,0.70)
Good (G)	(5.0,6.5,8.0)	Fairly High (Fh)	(0.50,0.65,0.80)
Very Good (Vg)	(7.0,8.0,9.0)	High (H)	(0.70,0.80,0.90)
Excellent (E)	(8.5,9.5,10.0)	Very High (Vh)	(0.85,0.95,1.00)

IV. DETAILS OF THE STUDY

The study has been started by analyzing the processes as well as the products in an assembly plant at Bengaluru. After studying the processes involved and zones in the division, a cross-functional team with five experts was formed. Five experts are the heads of various departments and they possess rich experience about the working culture of each zone at the division. An Audit sheet was designed; Expert rating and weightage was gathered in consultation with these five experts.

After a series of activities consisting assessment of the assembly plant, identification of required and non-required items, frequency of usage of each item, visual measurement, documentation, safety and various other aspects the criteria were selected for evaluation.

The next step is to determine the appropriate linguistic scale to assess the performance ratings and importance weights of the 5S performance levels. Furthermore, on the basis of linguistic level bank as shown in Table II, the linguistic assessments of performance ratings and importance weights of the 5S performance levels as shown in Table III are approximated by fuzzy numbers.

A.Measurement Of Performance Ratings And Importance Weights Of 5s Attributes Using Linguistic Terms

Table 3: Linguistic Variables Of Performance Rating Provided By Experts

SL.NO	**ENABLER**	**CRITERIA**	**ATTRIBUTE**	**E1**	**E2**	**E3**	**E4**	**E5**
1.	$5SE_1$	$5SC_1$	$5SA_{1,1}$	VG	E	VG	E	VG
			$5SA_{1,2}$	G	G	VG	VG	G
		$5SC_2$	$5SA_{2,1}$	F	G	F	F	F
			$5SA_{2,2}$	G	G	F	G	F
		$5SC_3$	$5SA_{3,1}$	P	F	P	G	G
			$5SA_{3,2}$	G	G	VG	VG	G
		$5SC_4$	$5SA_{4,1}$	E	VG	G	G	G
			$5SA_{4,2}$	G	G	F	F	G
		$5SC_5$	$5SA_{5,1}$	G	G	G	VG	VG
			$5SA_{5,2}$	E	VG	G	VG	VG

Table 4 Linguistic Variables Of Importance Weightage Provided By Experts

SL.NO	ENABLER	CRITERIA	ATTRIBUTE	E1	E2	E3	E4	E5
1.	$5SE_1$	$5SC_1$	$5SA_{1,1}$	H	H	FH	VH	H
			$5SA_{1,2}$	FL	L	M	FL	FL
		$5SC_2$	$5SA_{2,1}$	M	M	FL	M	FL
			$5SA_{2,2}$	FH	FH	M	FH	M
		$5SC_3$	$5SA_{3,1}$	H	H	FH	FH	H
			$5SA_{3,2}$	H	FH	H	H	FH
		$5SC_4$	$5SA_{4,1}$	VH	H	H	VH	H
			$5SA_{4,2}$	H	H	FH	H	FH
		$5SC_5$	$5SA_{5,1}$	FH	M	M	FH	M
			$5SA_{5,2}$	FH	M	FH	M	M

A. Aggregation Of Fuzzy Rating And Fuzzy Weights Of 5s

Let $R_1, R_2, \ldots, R_n$ and $W_1, W_2, \ldots W_n$ denote, respectively, the fuzzy ratings and the fuzzy importance weights of the criteria.

$R_j = (a_j, b_j, c_j) = (R_{j1} (+) R_{j2} (+) \ldots\ldots (+) R_{jm})/m$ (1)

$W_j = (x_j, y_j, z_j) = (W_{j1} (+) W_{j2} (+) \ldots\ldots (+) W_{jm})/m$ (2)

Consolidated fuzzy rating and fuzzy weights are used to determine the 5S level.

Fuzzy Performance Index (FPI)

$$FPI = \sum_{j=1}^{n} (Wj * Rj) / \sum_{j=1}^{n} Wj \quad (3)$$

As a sample, the average fuzzy rating and average fuzzy weight of 5S attribute "No necessary stock item" for Zone 2 has been shown as follows:

$5SA_{1,1}$=[VG+E+VG+E+VG]/5

from Eq (1)

=[(7.0,8.0,9.0)+(8.5,9.5,10.0)+(7.0,8.0,9.0)+(8.5,9.5,10.0)+(7.0,8.0,9.0)]/5

= (3.6, 5.8, 7.4)

$5SA_{1,1}$=[H+H+FH+VH+H]/5

from Eq (2)

=[(0.70,0.80,0.90)+(0.70,0.80,0.90)+(0.50,0.65,0.80)+(0.85,0.95,1.0)+(0.70,0.80,0.90)]/5

= (0.69, 0.80, 0.90)

Table 5 Average Fuzzy Ratings And Average Fuzzy Weights

Attribute	**Fuzzy Average Ratings**	**Fuzzy Average Weights**
$5SA_{1,1}$	(3.8,5.6,7.4)	(0.69,0.80,0.90)
$5SA_{1,2}$	(2.6,4.4,6.2)	(0.20,0.35,0.50)
$5SA_{2,1}$	(3.4,5.3,7.2)	(0.26,0.44,0.62)
$5SA_{2,2}$	(4.2,5.9,7.6)	(0.42,0.59,0.76)
$5SA_{3,1}$	(3.4,5.0,6.6)	(0.62,0.74,0.86)
$5SA_{3,2}$	(5.8,7.1,8.4)	(0.62,0.74,0.86)
$5SA_{4,1}$	(4.6,6.2,7.8)	(0.76,0.86,0.94)
$5SA_{4,2}$	(4.2,5.9,7.6)	(0.62,0.74,0.86)
$5SA_{5,1}$	(5.8,7.1,8.4)	(0.38,0.56,0.74)
$5SA_{5,2}$	(6.9,8.0,9.0)	(0.38,0.56,0.74)

