Dynamic Risk Identification Using Fuzzy Failure Mode Effect Analysis in Fabric Process Industries: A Research Article as Management Perspective

A. Sivakumar, S. S. Darun Prakash, P. Navaneethakrishnan

***Abstract*—**In and around Erode District, it is estimated that more than 1250 chemical and allied textile processing fabric industries are affected, partially closed and shut off for various reasons such as poor management, poor supplier performance, lack of planning for productivity, fluctuation of output, poor investment, waste analysis, labor problems, capital/labor ratio, accumulation of stocks, poor maintenance of resources, deficiencies in the quality of fabric, low capacity utilization, age of plant and equipment, high investment and input but low throughput, poor research and development, lack of energy, workers' fear of loss of jobs, work force mix and work ethic. The main objective of this work is to analyze the existing conditions in textile fabric sector, validate the break even of Total Productivity (TP), analyze, design and implement fuzzy sets and mathematical programming for improvement of productivity and quality dimensions in the fabric processing industry. It needs to be compatible with the reality of textile and fabric processing industries. The highly risk events from productivity and quality dimension were found by fuzzy systems and results are wrapped up among the textile fabric processing industry.

***Keyword*—**Break Even Point, Fuzzy Crisp Data, Fuzzy Sets, Productivity, Productivity Cycle, Total Productive Maintenance.

I. Introduction about Industry

THE textile industry in India plays an important role in Indian economy in terms of its contribution to Gross Domestic Product (GDP), Exports and its potential for employment generation. Nearly 2500 textile and its allied industries are functioning in Erode and Tirupur Districts of Tamil Nadu, India. An enormous amount of money is invested in this industry for processing the goods, namely grey fabric and calendared fabric. However, in the recent years, some of the industries had to be closed because they were unable to meet the environmental requirements.

Apart from these government regulations, the major problems are sickness, low yield, fluctuation of output, labor problems, accumulation of stock, deficiencies in the quality of fabric, high input but low throughput etc. in these sick textile industries. In the literature review, productivity measurements have been advocated by numerous authors such as [1] and [5].

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In fact, productivity measurement should be considered as an important part of a continuous cycle. This is where productivity development is based on the four phases of the productivity management cycle [2], [3] investigated the methodology and came up with certain valuable findings to facilitate validation [10]. In this investigation, a neuro-fuzzy system helped and to construct identify non-linear dynamic systems and fuzzy objective functions [4]-[6].

But these investigators did not identify Total Productivity Model (TPML) [11], [12] and Total Productive Maintenance (TPM) [13], [14]. According to simulation [6], [7] more comprehensive indices would incorporate the multiple dimensions of productivity and quality in a weighted fashion to create a more all-inclusive overall performance index for an organization [9].

II. Objectives of the Research

1. To identify and array the measurement instrument through identification of the critical risk priority dimensions for productivity and quality improvement and their operating measures.
2. To validate the measurement instrument from the data which is collected from the industry experts through questionnaire.
3. To identify and investigate the influence of an age of productivity and quality on sick textile industries.
4. To investigate and compare the success of robust framework implementation and issues relating to successful implementation for the achievement of better performance of organizations with benchmarks.

III. Research Methodology and Fuzzy Equation

The dimensions arrived at from this work are taken to increase the productivity of such sick fabric industries. The total investment of this sick fabric industry is approximately 50 million rupees. But the total productivity of this industry is not up to the planned level due to the improper applications of scientific and engineering procedures. Equations (1)-(3) were used for risk identification [8].

