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INVESTIGATION OF FMEA AND TPM FOR IMPROVED RELIABILITY AND QUALITY OF SMES

[1*]Waghmare, S. N., [2]Dr. Raut, D. N., [3]Dr. Mahajan, S. K. and [4]Dr. Bhamare, S. S.

[1,2]Production Engineering Department, VJTI, Matunga, Mumbai, Maharashtra, India
[3]Directorate of Technical Education, Govt. of Maharashtra, India
[4]RBTE, Pune, Maharashtra, India

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ABSTRACT

Despite their high enthusiasm and inherent capabilities to grow, SMEs in India are facing a number of problems like technological obsolescence, increasing domestic and global competition, and change in manufacturing strategies. To survive with such issues and compete with large and global enterprises, SMEs need to adopt innovative approaches in their operations. Failure Mode and Effects Analysis (FMEA) is one of the most effective techniques to achieve high reliability and Total Productive Maintenance (TPM) improves product quality, reduce waste, reduce manufacturing cost, increase equipment availability. This paper investigates the effect of different classes of failures on production process by using factor analysis. A survey was carried out to collect the data from different SMEs (473 industries) through questionnaire supplied to them. The Statistical Package for Social Sciences version 16 was used to analyse the effect of independent variables such as equipment problem, procedure problem, personnel error, and design problem, training deficiency, and management problem, external phenomena on dependent variables such as severity, occurrence, and detection. Also the effect of TPM pillars on quality of SMEs. This research paper further provides guidelines to SMEs to understand effect of FMEA and TPM on production process.

INTRODUCTION

Micro, small and Medium Enterprises (MSMEs) are one of the most vibrant and sensitive sectors in Indian economy. The significance of Micro, small and Medium Enterprises (MSMEs) is attributable to its capacity of employment generation, low capital and technology requirement, use of traditional or inherited skill, use of local resources, mobilization of resources and exportability of products. Despite their high enthusiasm and inherent capabilities to grow, SMEs in India are also facing a number of problems like technological obsolescence, increasing domestic and global competition, and change in manufacturing strategies. With the introduction of reform measures in India since 1991, the Govt. has withdrawn many protective policies for the Micro, Small and Medium Enterprise (MSMEs) and introduced promotional policies to increase competitiveness of the sector. To survive with such issues and compete with large and global enterprises, SMEs need to adopt innovative approaches in their operations (Annual Report *et al.,* 2012-13 Govt. of India). Failure modes and effects analysis (FMEA) is one potential tool used in reliability engineering. FMEA is a reliability procedure which documents all possible failures in a system design within specified ground rules. It determines, by failure mode analysis, the effect of each failure on system operation. The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones (George Pantazopoulos *et al.,* 2005).

The risk priority number (RPN). This number is used to rank order the various concerns and failure modes associated with a given design or process. *RPN* = Severity (S) x Occurrence (O) x Detection (D). Total Productive Maintenance (TPM) is a unique Japanese philosophy, which has been developed based on the productive maintenance concepts and methodologies. This concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company, Japan in the year 1971 (Nakajima *et al.,* 1988). TPM is a waste reducing approach to stabilise utilisation of machining resources. TPM focuses on improving machine availability and includes monitoring of machine equipment called overall equipment efficiency to visualise losses of utilisation.

***Corresponding author: Waghmare, S. N.,**
Production Engineering Department, VJTI, Matunga, Mumbai, Maharashtra, India

Implementation of TPM usually starts with a pilot project (Jostes *et al.,* 1994). The main focus of TPM is on the condition of the equipment and its influence on quality of output. Eight pillars of TPM are 5s, autonomous maintenance, continuous improvement (kaizen), planned maintenance, quality maintenance, education and training, office tpm, safety, health and environment control.

Literature review

Pramod, (2006) provided maintenance engineering community with a model named "Maintenance quality function deployment" (MQFD) for nourishing the synergy of quality function deployment (QFD) and total productive maintenance (TPM) and enhanced maintenance quality of products and equipment. The principles of QFD and TPM were studied. MQFD model was designed by coupling these two principles. The practical implementation feasibility of MQFD model was checked in an automobile service station. Kostina *et al.* (2012) developed a reliability assessment method with an extension of the existing ones and pooling them to a common framework and the system must identify the most unreliable parts of a production process and suggest the most efficient ways for the reliability improvement.

FMEA is in the centre of the proposed frame work, a reliability analysis type, and the most widely used in enterprises. The current research suggests extending the FMEA by introducing a classification of faults. Karaulova *et al.* (2012) used Faults classification for machinery enterprises developed the reliability assessment. The system identified the most unreliable parts of a production process and suggests the most efficient ways for the reliability improvement. Jevgeni Sahno *et al.* (2013) proposed Faults Classification for a Machinery Enterprise. Reliability engineering is dealing with an analysis of the causes of the faults in factories and developed a faults classification based on DOE-NE-STD-l004-92 standard shown as follows.

(1) Equipment Problem-Defective or failed part, Equipment failures, Bad equipment works, Contaminations, Critical human errors,
(2) Procedure Problem-Defective or inadequate, Lack of procedure, Error in equipment or material selection, Error in tool or cutting data selection.
(3) Personnel error-In adequate work environments, in attention to detail, Violation of requirement or procedure, Verbal communication problems.
(4) Design Problem-Inadequate designs, Drawing specification, or data error, Dimensions related problems, and Technological parameters problems.
(5) Training deficiency-No training provided, insufficient practice or hands-on experience, in adequate content, insufficient refresher training on or materials, inadequate presentations or materials.
(6) Management problem-Inadequate administrative controls, Work organisations or planning deficiency, Inadequate supervisors, Improper resource allocations, Policy not adequately defined or enforced,
(7) External Phenomena-Communication problems, Time delivery error, Defective product or material.

