Journal of Advances in Science and Technology
Vol. 19, Issue No. 1, March-2022, ISSN 2230-9659

Analysis the Relationship between the Quality, Productivity and Safety in Manufacturing Setup

Pujari Nitin Vishvanath[1]*, Dr. V. C. Jha[2], Dr. Rupesh Jagatarao Patil[3]

[1] Research Scholar, Kalinga University, Raipur

[2] Professor, Department of Mechanical Engineering,Kalinga University, Raipur

[3] Principal, Navsahyadri Education Society's, Navsahyadri Group of Institutes, Faculty of Engineering, Pune

Abstract- India is a rapidly developing nation, making quality, productivity, & safety enhancements particularly important. Quality, reliability, productivity, risk, flexibility, & safety are just few of the many factors that must be considered simultaneously if a company is to thrive in today's global marketplace. The economic growth of a country like India depends in large part on its level of industrialization. The manufacturing sector in India has been important to the country's recent economic success. We owe 17% of our GDP to the manufacturing sector. Quality, productivity, and safety, and the means to improve them, are of paramount importance in India because of the country's rapid economic development. This research will look at how well the Maharashtra manufacturing industry performs in terms of quality, safety, and productivity

Keywords- Manufacturing, Quality, productivity, safety, reliability

----------X----------

INTRODUCTION

In the manufacturing industry specifically, quality, productivity, & safety have long been considered three key measures of success. They are seldom stressed together, though. It is because the goals of quality management and productivity management are seen as competing that these three concepts are rarely stressed all at once (Omachonu 1994). According to recent studies, there should be a positive correlation between quality, productivity, & safety. However this theory relies more on inference and deduction than on tried and true models in the real world. The correlation between quality, productivity, & safety has been the subject of few mathematical models. Yet, these current models suffer from serious flaws. As a result of these flaws, current models are useless in practice.

In this post, we look at the logic behind the connection between efficiency, effectiveness, & protection. It is vital to choose a common base through which to relate quality, productivity, & safety as their definitions vary. Two industries, Maruti & Shree sai techno, will be used to test the models' viability in the manufacturing industry.

The definition of quality depends on perception of a person in a given situation, which can be cost oriented, user oriented, supplier oriented etc. Quality is defined as fitness for purpose (Juran, 1994). If the component perform in the safe manner in the required situation, it is called Quality product (Mahajan, 2010). The collection of activities through which we meet the quality needs of society is called quality function. In a manufacturing concern, the means through which the company meets the needs of customers is the quality function. Hence in general terms, quality function is the collection of activities which involves all the departments, vendors, links in distribution chain & consumers. This research will look at how well the Maharashtra manufacturing industry performs in terms of quality, safety, and productivity, and a model will to investigate the relationship between the characteristics.

PROPOSED METHODOLOGY

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. This systematic research focuses on objectives & data collection. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. Typically, it encompasses concepts such as paradigm and theoretical model, phases. The term Research is related to seek out the information and knowledge on a particular topic or subject. In other words, research is an art of systematic investigation.

DESIGN OF QUESTIONNAIRE

A pilot questionnaire collects data from respondents. Quantitative data can be collected in a uniform fashion with the use of a questionnaire, making it easier to analyze the acquired information. An initial survey is developed by taking into account respondents' levels of education and professional experience. The questions and their accompanying wording must be easily understood by the respondents.

SOURCES OF DATA

Both primary and secondary sources are used in this investigation. It aided in completely encompassing the scope of the research.

The search issue is targeted by collecting primary data. The data comes from interviews with professionals & academics in the Maharashtra area's many manufacturing sectors. The research focused on both medium- and large-sized businesses.

Publications like academic journals, government reports, trade magazines, websites, and others are mined for secondary data. The secondary information provides specifics about the various industries.

DATA COLLECTION

A structured questionnaire is prepared using literature survey and in-depth interview with concerned people. An in depth- interview helps in enriching the information and makes the qualitative analysis more focused. It helps in making the questionnaire more specific and accurate for a large stratified survey.

This study utilized a survey approach with a closed questionnaire. It was distributed in the industry professionals at Maharashtra region. The industries were randomly chosen in each zone. To ensure proper representation of manufacturing industries, we have chosen industries of different sizes, different types of production, different annual turnover and different year of establishments at various zones of Maharashtra state.

