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ENHANCING GRADUATE EMPLOYABILITY SKILLS: APPLICATION OF STATISTICAL TECHNIQUES FOR QUALITY ASSURANCE IN INDUSTRIES

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Abstract

Despite maintaining high standards in product quality during the production process, continuous run of machines and vibrations may send out defects that can result in poor quality output. The continuous monitoring and detection of the causes of error are required to bring the process back to acceptable quality levels. The implementation of statistical techniques such as quality control and design of experiments are needful for the industries to make an effective control process during production. The present study has carried out a survey to elicit the opinions of the executive engineers in the industries in regard to quality cognizance for producing quality products and the use of statistical techniques for achieving the target quality. The study findings recommend to an industry perspective in statistical techniques in the course curriculum and enhance the employability skills in the students of higher educational institutions (HEI).

Keywords: *Statistical Techniques, Quality Control, Binary Logistic Regression, Kruskal-Wallis Test, Higher Education Institutions.*

I. Introduction

Managing the quality of the product, preventing errors during the production process, and delivering products in line with the standards are among the important key responsibilities of the managers (Langford et al., 2000; Mittag and Rinne, 1995). Quality assurance includes mainly the two principal

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functions; quality engineering which aims to identify the causes of variations that occur in the product from the desired quality prior to production, and quality control i.e., an inspection process to determine the quality standards after the production. Overall quality assurance is a system of policy frameworks, setting procedures and protocols by an organization to achieve the desired quality of the product (Tsung, 2000). Despite maintaining high standards in the production process, machines can result in product variations due to assignable causes like wear-out situations, defects in the raw material, or operator error. The variations could also be random, which cannot be controlled, like temperature, air quality, and humidity. These factors are unavoidable and can result in a poor-quality product. Generally technologies know there is a relationship but they may not be able to indicate the degree of relationship in the form of rate of change, significance etc. although this approach helps a planner in planning for his future.

The statistical quality control processes help in identifying the causes of variations in the product. If the variations have occurred due to assignable causes, corrective measures become necessary to implement to bring back the process in acceptable limits (Bakker et al., 2006; Ivy and Nembhard, 2005; Nagata, 2019). The traditional approaches to maintaining quality control have been replaced with new and effective statistical tools and techniques with the application of Information Technology (IT) (Mittal, 2020a, 2020b).

Statistical techniques are formal techniques implemented with the use of collected information and quality standards and benchmarks to find new ideas to enhance the quality of the products and services. Statistical techniques like hypothesis testing, regression analysis, statistical process control (SPC), design, and analysis of experiments can be used in quality improvement (Nagata, 2019). The most popular in industries the statistical process control helps in monitoring and controlling the process. This technique helps in identifying the assessable causes of variations. Design

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and analysis of experiments help in evaluating the factors that can impact the outcome variables.

The implementation of statistical techniques for quality assurance and improvement in product quality requires specific knowledge and skills in the field of applied statistics (Bakker et al., 2006) like AI, Big data (Arora et al., 2021; Mittal, 2020c). There is a need to carefully designed the learning opportunities at school, or college, or in a workplace training course that can transform the statistical ideas into real situations in the manufacturing process (Ruigrok and Wagner, 2003). The present study aims to identify and analyze opinions of the industry managers in regard to quality cognizance with the use of statistical techniques.

The study has presented five sections in the paper. Section 1 has introduced the concept of statistical techniques in quality control, section 2 provides the previous research work, section 3 defines the methodology of the research work, section 4 gives the results of primary survey analysis, and section 5 concludes the findings and recommendation for the educators and the government for policy framework.