Shamsuddin *et al.* (2005) presented a generic model on using the total productive maintenance (TPM) concept in conjunction with ecology oriented manufacturing (EOM) and 5S focusing on their joint strengths in attaining organizational goals in furtherance to the equipment maintenance objectives. Moradi, *et al.* (2011) explicated relations between 5S and pillars of Total Productive Maintenance (TPM). In order to evaluate performance and effectiveness of 5S benefited from a checklist by which status of implementation and execution of 5S in a foodstuff production factory in Iran has been studied. Rajesh Bajaj *et al.* (2011) carried out efforts towards identifying the specific TPM activities, which can be implemented for a particular type of enterprise and achieve the benefits; without investing the resources. For large enterprises allocation of all these resources may not be a difficult. However for a medium or small or micro enterprise, which are always under constraint due to resource paucity, application of Total Productive Maintenance in totality may not be feasible. Next best alternative he suggested is to identify pillar wise activities, which can be undertaken by the medium, small or micro enterprises to achieve the benefits from TPM.

Gupta *et al.* (2014) implemented some of the 5S and kaizen principles to assist small scale manufacturing organisations to become more efficient and more productive. The 5S and kaizen rules in the organisation have been analysed and implemented through case study. Vardhan S *et al.* (2015) demonstrated the contributions of Quality Maintenance (QM) Pillar of TPM approach in improving the product quality in a food industry manufacturing potato chips. QM Pillar is an important initiative of TPM methodology which aims to give customer delight through defect free manufacturing. Quality and reliability are synonymous. A system cannot be reliable if it does not have high quality. Likewise, a system cannot be of high quality if it is not reliable. The goal of quality and reliability systems is the same –to achieve customer satisfaction. If a system is unreliable, it is unpredictable and if it is unpredictable, it is not of high quality Christian N. Madu *et al.*, (1999). In order to retain in global competition it is necessary for SMEs sector to concentrate on reliability and quality aspect.

Conceptual framework

The investigation in the scope of research problem is governed by the conceptual framework presented in Figure 1.

MATERIALS AND METHODS

Dependent variables are the ones that depend on other variables. The value of dependent variable depends on independent variable. They are not directly tangible, but have a strong correlation with independent variables. Independent variables mainly contribute to measurement of model Patil *et al.*, (2012). In this Research model, the Independent variables are equipment problem, procedure problem, personnel error training deficiency, management problem, external phenomena and tpm pillars. The dependent variables are severity; occurrence, detection and quality. Based on the literature review following hypotheses are investigated in the empirical analysis:

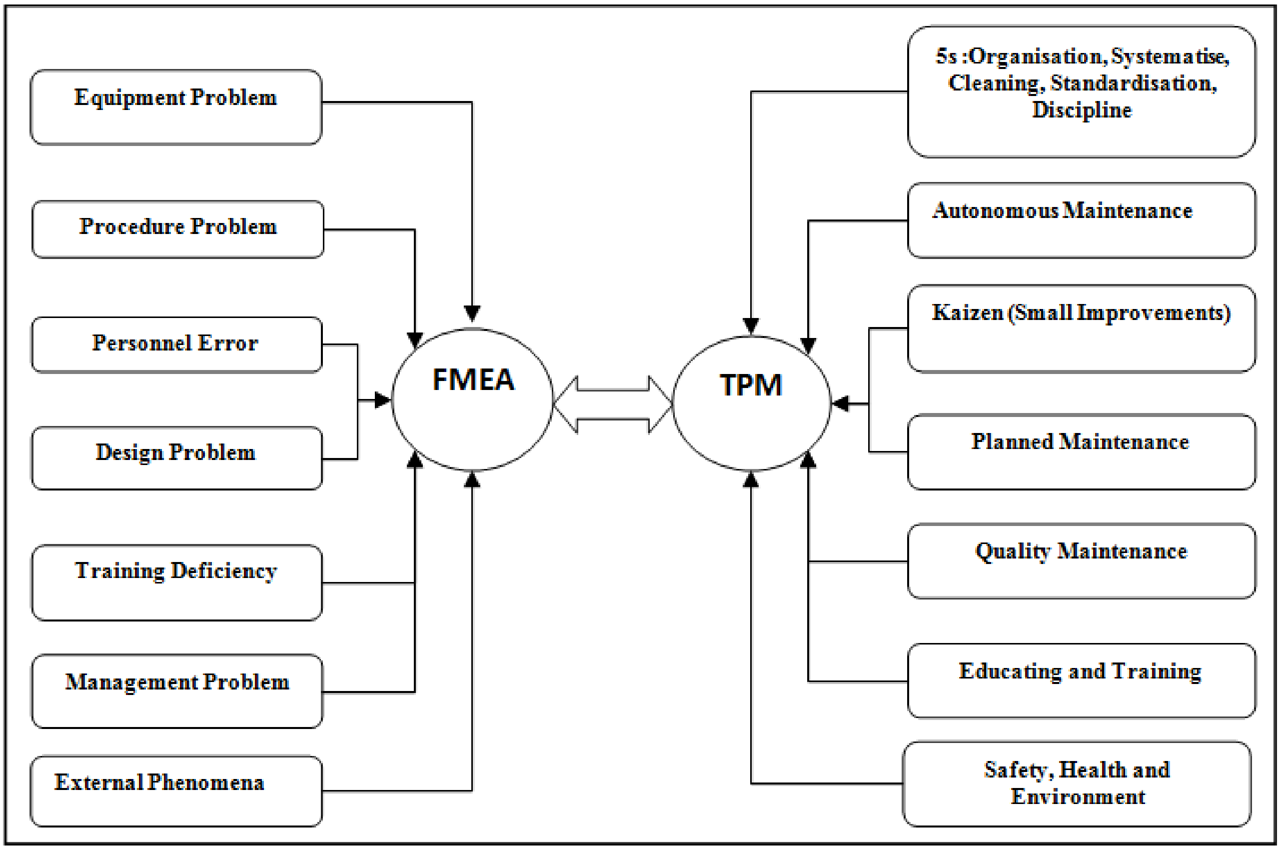


Figure 1. Conceptual Framework

Hypothesis

H1 Equipment Problem has significant effect on the production process.

H2 Procedure Problem has significant effect on the production process.

H3 Personnel Error has significant effect on the production process.

H4 Design Problem has significant effect on the production process.

H5 Training Deficiency has significant effect on the production process.

H6 Management Problem has significant effect on the production process.

H7 External Phenomena has significant effect on the production process.

H8 5s (Organization, Systematize, Cleaning, Standardization, and Discipline) has significant effect on the quality.

H9 Autonomous Maintenance has significant effect on the quality.

H10 Kaizen (Small Continuous Improvements) has significant effect on the quality.