The fieldwork was conducted in four phases, as seen in Table 1. Initial phase includes interviews of local manufacturing industries in Maharashtra State of India. This information collected from interviews helped in ascertaining the relevance of questions in the pilot questionnaire. It also helped in assessing the role of influential factors within the manufacturing industry.

Second phase involved open-ended, moderately directed interviews and direct field observations in local manufacturing industries in Maharashtra State of India. These methods provided data for conducting a detailed analysis of the dynamics of various industries. These methods also brought out the qualitative analysis of this study. First survey was conducted with a closed questionnaire in this phase. It covered 50 respondents from local industries in Maharashtra State of India. The details of the respondents is shown below-

A questionnaire based on Likert scale was circulated .Questionnaire is being used to get a person's perspective on a Likert's scale which measures from 1 to 5 with meaning ranging from "not important" to "most important". To make the questions of questionnaire easy to understand by various respondents, all of them were educated so that they can select the right option .All the terms associated with the questions were explained deeply to them. This helped them to understand importance of question. Also the feedback was taken to ensure that they understood question incorrect perspective.

FINDING FROM PILOT QUESTIONNAIRE

After the analysis of pilot questionnaire, the different variables of critical success factors and performance measures are scrutinized to be included in the final questionnaire. The critical success factors commonly known as input factors reduced from 62 to 43 variables and performance measures which are commonly known as output factors are made from 38 to 47 variables .The overlapping variables are also identified and merged into a single variable.

Table 1: Phases of field work

	Outcomes
Preliminary research	Identification of research sample
Phase-I	Interviews and their evaluations
Phase-II	Pilot survey
Phase-III	Preliminary impressions and evaluations of the framework
Phase-IV	Final survey

In the third phase the analysis of the data collected from respondents is done. Based on the suggestions from various respondents some factors are either added or deleted or modified. All the suggestions from the respondents are incorporated in the final questionnaire.

The last phase of the fieldwork comprises of a survey consisting of distribution of final questionnaire to the various respondents across the Maharashtra state. A total of 450 questionnaires were circulated to the various Medium and Large manufacturing industries. Out of 450 only 250 questionnaires were returned with valid responses .The questionnaires were filled by the respondents having sound knowledge of their respective work. First of all initial screening of the questionnaire was done to check whether all the questions have been properly tick marked or not

.After the final screening only 250 questionnaire work sorted out to be included for further analysis. The questionnaire were also categorised based on age of the industry, experience of respondents, their qualification and designation. After sorting all the data are systematically recorded in MS Excel sheet.

RESPONSE RATE & PROFILE OF THE RESPONDENTS

After the distribution of final questionnaire, a continuous follow up procedure was followed to get the responses. It resulted in receiving a total of 312 responses out of which only 250 were valid responses. It resulted in a response rate of 64% which is quite encouraging. Some other authors have also used questionnaire as a tool for collecting the data.

Figure present below show the classification of respondents of questionnaires.