$$\mu_{\tilde{A}1}(x) = \begin{cases} (x-a)/(b-a), a \le x \le b, \\ (d-x)/(d-b), b \le x \le d, \\ 0, \quad otherwise. \end{cases} \quad (1)$$

$$\mu_{\tilde{A}2}(x) = \begin{cases} (x-a)/(b-a), a \le x \le b, \\ 1, \quad b \le x \le c, \\ (d-x)/(d-c), c \le x \le d, \\ 0, \quad otherwise. \end{cases} \quad (2)$$

$$\bar{x}_0(\tilde{A}) = \frac{\int_a^d x\, \mu_{\tilde{A}}(x)dx}{\int_a^d \mu_{\tilde{A}}(x)\,dx} \quad (3)$$

$$(\tilde{A}) = U_\alpha \alpha\,(A_\alpha) = U_\alpha \alpha \left[(x)_\alpha^L, (x)_\alpha^U\right] (0 < \alpha < 1) \quad (4)$$

Fig. 2 illustrates criterion related correlation structure on Productivity and Quality Dimensions. The data collection and validation were carried out from May 2007 to May 2008 and subsequently implementation phase got started by the basis of the results from December 2008 to December 2010 in various industries. Ã is expressed by it is α– level sets [8]. It is represented in (1)-(4). Much information in FMEA can be expressed in a linguistic way such as likely, important or very high and so on. To overcome the above drawbacks, fuzzy logic has been widely applied in FMEA. This method requires a vast amount of expert knowledge and expertise. Fuzzy risk priority numbers are calculated for ten failure mode dimension, ten failure modes and all α levels, where the α levels are set as 0, 0.1, 0.2,……1.0 and solved by Linear Programming (LP) model. To sum up, this framework study will be of immense use to the textile processing and allied industries for improving the key performance indicators. Table I shows the Average OEE for all Machines after Implementing TPM. It satisfies the customers with a high quality fabric that is made available by means of the effective utilization of resources. Tables II and III give the Average Overall Equipment Effectiveness (OEE) for Jigger Machines after the identified result shown in Fig. 3.

TABLE I
AVERAGE OEE FOR ALL MACHINES AFTER IMPLEMENTING TPM

1 week / shift 1	Parameters (%)	Type of machines			
		Jigger	Stenter	Squeezing	Calender
	Availability	84.23	86.10	86.53	86.3
	Perform.	72.91	76.01	82.72	81.60
	Quality	91.61	98.62	98.22	98.45
	OEE	56.25	64.48	70.35	69.24

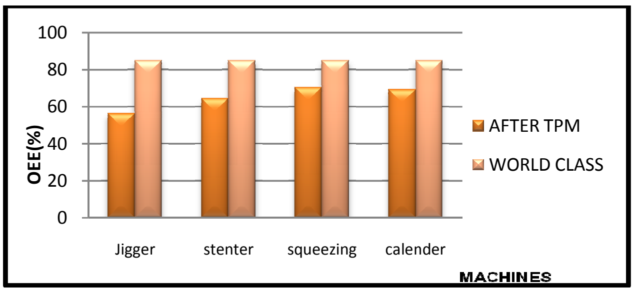

Fig. 1 OEE for all machines after implementing TPM

IV. RESULTS AND DISCUSSION

After an extensive survey, the work identified ten critical dimensions for Productivity and Quality Dimensions and their role in both fabric manufacturing and allied textile sector. Survey instruments comprising 90 items with respect to the textile sector have been developed based on the data collected from the textile engineers, field specialists and executives in the Erode and Tirupur Districts of Tamil Nadu, India. The results from fabric dyeing industries are as follows where as Figs. 1 and 4 illustrate OEE for all machines after implementing TPM. Fig. 2 illustrates Criterion related correlation structure on Productivity and Quality Dimensions.

- The total productivity value of fabric 2 is 0.936 for the period 0. This value is lesser than the corresponding break even value 0.993, thus indication the necessity of improving the utilization of resources (Partial Productivity resources) that corresponds to fabric 2 even though after implementing TPM and TOC.
- Increases of production by maximize the equipment utilization. Also Product quality improvement via the quality rate of the equipment.
- Improvement Planned maintenance of the equipment.
- Weak points will be revealed and priorities in the equipment of corrective actions will be given.
- Economy in natural resources and energy, via the reduction of downtimes, the total process time as well as to maximize the equipment utilization by total productive maintenance approach. Fig. 4 illustrates the Performance of OEE after Implementing TPM in Every Textile Dyeing Machines.