H11 Planned Maintenance has significant effect on the quality.

H12 Quality Maintenance has significant effect on the quality.

H13 Educating and Training has significant effect on the quality.

H14 Safety, Health and Environment have significant effect on the quality.

Data Collection

We surveyed 473 small to large size firms through a survey questionnaire. As Hair *et al*. (2012) suggests a general rule for researcher to obtain observations five times greater than the number of variables to be analysed. Thus 473 were adequate to take up the analysis. Table 1 shows descriptive statistics of respondent companies.

Table 1. Profile of Respondent SMEs

Parameter	Number of Companies	Percentage %
Number of employees		
1. Less than 10	77	16.28
2. Less than 20	145	30.66
3. Less than 50	163	34.46
4. Less than 100	74	15.64
5. More than 100	14	2.96
Total	473	100.00
Organisation Type		
1. Micro	140	29.60
2. Small	161	34.04
3. Medium	172	36.36
Total	473	100.00
Sector		
Metal Processing	79	16.70
Machinery and Equipment	168	35.52
Packaging	31	6.55
Chemical	35	7.40
Food Processing	12	2.54
Automobile	57	12.05
Others	91	19.24
Total	473	100.00

Measures

Respondent were asked to rate Severity, Occurrence, Detection and Quality important to their industry on production process.

Scale for Severity- 1=None, 2= Slight, 3=Moderate, 4= High Severity, 5= Extreme Severity

Scale for Occurrence - 1=Extremely Unlikely, 2=Very Low Likelihood, 3= Moderately Low Likelihood, 4=Moderately High Likelihood, 5=Extreme Likelihood

Scale for Detection – 1=Extremely Likely, 2=High Likelihood, 3=Medium Likelihood, 4=Low Likelihood, 5=Remote Likelihood

Scale for TPM Pillars: 1 = Not at all, 2 = moderately important, 3 = strongly important, 4 = Very strongly important, 5 = extremely important

Validity and Reliability

Kaiser-Meyer-Olkin (KMO) and Bartlett's test is used for determining sampling adequacy for conducting factor analysis. First we conducted KMO and Bartlett's test to check sampling adequacy for factor analysis. The KMO values for our test carried out were from 0.653 to 0.909 and Bartlett's value lower than 0.001. The test resulted for KMO in the values greater than 0.5 indicating the sample being adequate for factor analysis (Kaizer, 1974). Bartlett's test of sphericity showed the significance level lower than the 0.001 that the correlation matrix was not identity matrix (Jantunen, 2005). Convergent validity is considered to be satisfactory when items load high on their respective factors and all high loadings greater than 0.40 signifying convergent validity Narkhede *et al*. (2012). Reliability is the degree to which measures are free from error and therefore yield consistent results Thanasegaran *et al*. (2009). Internal consistency concerns the reliability of the test components. The most popular method of testing for internal consistency in the behavioural sciences is coefficient alpha Drost *et al.* (2011). The suggested Cronbach alpha is a minimum of 0.60 Bokade *et al*. (2014), Hair, (2012), Hulland, (1999). The reliability test resulted in Cronbach alpha was 0.613 to 0.865, above 0.60 indicating significant reliability of measures.

Table 2 shows correlation matrix of severity for H1,H2,H3,H4, Table 3 shows statistics of construct of severity for H1,H2,H3,H4, Table 4 shows correlation matrix of severity for H5,H6,H7 and Table 5 shows statistics of construct of severity for H5,H6,H7. Table 6 shows correlation matrix of occurrence for H1,H2,H3,H4, Table 7 shows statistics of construct of occurrence for H1,H2,H3,H4, Table 8 shows correlation matrix of occurrence for H5,H6,H7 and Table 9 shows statistics of construct of occurrence for H5,H6,H7 Table 10 shows correlation matrix of detection for H1,H2,H3,H4, Table 11 shows statistics of construct of detection for H1,H2,H3,H4, Table 12 shows correlation matrix of detection for H5,H6,H7 and Table 13 shows statistics of construct of detection for H5,H6,H7 Table 14 shows correlation matrix of quality for H8,H9,H10,H11, Table 15 shows statistics of construct of quality for H8,H9,H10,H11,H12,H13,H14 and Table 16 shows correlation matrix of quality for H12,H13,H14.

Table 2. Correlations matrix

	AVGSEV	EP	PP	PE	DP
AVGSEV	1.000	.877	.841	.816	.822
EP	.877	1.000	.707	.674	.672
PP	.841	.707	1.000	.660	.640
PE	.816	.674	.660	1.000	.619
DP	.822	.672	.640	.619	1.000

Table 3. Statistics of construct

Constructs	KMO values	Cronbach Alpha	Eigen Values	% Variance explained	No. of Factors Indicated
EP	.909	.841	6.955	32.375	05
PP		.850	1.580	39.731	04
PE		.860	1.327	45.909	04
DP		.865	1.160	51.310	04

Table 4. Correlations matrix

	AVGSEV	TD	MP	EXP
AVGSEV	1.000	.837	.869	.774
TD	.837	1.000	.651	.588
MP	.869	.651	1.000	.659
EXP	.774	.588	.659	1.000

Table 5. Statistics of construct

Constructs	KMO values	Cronbach Alpha	Eigen Values	% Variance explained	No. of Factors Indicated
TD	.870	.794	5.807	33.218	05
MP		.738	1.401	41.233	05
EXP		.787	1.333	48.859	03

Table 6. Correlations matrix

	AVGOCC	EP	PP	PE	DP
AVGOCC	1.000	.785	.725	.720	.683
EP	.785	1.000	.447	.489	.439
PP	.725	.447	1.000	.437	.430
PE	.720	.489	.437	1.000	.381
DP	.683	.439	.430	.381	1.000

Table 7. Statistics of construct

Constructs	KMO values	Cronbach Alpha	Eigen Values	% Variance explained	No. of Factors Indicated
EP	.768	.681	4.165	18.629	05
PP		.698	1.789	26.632	04
PE		.700	1.555	33.587	04
DP		.716	1.434	40.000	04