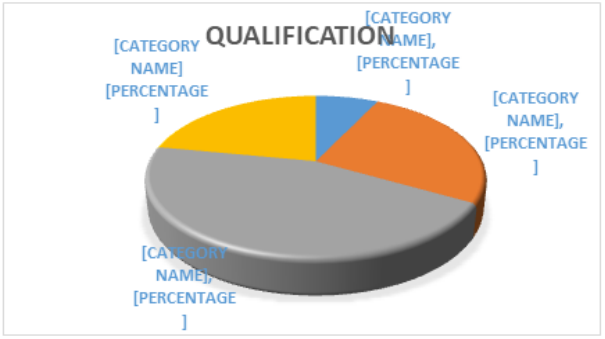


Figure 1: Qualification of Respondents

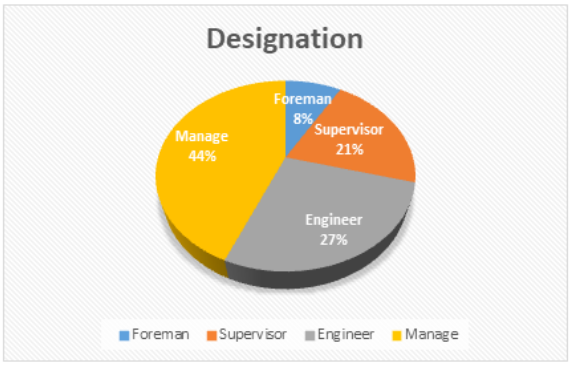


Figure 2: Designation of Respondents

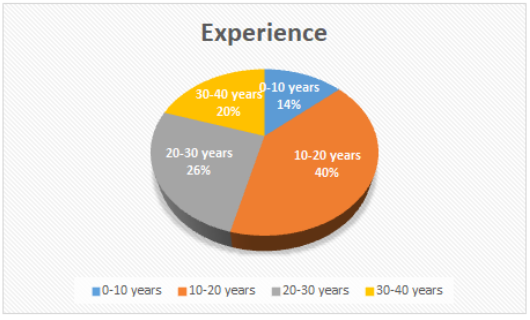


Figure 3: Experience of Respondents

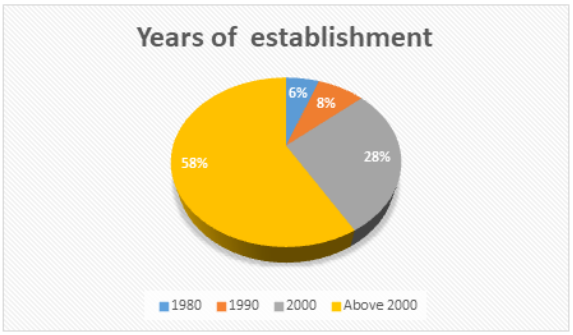


Figure 4: Year of establishment of Respondent industries

DATA ANALYSIS

The data analysis is done with the help of statistical tools such as mean (central tendency measure) and standard deviation (measure of variability). The table given below shows the minimum and maximum score of input and output factors with variance. Also 100% of the questions revealed a mean score of more than 4.0, indicating a high importance to various aspects of performance improvement. Furthermore, the standard deviation values were relatively low (for majority of questions, standard deviation value was less than 30% of the mean).

(A) Input data

Table 2: Statistical analysis of input data

	Mean	Minimum	Maximum	Range	Max.\ Min.	Variance
Item Means	4.2612	3.78	4.62	0.84	1.23	0.042

(B) Output data

Table 3: Statistical analysis of output data

	Mean	Minimum	Maximum	Range	Max.\ Min.	Variance
Item Means	4.0403	3.62	4.40	0.78	1.20	0.047

TESTING OF DATA

The tests of normality, reliability, adequacy and validity are the four major tests used to evaluate a measurement tool and subsequent measurements. The data should follow normal distribution. Normality test refers the bell shape nature of the curve. Reliability tells the accuracy and precision of a measurement procedure. Data adequacy confirms that obtained data is sufficient for analysis. Validity refers to the extent of measure. The tests of sound measurement are:

- Sample Adequacy
- Normality
- Validity
- Reliability

The distribution pattern of the data is of prime concern. It is to be checked how the shape of normal curve departs from the normal distribution Pattern. The size of sample is of prime importance. Larger sample size reduces sampling error. For sample sizes of 200 or more, however, these same effects may be negligible. Moreover, when group comparisons are made, such as in ANOVA, the differing sample sizes between groups are large enough, can even cancel out the detrimental effects. Thus this research has 250 responses (large sample size).

a) In the book 'Elementary Statistics: A Modem Approach' written in 2003 by Altares et.al a Sloven's formula is given for sample size calculation.

$n=N/l+N*e^2$

Where: n=Sample Size (Minimum and Adequate for Analysis)

N= Population Size@ (185 Medium, 1201 Large Registered Units)[data taken from District Industrial Corporation, Maharashtra]

e= Margin of Error denotes the allowed probability of committing an error in selecting a small representative of the population (0.05 for 95 % Confidence Level)

= 1386/ (1+1386*0.05*0.05)

= 310 (Samples)

Based on the above listed considerations given for the calculation of minimum number of responses, the number of responses taken for study i.e. 250 is sufficient for further studies. It indicates that the sample size is adequate.