V. CONCLUSIONS

The following conclusions are brought after implementing fuzzication rate in the most commonly used fuzzy numbers are triangular and trapezoidal fuzzy numbers, whose membership functions are respectively defined in the equation. These three risk factors are assumed to be equally important. This may not be the case when considering a practical application of FMEA. These three factors are difficult to be precisely estimated. The present work deals with Fuzzy Weighted Geometric Mean Method (FWGMM) for risk evaluation and prioritization of failure modes in FMEA.

This method can overcome both the drawbacks of the crisp RPN and fuzzy if–then rules in order to identify critical risk priority number. This FRPNs is perfectly consistent with the ranking achieved by former intuitive analysis i.e., traditional FMEA. The defuzzified centroid values of the ten FRPNs give the priority ranking of the ten failure dimensions as $FM6 > FM10 > FM7 > FM8 > FM2 > FM9 > FM4 > FM3 > FM5 > FM1$. So, the final conclusion for this case study is that productivity and quality dimension (FM6) i.e., LPP is given top priority for dynamic correction, followed by failure modes 10, 7, 8, 2, 9, 4, 3, 5 and 1.

VI. Tables and Figures

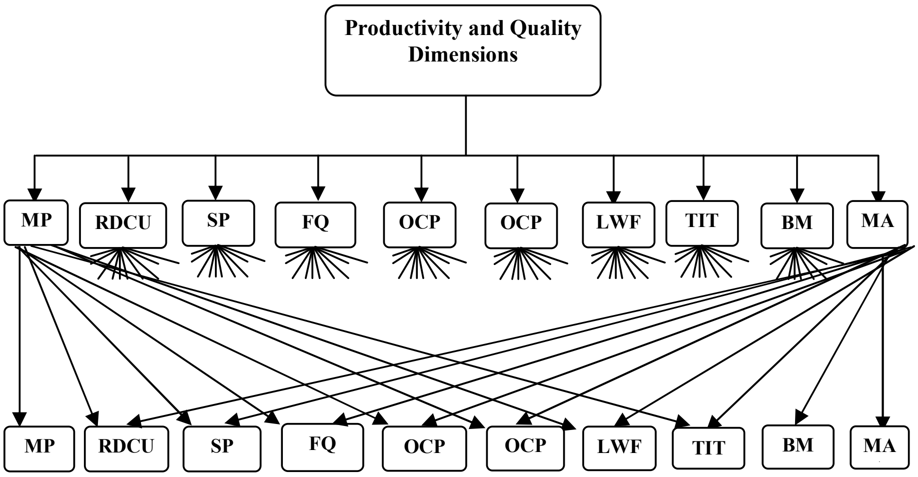

Fig. 2 Criterion related correlation structure on Productivity and Quality Dimensions

TABLE II
Average Overall Equipment Effectiveness (OEE) for Jigger Machines (for Example)

First Week / Shift 1	**Jigger Machines (12 Machines) – OEE (%)**											
Production Parameters	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Total Time (minutes)	480	480	480	480	480	480	480	480	480	480	480	480
Production Breaks	90	90	90	90	90	90	90	90	90	90	90	90
Machine Down Time	56	63	65	63	65	60	60.	66	69	52	60	53
Ideal Prod. Rate of machine	2	2	2	2	2	2	2	2	2	2	2	2
Total Fabric Production (m)	471	482	490.	475	466	500	474	466	459	503	460	504
Total Fabric Rejected (m)	35	48	38	43	44	37	37	30	38	51	36	47
Total Good Fabric Produced	436	434	452	433	422	463	437	436	421	452	424	457
Total Planned Prod. Time	390	390	390	390	390	390	390	390	390	390	390	390
Total Operating Time	334	326	325	327	325	330	330	324	321	338	330	337
Machine Availability (%)	85.68	83.75	83.32	83.75	83.32	84.39	84.39	83.11	82.25	86.74	84.61	85.46
Performance (%)	70.52	74	75.56	72.81	71.77	76.04	71.99	71.77	71.65	74.28	69.86	74.72
Quality (%)	92.52	90.10	92.09	91.22	90.63	92.57	92.37	93.96	91.85	89.26	92.07	90.76
OEE (%)	55.89	55.62	57.94	55.54	54.09	59.34	56.07	55.97	54.01	58.32	54.41	57.87