Table 8. Correlations matrix

	AVGOCC	TD	MP	EXP
AVGOCC	1.000	.837	.869	.774
TD	.837	1.000	.651	.588
MP	.869	.651	1.000	.659
EXP	.774	.588	.659	1.000

Table 9. Statistics of construct

Constructs	KMO values	Cronbach Alpha	Eigen Values	% Variance explained	No. of Factors Indicated
TD		.613	2.739	16.638	05
MP	.653	.630	1.681	26.850	05
EXP		.625	1.557	36.311	03

Table 10. Correlations matrix

	AVGDET	EP	PP	PE	DP
AVGDET	1.000	.780	.659	.736	.761
EP	.780	1.000	.464	.505	.529
PP	.659	.464	1.000	.349	.374
PE	.736	.505	.349	1.000	.536
DP	.761	.529	.374	.536	1.000

Table 11. Statistics of construct

Constructs	KMO values	Cronbach Alpha	Eigen Values	% Variance explained	No. of Factors Indicated
EP		.687	4.684	21.253	05
PP	.807	.765	1.674	28.850	04
PE		.713	1.604	36.127	04
DP		.698	1.418	42.561	04

Table 12. Correlations matrix

	AVGDET	TD	MP	EXP
AVGDET	1.000	.816	.769	.718
TD	.816	1.000	.576	.547
MP	.769	.576	1.000	.469
EXP	.718	.547	.469	1.000

Table 13. Statistics of construct

Constructs	KMO values	Cronbach Alpha	Eigen Values	% Variance explained	No. of Factors Indicated
TD		.631	4.059	23.718	05
MP	.777	.702	1.508	32.528	05
EXP		.731	1.435	40.912	03

Table 14. Correlations matrix

	AVGPLRS	5S	AM	KAI	PM
AVGPLRS	1.000	.566	.629	.677	.668
5S	.566	1.000	.133	.162	.343
AM	.629	.133	1.000	.287	.298
KAI	.677	.162	.287	1.000	.363
PM	.668	.343	.298	.363	1.000

Table 15. Statistics of construct

Constructs	KMO values	Cronbach Alpha	Eigen Values	% Variance explained
5S		.725	4.122	39.073
AM		.705	1.633	54.549
KAI		.688	1.447	68.263
PM	.702	.691	1.061	78.322
QM		.712	.919	87.033
ET		.698	.828	94.882
SHE		.713	.540	100.000

Table 16. Correlations matrix

	AVGPLRS	QM	ET	SHE
AVGPLRS	1.000	.586	.646	.581
QM	.586	1.000	.288	.155
ET	.646	.288	1.000	.116
SHE	.581	.155	.116	1.000

RESULTS AND DISCUSSION

We investigated (H1, H2, H3, H4) the effect of Equipment Problem, Procedure Problem, Personnel Error, and Design Problem on severity of failure. The investigation resulted in the R^2 (proportion of variation that is explained by the model) value of 0.945 representing a good model fit. This value is significant to define a high strength of association of the variables (Bokade *et al.*, 2014). H1 is supported with β value of .344 and P value .000. H2 is supported with β value of .264 and P value .000. H3 is supported with β value of .241 and P value .000. H4 is supported with β value of .272 and P value .000. Again we investigated (H5, H6, H7) the effect of Training Deficiency, Management Problem, and External Phenomena on severity of failure. The resulted in the R^2 value of 0.914 representing a good model fit. H5 is supported with β value of .404 and P value .000. H6 is supported with β value of .447 and P value .000. H7 is supported with β value of .242 and P value .000. The results for Hypothesis of occurrence, detection and quality as shown in Table 17.

Table 17. Hypothesis Test Results

	Hypothes	R^2	ß	p	Remark
Severity	H1 (EP)	0.94	0.34	0.00	Support
	H2 (PP)	0.94	0.26	0.00	Support
	H3 (PE)	0.94	0.24	0.00	Support
	H4 (DP)	0.94	0.27	0.00	Support
	H5 (TD)	0.91	0.40	0.00	Support
	H6 (MP)	0.91	0.44	0.00	Support
	H7	0.91	0.24	0.00	Support
Occurrence	H1 (EP)	0.92	0.38	0.00	Support
	H2 (PP)	0.92	0.30	0.00	Support
	H3 (PE)	0.92	0.29	0.00	Support
	H4 (DP)	0.92	0.26	0.00	Support
	H5 (TD)	0.84	0.49	0.00	Support
	H6 (MP)	0.84	0.40	0.00	Support
	H7	0.84	0.27	0.00	Support
Detection	H1 (EP)	0.90	0.32	0.00	Support
	H2 (PP)	0.90	0.28	0.00	Support
	H3 (PE)	0.90	0.30	0.00	Support
	H4 (DP)	0.90	0.32	0.00	Support
	H5 (TD)	0.86	0.43	0.00	Support
	H6 (MP)	0.86	0.37	0.00	Support
	H7	0.86	0.30	0.00	Support
Quality	H8 (5S)	0.90	0.35	0.00	Support
	H9 (AM)	0.90	0.38	0.00	Support
	H10	0.90	0.40	0.00	Support
	H11	0.90	0.28	0.00	Support
	H12(QM	0.80	0.37	0.00	Support
	H13 (ET)	0.80	0.48	0.00	Support
	H14(SHE	0.80	0.46	0.00	Support

Normality of the error terms were tested by examining Histogram and Normal Probability plot (Bokade *et al.*, 2014). The simplest diagnostic for normality is a visual check of histogram and a more reliable approach is the normal probability plot. The normal distribution forms a straight diagonal line and the plotted values are compared with the diagonal. If a distribution is normal the line representing the actual data distribution closely follows the diagonal (Hair *et al.*, 2007). Figure 2 shows Histogram for normality check and Figure 3 shows Normal Probability Plot for normality check of H1, H2, and H3, H4 for severity and Figure 4 shows Histogram for normality check and Figure 5 shows Normal Probability Plot for normality check of H5, H6, and H7 for severity.