Normality

A lot of statistical tests are based on the assumption that the data is normally distributed. So first of all we should check the trueness of this assumption. The normality test is carried out for all input items and all output items. Normality test refers the bell shape nature of the curve. It is necessary that data follows normal distribution i.e. the data should lie within the inverted bell shaped curve. At a confidence level of 95%, a clearance of 2.5% on either side is taken.

Skewness and Kurtosis refer to the shape of the distribution. These are used with interval and ratio level data. When the observed distribution is exactly normal, values of skewness and kurtosis are zero. For a good data, the values of skewness and kurtosis should be nearer to zero.

The Kolmogorov - Smimov statistic and the Shapiro - Wilks Statistics with a significance level for testing normality is produced with a normal probability and detrended probability plots. If the significance level is greater than 0.05, then normality is assumed.

Table 4: Normality for input variables Case Processing Summary

				CASES		
	valid		**missing**		**total**	
	N	%	N	%	N	%
INPUT VARIABLES	43	100.0%	0	0.0%	43	100.0%

Descriptive

		statistic	**Std. error**
INPUT VARIABLES	Mean	4.2613	.03108
	95% Confidence interval for Mean Lower bound	4.1984	
	upper bound	4.3240	
	5% Trimmed Mean	4.2664	
	Median	4.2759	
	Variance	.042	
	Std. Deviation	.20382	
	Minimum	3.77	
	Maximum	4.61	
	Range	.84	
	interquartile Range	.28	
	Skewness	-3.52	.361
	Kurtosis	-.245	.709

Tests of Normality

*. This is a lower bound of the true significance.

a. . Lilliefors Significance Correction

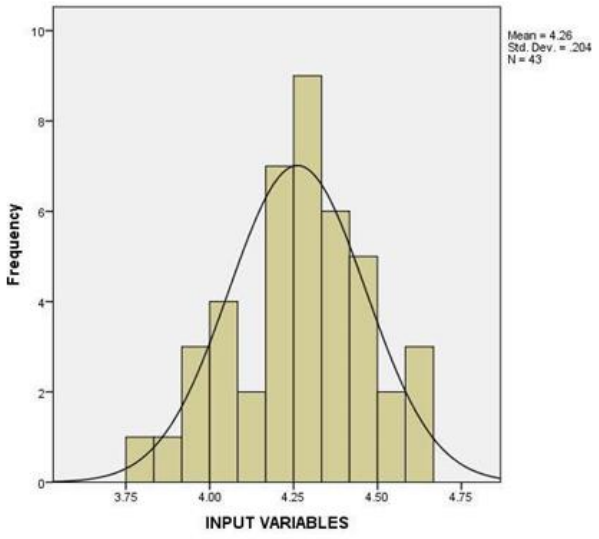


Table 5: Normality for output variables

Case Processing Summary

				CASES		
	valid		missing		total	
	N	%	N	%	N	%
OUTPUT VARIABLES	47	100.0%	0	0.0%	47	100.0%