The aggregated fuzzy ratings of main criteria "parts or materials" for Zone 2 has been calculated as:

$5SA_1$=[(3.80, 5.60, 7.40)(*)(0.69, 0.80, 0.90)+(2.60, 4.40 ,6.20)(*)(0.20, 0.35, 0.50)]/[(0.69, 0.80, 0.90)+(0.20, 0.35, 0.50)]

$5SA_1$= (3.530337, 5.234783, 6.971429) from Eq.(3)

Other aggregated fuzzy ratings are calculated in a similar manner. After applying the equation (3) Fuzzy Performance Index (FPI) of Zone 2 is (4.584, 6.11, 7.611)

B. Determination Of Euclidean Distance To Match Fpi With Approximate Efficiency Level

Once the FPI has been obtained, it can be matched with linguistic level. Euclidean distance method is the most widely used method for matching the membership function with linguistic term. In our project, the performance level has been set as

- Extremely Effective [EE]=(7.0,8.5,10)
- Very Effective [VE]=(5.5,7.0,8.5)
- Effective [E]=(3.5,5.0,6.5)
- Fairly [F]=(1.5,3.0,4.5)
- Poorly [P]=(0.0,1.5,3.0)

The membership function used for calculating FPI is given by,

$$f_A(x) = \begin{cases} (x-a)/(b-a), & a \le x \le b, \\ (x-c)/(c-b), & b \le x \le c, \\ 0, & otherwise \end{cases}$$

$$d(FPI, PL_i) = \left\{ \sum_{x \in p} \left(f_{FPI}(x) - f_{PL_i}(x) \right)^2 \right\}^{1/2}$$

W $_{ijk}$ is the fuzzy importance weight of the flexibility element capability ijk.

Then, by using the Euclidean distance method, the Euclidean distance D from the FPI to each member in set FL is calculated by Equation 5:

(D (FPI, EE) = 1.41; D (FPI, VE) = 3.01; D (FPI, E) = **1.33**; D (FPI, F) = 2.03;

D (FPI, P) = 2.03)

By matching a linguistic label with minimum D, the efficiency level of Zone 2 has been identified as "**Efficient**".

C. Identification Of Importance Index Of Various 5s Attributes

5S performance cannot be stopped with determination of performance level; it must identify the principle obstacles for improvement by calculating Fuzzy Performance Importance Index (FPII).

$$FPII_{ijk} = W'_{ijk} \otimes R_{ijk}$$

Where,

W'_{ijk}=(1.0,1.0,1.0)- W_{ijk}

W $_{ijk}$ is the fuzzy importance weight of the flexibility element capability ijk.

The FPIIs of each flexibility element capability are obtained and defuzzified by applying the following equation,

Ranking Score = (l + 2m + u)/4 (7)

As above, total score of 5S attribute “No necessary stock item” is found to be **1.23**.

Similarly, scores have been computed for all 59 5S attributes for Zone 2 and are shown in table 6.

Table 5 Fuzzy Performance Importance Index (Fpii) Of Various Sub-Criteria

ATTRIBUTE	(1.0,1.0,1.0)-W	FPII	RANKING
$5SA_{1,1}$	(0.10,0.20,0.31)	(0.380,1.120,2.294)	1.23
$5SA_{1,2}$	(0.50,0.65,0.80)	(1.300,2.860,4.960)	3.00
$5SA_{2,1}$	(0.38,0.56,0.74)	(1.292,2.968,5.328)	3.14
$5SA_{2,2}$	(0.24,0.41,0.58)	(1.008,2.419,4.408)	2.56
$5SA_{3,1}$	(0.14,0.26,0.38)	(0.476,1.300,2.508)	1.40
$5SA_{3,2}$	(0.14,0.26,0.38)	(0.812,1.846,3.192)	1.92
$5SA_{4,1}$	(0.06,0.14,0.24)	(0.276,0.868,1.872)	0.97
$5SA_{4,2}$	(0.14,0.26,0.38)	(0.588,1.534,2.888)	1.64
$5SA_{5,1}$	(0.26,0.44,0.62)	(1.508,3.124,5.208)	3.24
$5SA_{5,2}$	(0.26,0.44,0.62)	(1.794,3.520,5.580)	3.60

V. CONCLUSIONS

The project emphasis on the importance of 5S as a powerful lean management tool which aims at introducing standard operational practices that ensure efficient, repeatable, safe ways of working. This study has addressed the questions of how to measure and improve 5S performance. Considering the limitations of the conventional evaluation approaches, a fuzzy 5S performance index which focuses on the application of linguistic approximation and fuzzy arithmetic was designed for addressing 5S measurement, stressing the multiplicity of meaning and ambiguity of attribute measurement.

The proposed model demonstrates an unprecedented application of fuzzy logic. Furthermore, the proposed model has the following novel features:

– The model can provide more informative and reliable analytical results. The FPI of 5S system is expressed in a range of values, which can provide a holistic picture of its performance.
– The model can systematically identify the system’s weaknesses and provide the means to devise a comprehensive improvement plan. The model thus facilitates systematic continuous quality improvement over the full range of activities and processes.

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