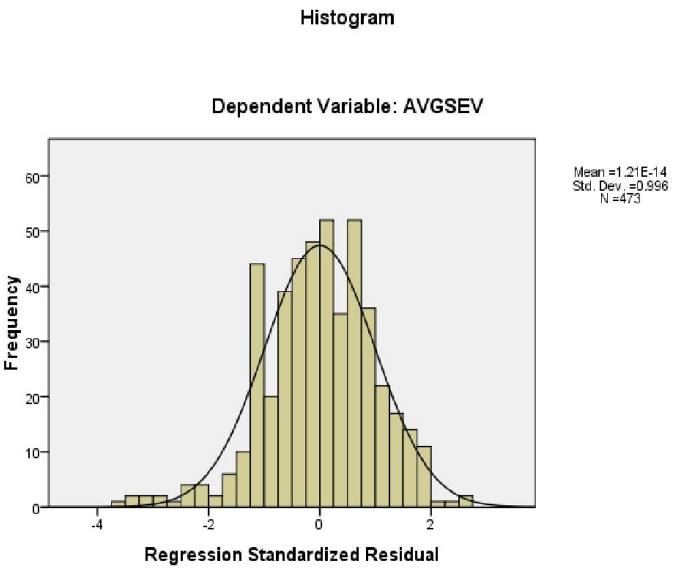


Figure 2. Histogram for normality check

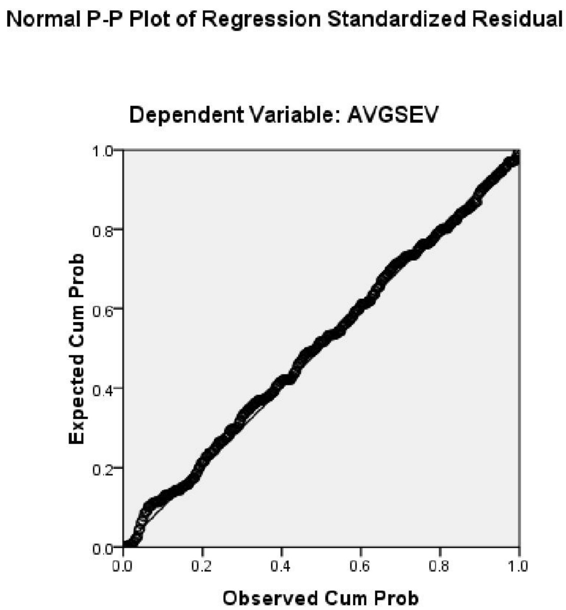


Figure 3. Normal Probability Plot for normality check

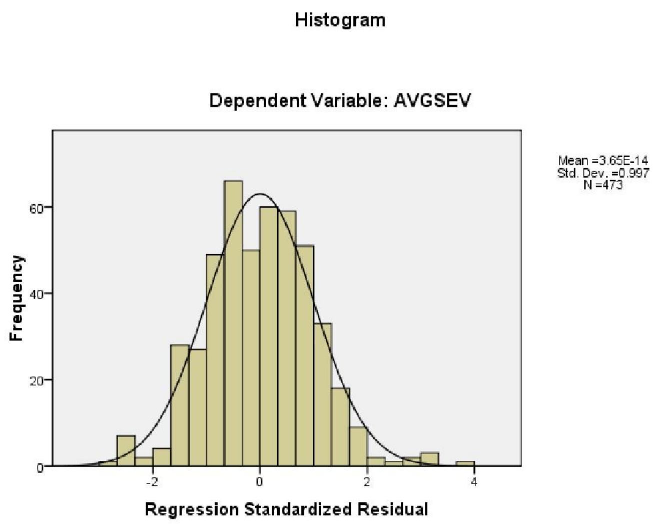


Figure 4. Histogram for normality check

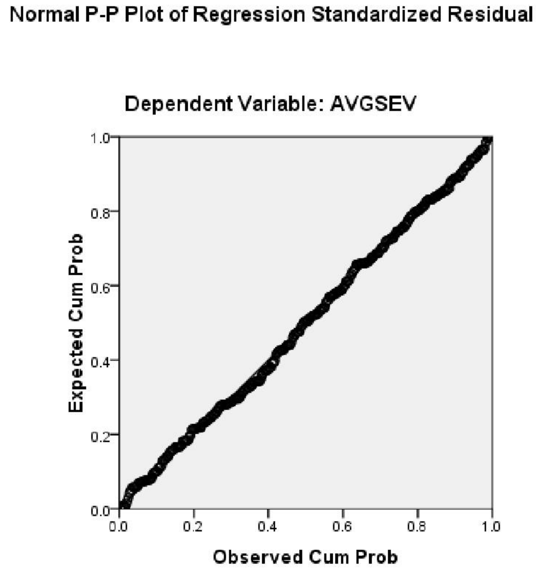


Figure 5. Normal Probability Plot for normality check

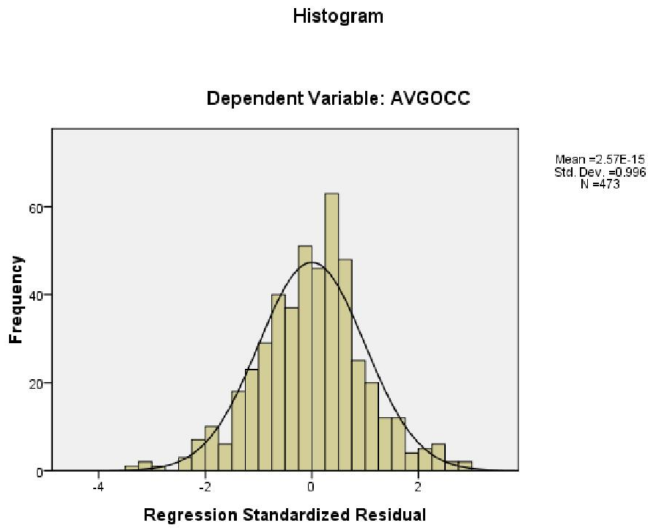
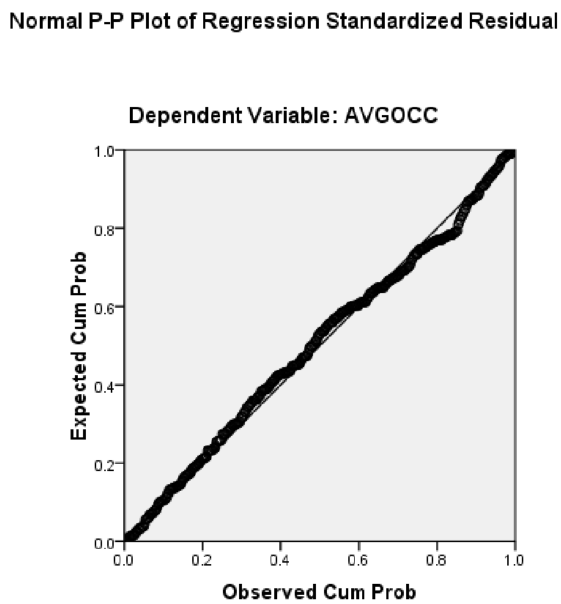