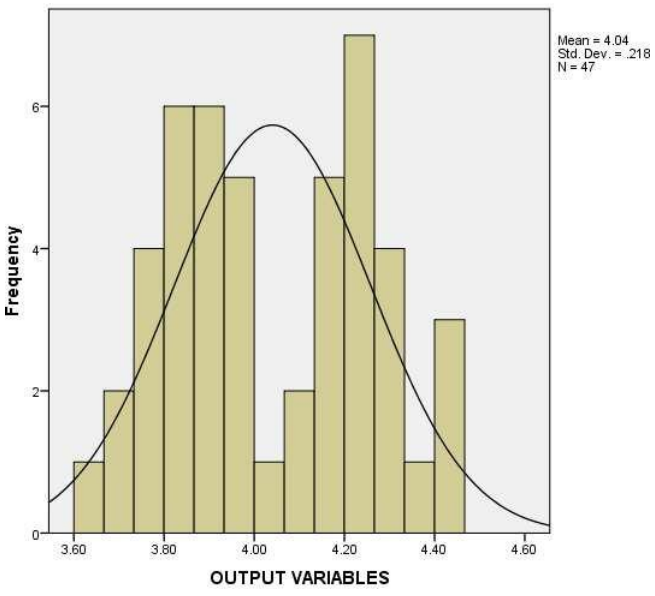
Descriptive

		statistic	Std. error
OUTPUT VARIABLES	Mean	4.0404	.03178
	95% Confidence interval for Mean Lower bound	3.9765	
	upper bound	4.1044	
	5% Trimmed Mean	4.0407	
	Median	4.0000	
	Variance	.047	
	Std. Deviation	.21788	
	Minimum	3.63	
	Maximum	4.41	
	Range	.78	
	interquartile Range	.38	
	Skewness	.008	.347
	Kurtosis	-l.184	.681

Tests of Normality

	Kolmogorov-Smimov•			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
OUTPUT VARIABLES	.120	47	.088	.952	47	.052

a. Lilliefors Significance Correction



Validity of Instrument

Validity is used to check the quality of a test. The term validity refers to a measure of closeness what it claims to measure. The three most important type of validity tests for research are:

Content Validity

Nunnally (1978) opines that content validity depends on how well the researchers created the measurement items to cover the content domain of the variable being measured. Its determination is subjectively judged. If a factor has items that cover all possible aspects of the variable being measured, then it is said to have content validity. The philosophy mentioned by various researchers is being used here to frame the questionnaire. In our study an exhaustive literature review has been done for the selection of measurement items and knowledge has been collected by visiting the plants. Academics, researchers, and specialists have all contributed to a thorough analysis. All these ensure the content validity at the stage of questionnaire formation.

Criterion Validity

Criterion validity tells us how well one variable predicts an outcome based on information from other variables.

In this research criterion-related validity of the instrument evaluated the correlation coefficients between six input and six output performance measurement factors. The correlation coefficients between all of the variables are positive & statistically significant. The Bivariate correlation between the input and output factors are shown below in Table 6.

Table 6: Bivariate Correlations among the input and output factors' Correlations

		OFI	OF2	OF3	OF4	OF5	OF6
IFI	Pearson Correlation	.438**	.261	.505**	.342**	.157	.164
IF2	Pearson Correlation	.567**	.559**	.557**	.494**	.499**	.687**
IF3	Pearson Correlation	.210*	.466**	.460**	.400**	.549**	.422**
1F4	Pearson Correlation	.320**	.424**	.393**	.446**	.649**	.457**
IFS	Pearson Correlation	.473**	390**	.343**	.243**	.328**	.461**
IF6	Pearson Correlation	.479**	.689**	.346**	.169	.629**	.683**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Construct Validity

If a factor measures a theoretical construct which is designed to measure then it has construct validity. Factor analysis is most commonly used to identify the items to be included in measuring instrument. Appropriateness of the data is also measured by examining the minimum no. of

observations required per variable to proceed for factor analysis. A general rule is given by Hair et al. (1998) that sample size should be at least 5 times the no of variables. Flynn et al. (1994) stated that a sample size of 30 or more is statistically sufficient for the analysis.

Construct validity is thus an assessment of the quality of an instrument or experimental design. It says 'Does it measure the construct it is supposed to measure'. If you do not have construct validity, you will likely draw incorrect conclusions from the experiment It measure if the items are belonging to same group or not. If the items do not belong to that group, eliminate that or check the appropriate group. This is done with the help of principal component factor analysis. The factor matrices showed that they are uni-factorial with Eigen values (Eigen values represent the amount of variance explained by the factor, or relative importance of each factor in accounting for variance associated with the set of variables being analyzed) greater than the accepted criterion. The component matrix, Eigenvalue and percentage of variance for all input and output values are shown below-