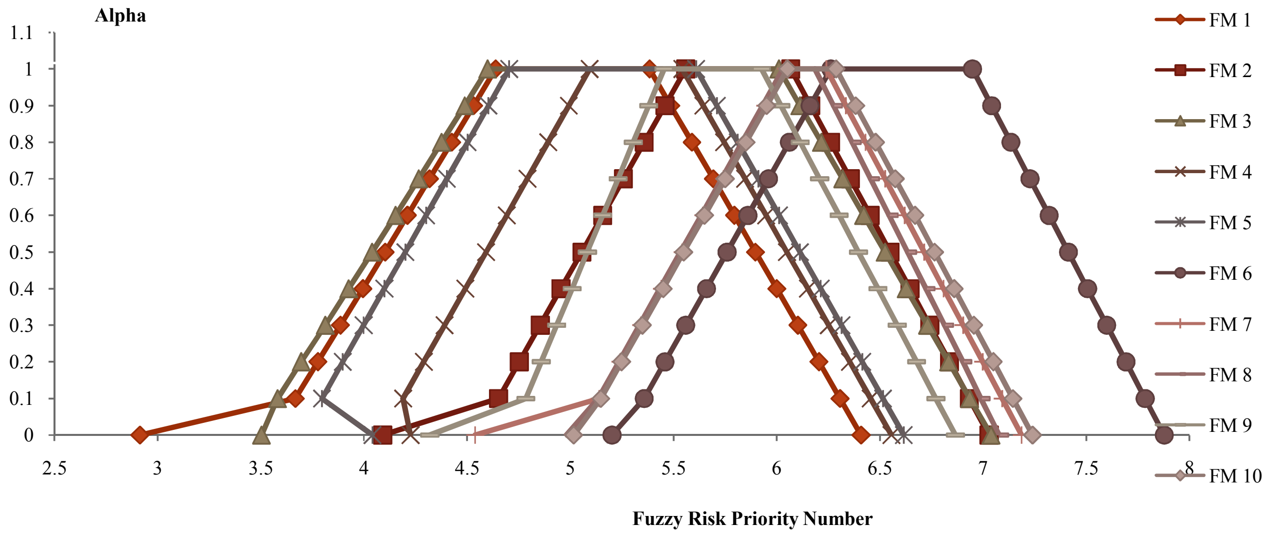

Fig. 3 Fuzzy Risk Priority Numbers (RPN) of the Ten Failure Modes

TABLE III
OEE PERFORMANCE OF FABRIC MACHINES FOR A WEEK AFTER TPM

	Production Parameters	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Stenter machine	Total Time (minutes)	480	480	480	480	480	480
	Production Breaks (minutes)	90	90	90	90	90	90
	Machine Down Time (minutes)	50	55	50	60	45	65
	Ideal Production Rate of Machine (minutes)	75	75	75	75	75	75
	Total Fabric Production (m)	22000	18000	17800	19000	18000	20000
	Total Fabric Rejected (m)	570	160	102	150	300	350
	Total Good Fabric Produced (m)	21430	17840	17698	18850	17700	19650
	Total Planned Production Time (minutes)	390	390	390	390	390	390
	Total Operating Time (minutes)	340	335	340	330	345	325
	Machine Availability (%)	87.17	85.89	87.17	84.61	88.46	83.33
	Performance (%)	86.27	71.64	69.8	76.76	69.56	82.05
	Quality (%)	97.4	99.11	99.42	99.21	98.33	98.25
	OEE (%)	73.24	60.98	60.49	64.43	60.62	67.17
Squeezing machine	Total Time (minutes)	480	480	480	480	480	480
	Production Breaks (minutes)	90	90	90	90	90	90
	Machine Down Time (minutes)	50	65	55	40	60	45
	Ideal Production Rate of Machine (m/ mins)	55	55	55	55	55	55
	Total Fabric Production (m)	14500	13500	15000	17250	15500	17000
	Total Fabric Rejected (m)	255	250	500	275	328	300