Figure 6. Histogram for normality check



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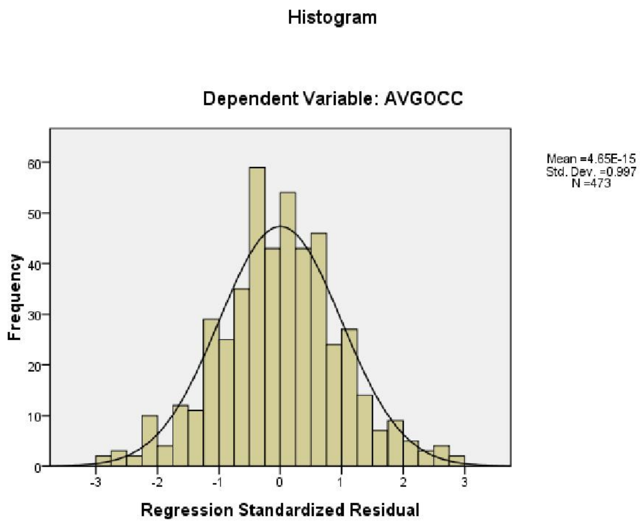


Figure 8. Histogram for normality check

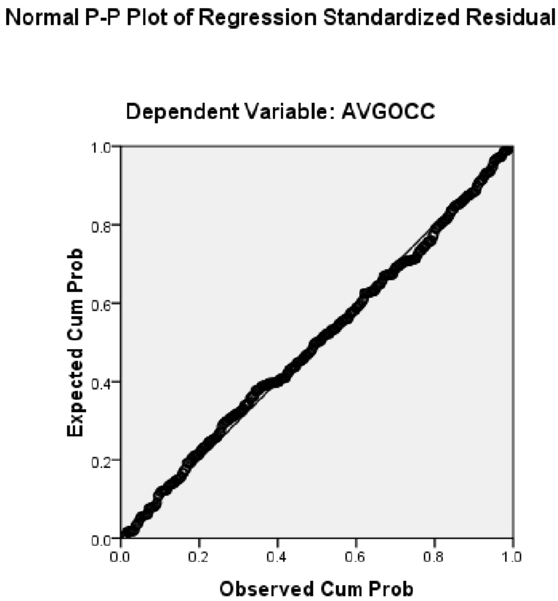


Figure 9. Normal Probability Plot for normality check

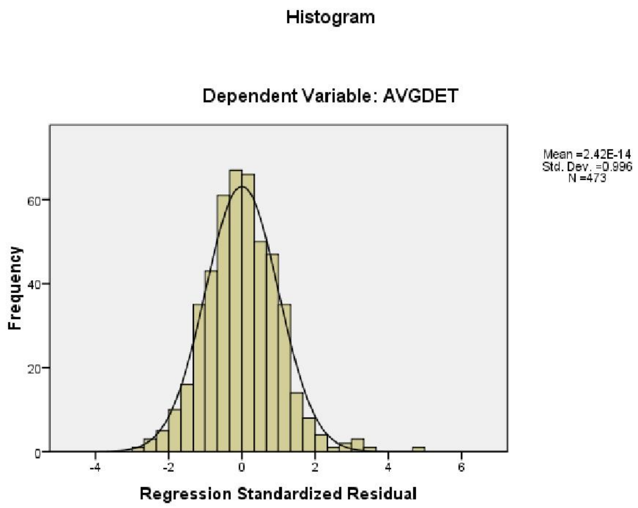
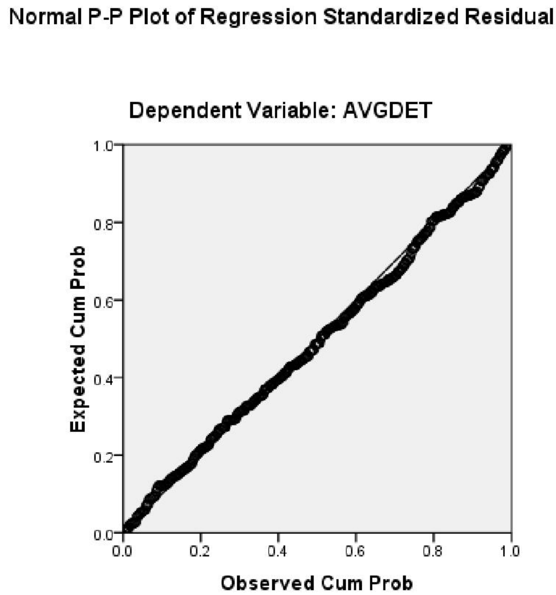


Figure 10. Histogram for normality check



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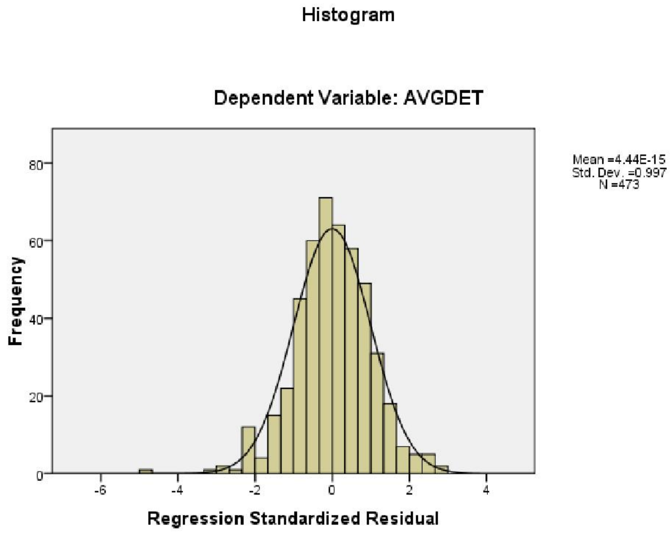