Table 7: Component matrix and total variance explained for Input Factor

Sr. No.	Name of loaded items	Values of item loaded	Eigen values	Percentage of Variance
		Component 1		
Input Factor 1	Top management's clarity of vision, mission, and Strategic direction for QPS	.741	2.351	58.787
	Top management's commitment for QPS improvement	.805	.648	16.201
	Allocating sufficient resources to quality & safety improvement projects.	.758	.533	13.321
	Management's promise of a pleasant workplace.	.761	.468	11.691
Input Factor 2	Employee Growth & Development	.554	1.989	39.776
	Proper Planning, Implementation and Procurement Policy	.552	.917	18.337
	Incentives for Employee Performance based on Their Ability to Deliver	.780	.809	16.183
	Periodic Performance, Quality, and Safety-Related Employee Training & Awareness Programs	.589	.722	14.442
	Employees are encouraged to execute their own creative ideas.	.650	.563	11.262
Input Factor 3	Teamwork in the organization	.346	1.965	49.135
	Congenial (Friendly, Pleasant, Agreeable) Work environment	.842	.943	23.565
	Employees are pushed to act on their own original thoughts.	.855	.743	18.571
	Advancing cleaner workplaces, larger work areas, better work practices, and the usage of protective gear	.637	.349	8.729
Input Factor 4	Favourable Govt. Safety Policies,	.647	2.430	48.603
	Rules & Implementation of osha regulations	.816	.939	18.774
	Processes are planned & overseen methodically in accordance with relevant system standards, such as the Quality System (ISO 9000), the Environmental System (ISO 14000), and the Occupational Health & Safety System (OHSAS 18000).	.854	.721	14.429
	Fair Compensation cost to employees	.681	.589	11.772
	Well Defined rules, regulations & operating procedures	.389	.321	6.422
Input Factor 5	Intensified Safety inspections	.689	1.998	39.969
	Proper Accident Investigations & Reporting	.862	.958	19.162
	Using proper machines , tools and equipment and protectors	.650	.879	17.582
	Tighter Adhering to desks & tables	.471	.790	15.803
	Collecting data with statistical process control charts and graphs	.369	.374	7.485
Input Factor 6	Quality audits & assessments of activities at regular intervals.	.850	2.496	49.918
	Quality Assurance	.879	.956	19.123
	The use of Certification Programs	.681	.810	16.205
	Proper implementation of QMS	.669	.436	8.716
	Adoption of Quality control tools	.298	.302	6.038

Table 8: Component matrix and Total Variance explained for Output Factor

Sr. No.	Name of loaded items	Values of item loaded	Eigen values	Percentage of Variance
		Component 1		
Output Factor 1	Increases in the use of cutting-edge technology & productive capability in manufacturing	.904	2.219	55.483
	Decrease in delivery lead time	.821	.994	24.861
	Improved product quality at lower cost	.124	.498	12.459
	Defective goods are carefully labeled, separated from good materials, and stored in a secure location until disposal can be arranged.	.844	.288	7.196
Output Factor 2	Increase in total productivity factor	.751	.999	24.984
	Optimum human resource utilization	.693	.730	18.246
	the percentage of downtime has decreased	.179	.533	13.321

	Increase in Return on investment	.512	1.745	34.900
	Growth in market share	.497	.934	18.684
Output Factor 3	Results in Decreased scrap & Rework	.713	.872	17.435
	Decreased delay cost	.725	.850	16.993
	resulted in increased revenue, savings, or viability in the market	.449	.599	11.988
Output Factor 4	Increase in safety reputation of organization	.435	1.719	42.969
	Increased number of days without any safety breaches, indicating improved safety.	.689	.971	24.267
	Correction of safety infractions within the time constraint	.760	.686	17.143
	Decreased injuries / illness	.690	.625	15.621
Output Factor 5	Communication within the company is strong generally.	.835	2.131	42.613
	Employee suggestions are rewarded and recognized.	.851	.994	19.890
Output Factor 6	Improved Customer Satisfaction	.723	1.835	45.872
	Typical market value for the product's price	.828	.991	24.775
	Enhanced Customer retention	.778	.682	17.056
	Customer Feedback and Suggestions always welcome & entertained	.146	.492	12.297

Reliability of Instrument

Reliability refers to the extent to which an experiment or measuring procedure yields a same value on repeated trials. (Carmines and Zeller, 1979).Generally the internal consistency method is used in the instrument development process involving the field studies. Internal consistency can be estimated using reliability coefficient Cronbach α. The computation of Cronbach's alpha is based on the number of items on the survey (k) and the ratio of the average inter-item covariance to the average item variance.