	Total Good Fabric Produced (m)	14245	13250	14500	16975	15172	16700
	Total Planned Production Time (minutes)	390	390	390	390	390	390
	Total Operating Time (minutes)	340	325	335	350	330	345
	Machine Availability (%)	87.17	83.33	85.89	89.74	84.61	88.46
	Performance (%)	77.54	75.52	78.69	89.61	85.39	89.59
	Quality (%)	98.24	98.14	98.46	98.4	97.88	98.23
	OEE (%)	66.4	61.73	66.54	79.12	70.71	77.84
Calender machine	Total Time (minutes)	480	480	480	480	480	480
	Production Breaks (minutes)	90	90	90	90	90	90
	Machine Down Time (minutes)	45	50	40	60	55	50
	Ideal Production Rate of Machine	70	70	70	70	70	70
	Total Fabric Production (m)	18500	20000	19000	18000	20000	21000
	Total Fabric Rejected (m)	250	355	250	200	300	375
	Total Good Fabric Produced (m)	18250	19645	18750	17800	19700	20625
	Total Planned Production Time (minutes)	390	390	390	390	390	390
	Total Operating Time (minutes)	345	340	350	330	335	340
	Machine Availability (%)	88.46	87.17	89.74	84.61	85.89	81.93
	Performance (%)	76.6	84.03	77.55	77.92	85.28	88.23
	Quality (%)	98.64	98.22	98.68	98.88	98.12	98.21
	OEE (%)	66.83	71.94	68.67	65.19	71.86	70.99

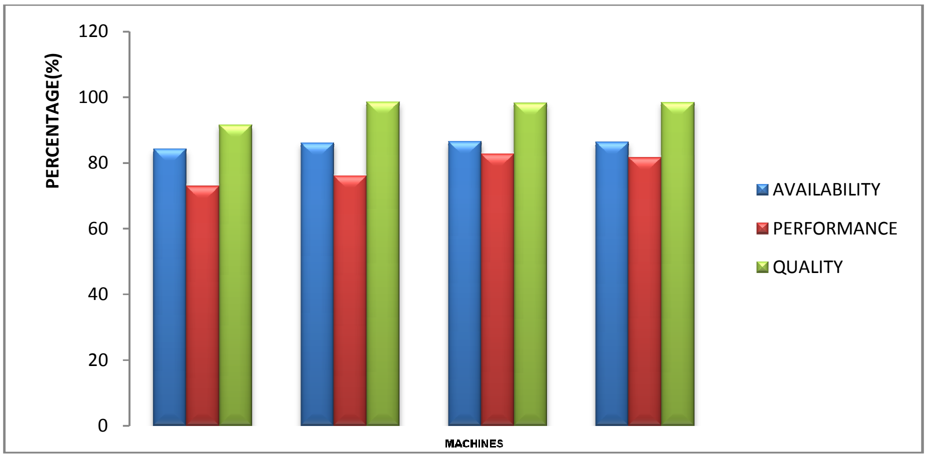

Fig. 4 Performance of OEE after Implementing TPM in Every Textile Dyeing Machines

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