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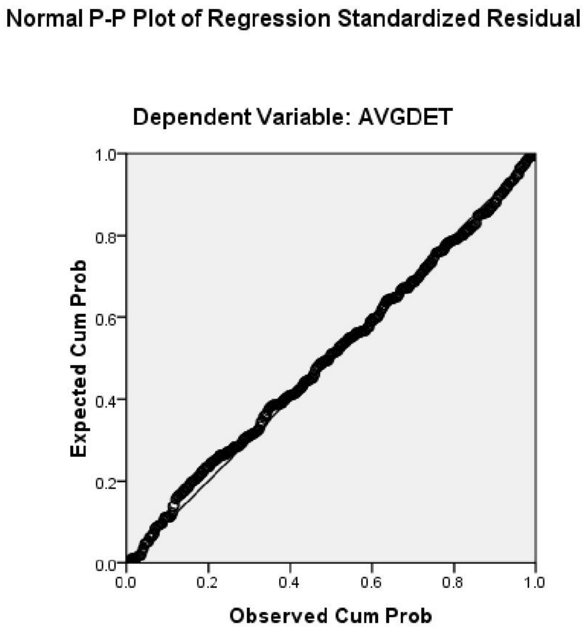

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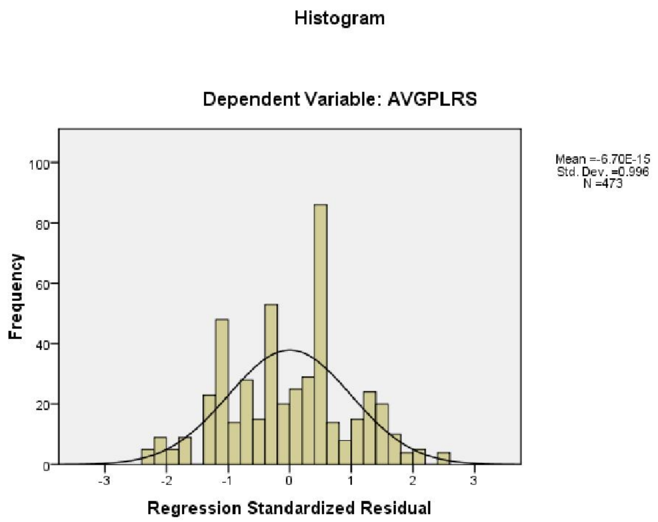

Figure 14. Histogram for normality check

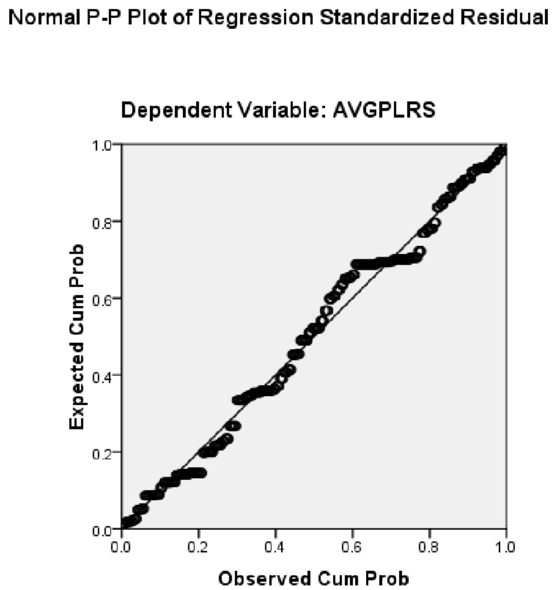

Figure 15. Normal Probability Plot for normality check

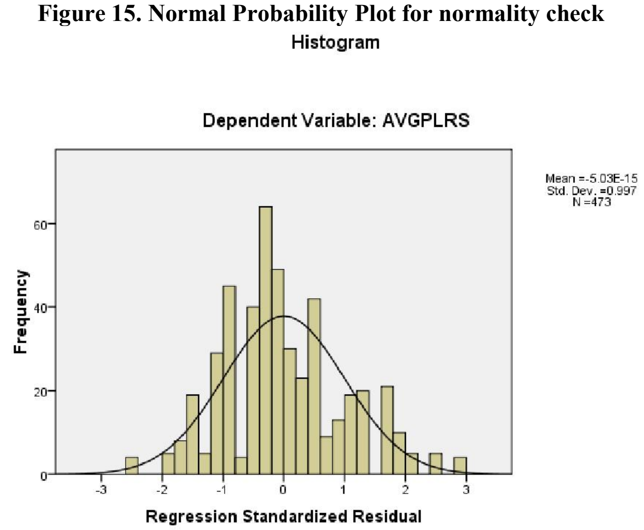

Figure 16. Histogram for normality check

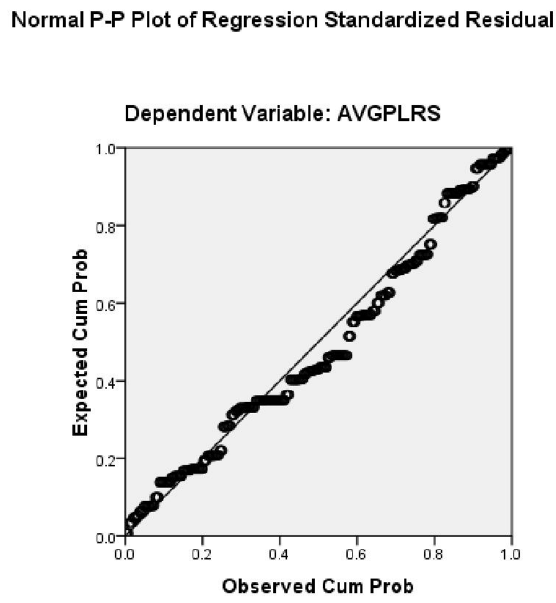

Figure 17. Normal Probability Plot for normality check

Figure 6 shows Histogram for normality check and Figure 7 shows Normal Probability Plot for normality check of H1, H2, and H3, H4 for occurrence and Figure 8 shows Histogram for normality check and Figure 9 shows Normal Probability Plot for normality check of H5, H6, and H7 for occurrence. Figure 10 shows Histogram for normality check and Figure 11 shows Normal Probability Plot for normality check of H1, H2, and H3, H4 for detection and Figure 12 shows Histogram for normality check and Figure 13 shows Normal Probability Plot for normality check of H5, H6, and H7 for detection. Figure 14 shows Histogram for normality check and Figure 15 shows Normal Probability Plot for normality check of H8, H9, and H10, H11 for quality and Figure 16 shows Histogram for normality check and Figure 17 shows Normal Probability Plot for normality check of H12, H13, and H14 for quality.