$$a = \frac{k\,(cov/var)}{1 + (k-1)(cov/var)}$$

The reliability analysis of a questionnaire determines its ability to yield consistent results. The Cronbach's alpha value ranges from 0 to 1. If the value lies between 0.6 to 1 then instrument is said to be reliable. (Wee and Quazi, 2005, Sarode and Bhavaskar, 2011). Nunnally (1978) suggested that if this value is greater than 0.7 then it suggests good internal consistency. The Cronbach's alpha value for all 43 input items is found to be 0.803 and for 47 output items is 0.744 respectively. The above values indicate that the questionnaire is reliable. The Cronbach's alpha value for individual input and output items are shown below-

Table No. 9: Reliability of input data

Case processing summary

	No. of respondent	Percentage
Valid	250	100.0
Excluded[a] cases	0	.0
Total	250	100.0

Reliability Statistics

Cronbach's Alpha	standardized items Cronbach's Alpha	No. of items
.803	.811	43

Table No. 10: Reliability of output data

Case processing summary

	No. of respondent	Percentage
Valid	250	100.0
Excluded[a] cases	0	.0
Total	250	100.0

Reliability Statistics

Cronbach's Alpha	standardized items Cronbach's Alpha	No. of items
.744	.747	47

CONCLUSION

The research instrument has been successfully developed which will help manufacturing industries to evaluate QPS improvement approaches. These QPS critical factors permit top management to better understand safe practices. Managers can use the instrument reported in this study to evaluate the implementation factors and its impact on the organization's performance. Empirical results of this study show that the instrument is a reliable and valid. The measurement instrument has been validated with Indian manufacturing industry. The manufacturing companies can use this instrument to audit QPS practices in their organizations. The periodic use of the instrument will help in identifying the areas where improvements for QPS is needed. Further research can be carried out for performance improvement of manufacturing industries in various regions of the country as well as in global context. For this study the data has been taken during a fixed time duration. In this study different manufacturing industries have been considered. Further studies can be carried out in industries of specific type, size and category.

REFERENCES

1. Berkel Rene van. 2007. Eco-efficiency in primary metals production : context, perspectives and method. Resources, conservation & recycling. 51 (3):511-540
2. Brah S.A.,Rao B.M. and Tee Serene. 2002. Relationship between TQM and

performance of performance of Singapore companies. Int. J. of quality and reliability management. 19 (4): 356-379
3. Brawner, J. G., Harris, G. A., & Davis, G. A. (2022). Will the real relationship between lean and safety/ergonomics please stand up?. Applied Ergonomics, 100, 103673.
4. Bussier, M. J. P., & Chong, H. Y. (2022). Relationship between safety measures and human error in the construction industry: working at heights. International journal of occupational safety and ergonomics, 28(1), 162-173.
5. Carmines E. and Zeller R. 1979. Reliability & Validity assessment, Quantitative applications in social sciences, Sage publications, Newbury park, CA Choi Sang D. 2006. A survey of the Safety Roles and Costs of Injuries in the Roofing Contracting Industry. The journal of SH&E Research. 39 (1):1-20
6. Choudhry R. M. 2015. Achieving productivity & safety in construction projects.Journal of Civil Engineering & Management.:1-8
7. Colledani. M.and Tolio T. 2009. Integrated Analysis of Quality and Production logistics Performance in manufacturing lines. International Journal of Production Research. 1: 1-32.
8. Cristina Mele and Malio Calirsio . 2006. The evolving path of TOM : towards business excellene & stakeholder value . International journal of quality & reliability management.| 23(5) : 464-489
9. Crosby P.B. 1979. Quality is free. New American Library. New York Crosby P.B.1984. Quality without tears: the art of hassle free management. McGraw hills. New York
10. De Toni A. and Tonchia S. 2001. Performance Measurement Systems: Models, Characteristics and Measures. International Journal of Operations & Production Management.21(1-2):1-34.
11. Delray Beach. FL Lokhande A.D, Shrivastava R.L. and Shrivastava R. R. 2014. A review on Critical Success Factors of remanufacturing. Int. J. of Entrepreneurship & Business Environment perspective . 3(2): 132-145

Corresponding Author

Pujari Nitin Vishvanath*

Research Scholar, Kalinga University, Raipur