The resulting equations after analysis.

For Hypothesis H1, H2, H3, H4

Severity = 0.344 EP + 0.264 PP + 0.241 PE + 0.272 DP
Occurrence = 0.385 EP + 0.309 PP + 0.244 PE + 0.269 DP
Detection = 0.328 EP + 0.282 PP + 0.300 PE + 0.322 DP

For Hypothesis H5, H6, H7

Severity = 0.404 TD + 0.447 MP + 0.242 EXP
Occurrence = 0.498 TD + 0.407 MP + 0.274 EXP
Detection = 0.432 TD + 0.377 MP + 0.305 EXP

For Hypothesis H8, H9, H10, H11

Quality = 0.351 5S + 0.380 AM + 0.408 KAI + 0.286 PM

For Hypothesis H12, H13, H14, H15

Quality = 0.375 QM + 0.484 ET + 0.467 SHE

Conclusions

In this study, we have empirical studied the effect of equipment problem, procedure problem, personnel error training deficiency, management problem, and external phenomena on severity, occurrence and detection of production process and the effect of tpm pillars on quality of process. The aim of this paper is to observe effect failures and tpm pillars on quality and reliability of SMEs. This paper provides guidelines for SMEs to reduce failures for improving reliability of production process and to implement tpm pillar wise for improving quality of production process. The study has not considered the cost factor and further research can be carried out by considering cost factor.

REFERENCES

Ahmed, S., Hj. Hassan, M. and Taha, Z. 2005. TPM can go beyond maintenance: excerpt from a case Implementation. *Journal of Quality in Maintenance Engineering*, *11*(1), 19-42.

Annual Report 2012-13 Micro Small and Medium Enterprises, Ministry of Micro, Small and Medium Enterprises, Government of India.

Christian N. Madu, 1999. "Reliability and quality Interface", *International Journal of Quality and Reliability Management*, Vol. 16 No. 7, 1999, pp. 691-698.

Drost, Ellen, A. 2011. "Validity and reliability in social science research." *Education Research and Perspectives* 38.1: 105.

George Pantazopoulos and George Tsinopoulos, 2005. "Process Failure Modes and Effects Analysis (PFMEA): A Structured Approach for Quality Improvement in the Metal Forming Industry", *Journal of Failure Analysis and Prevention,* volume- 2, pp.5-10.

Gupta, Shaman and Sanjiv Kumar Jain, 2014. "The 5S and kaizen concept for overall improvement of the Organisation: a case study." *International Journal of Lean Enterprise Research* 1.1 (2014): 22-40.

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E. and Tatham R.L. 2012. Multivariate Data Analysis. Seventh Edition *Pearson Publication, Dorling Kindersley (India) Pvt Ltd.*

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E. and Tatham R.L. 2007. Multivariate Data Analysis. Sixth Edition, *Pearson Publication, Dorling Kindersley (India) Pvt Ltd.*

Hulland, J. 1999. "Use of partial least squares (PLS) in strategic management research: A review of four recent studies", *Strategic Management Journal,* Vol. 20(2), pp.195–204.

Jantunen, A. 2005. Knowledge-processing capabilities and innovative performance: an empirical study. *European Journal of Innovation Management*, *8*(3), 336-349.

Jevgeni Sahno, 2013. "Knowledge Management Framework for Six Sigma Performance Level Assessment", A Rocha et al. (Eds.): Advances in Information Systems and Technologies. AISC 206, pp. 255-267) Springer-Verlag Berlin Heidelberg 2013.

Jostes, R., Helms, M, 1994. "Total productive maintenance and its link to total quality management", *Work study*, Vol. 43, No.7.

Kaizer, Henry, F. 1974. "An Index of Factorial Simplicity", *Psychometrika*, Vol. 39, pp.31-36.

Karaulova, T. 2012. "Framework of reliability estimation for manufacturing processes", *ISSN 1392-1207. MECHANIKA. 2012 Volume 18(6): 713-720*

Kostina, M., T. Karaulova, J. Sahno and M. Maleki, 2012. "Reliability estimation for manufacturing processes", *Journal of Achievements in Materials and Manufacturing Engineering* volume 51, issue 1 march, pp.7-13.

Moradi, M., M. R. Abdollahzadeh, A. Vakili, 2011. "Effects of Implementing 5S on Total Productive Maintenance: A case in Iran", Quality and Reliability (ICQR), 2011 IEEE International Conference on Date14-17 Sept. 2011

Nakajima, S. 1988. *Introduction to TPM,* Productivity Press, Cambridge.

Narkhede, B. E., Nehete, R. S. and Mahajan, S. K. 2012. "Exploring linkages between manufacturing Functions, operations priorities and plant Performance in manufacturing SMEs in Mumbai", *International Journal for Quality research*, Vol.6(1), pp.9-22.

Patil, Bhushan T., B. E. Narkhede, S. K. Mahajan, and Aditya P. Joshi, 2012. "Performance Evaluation of Enterprise Resource Planning (ERP) Systems in Indian Manufacturing Industries." *Performance Evaluation* 2, no.

Rajesh Bajaj, 2011. "Total productive maintenance application to medium/small/micro enterprises", *Tecnia Journal of Management Studies Vol. 6 No. 1, April 2011 – September 2011*

Sanjay Bokade and Raut, D.N. 2014. "Flexibility and Effectiveness in Reverse Logistics of Product Returns in the Form of Parts and Sub-Assemblies.", *International Journal of Development Research Vol. 4, Issue, 3, pp. 491-495.*

Thanasegaran, Ganesh, 2009. "Reliability and validity issues in research." *Integration and Dissemination* 4: 35-40.

Vardhan, S., Gupta, P. and Gangwar, V. 2015. "The Impact of Quality Maintenance Pillar of TPM on Manufacturing Performance", Industrial Engineering and Operations Management (IEOM), 2015 *International Conference* on 3-5 March 2015 Page(s):1 - 6 Print ISBN: 978-1-4799-6064-4

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