2. Literature Review

Previous studies have focused on the benefits of statistical procedures on the benefits of the improvement in quality in the manufacturing process. The results of the studies have contributed to developing the theoretical frameworks for the industries for the implementation of statistical techniques in the process control of the products. In early 1920s, statistical process control and control charts were developed (MacCarthy and Wasusri, 2002). Statistical process control (SPC) is the statistical method that helps in managing and controlling the product quality with time and improves the process. It combines the statistical test procedures with chronological presentations of summarized information (Bhatia and Mittal, 2019). Statistical process control detects the variations and the trends in a

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simple manner that can be understood by any worker looking after the product. Jin et al. (2019) identify the benefits of the use of control charts that helps to show the process in normal variations or going out of control. The study concluded that SPC is important and can be used for quality assurance. Parmar and Deshpande (2014) have conducted cases analysis of the manufacturing companies and concluded the significant use of statistical process control tools and techniques in achieving the quality. The authors emphasized that the right skills and knowledge of statistical techniques in the employees is important for the implementation of SPC that can help to reduce the defects significantly.

The managers must keep the participants involved in learning opportunities instead of using formal training to transmit the statistical knowledge to operators (Mittal and Raghuvaran, 2021). The learning creates statistical thinking in the real situations in the workshop and helps them in making decisions. The employees can bring a new way of looking at the statistical graphs, even if they are statistically insignificant.

Despite the significance of planning and monitoring, and evaluating process control during the manufacturing process, very few studies have focused on setting the survey analysis of industries for understanding the use of statistical techniques in SPC (Bakker et al., 2006; Parmar and Deshpande, 2014; Suthar et al., 2010). Binary logistic regression is suitable for analyzing the survey data where empirical relations exists between the response variable and causal variables (Suthar et al., 2010; Yanfeng et al., 2010).The present study has carried out a survey of 38 companies on the techniques used for quality improvements and identify the gaps in the learning process at the graduate level and the implementation in real situations.

3. Methodology

The study examines the relationship between the statistical procedures used for measuring and monitoring product quality in the industries and the

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learning of the applied statistical techniques at the university level. The survey result finds a wide gap and aims to suggest ways to bridge the gap between the two by defining the role of industries, academic institutions, and the government. The salient findings, conclusion and thereby recommendations from the survey are discussed in the subsequent sections. The study has used Binary logistic regression for analyzing this type of survey data where the developed model finds out the empirical relations between the response variable and these causal variables.The analysis is carried on the survey data, collected predominantly on different types of companies situated in NCR of Delhi. In total, survey results are based on 38 industries. The industry survey data has been analyzed on the use of various statistical techniques to achieve product quality.

It is observed that quality consciousness and the need to satisfy customer's requirements are the two important paradigms for any company. The study has also carried out the sector-wise analysis (automobile/electrical/general) in the quality performance. An attempt was made to find out the reasons for such improved performances in the automobile sector. The reasons exhibited by the companies on aforesaid aspects were studied, and it is found that these reasons could be attributed to the following four important causal variables viz. type of company (x1), age of the company (x2), turnover the company (x3), and the strength of the employees (x4). In order to quantify this causal relationship with certain indicators, statistical regression analysis is used with a certain degree of confidence along with error of predictions. The general form of the empirical relationship can be represented as:

$$z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k + error$$

In a generic regression analysis, indicators, as well as causal variables, are independent and continuous. Survey data responses are rarely continuous and are generally dichotomous like YES/NO. The causal factors may be binary, categorical, or numerical in nature and may or may not be independent of each other. The study has used Binary logistic regression

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for analyzing this type of survey data where the developed model finds out the empirical relations between the response variable and these causal variables (Suthar et al., 2010; Yanfeng et al., 2010). Models were developed to find out how the propensity of a given company varies to move from ‘0’ to ‘1’ in the form of probability where the median is taken as the cut-off point. Questions were asked in retrospect of the aspect of Use of Statistical techniques and Data analysis in the industries, which are discussed in the subsequent sections. The analysis and the inferences drawn on survey data are presented in section 4, followed by recommendations in section 5.

3.1 Variables

3.1.1 Type of company (x_1)

There is a general feeling that since automobile companies have to maintain the standards as per the international market and from the remaining also electronics component manufacturing industries, the products may be quality sensitive due to technicality and heavy competition. The study has considered automobile companies and their ancillaries with scale factor 3, electronics component manufacturing as scale factor 2, and other general companies with a scale factor of 1.

3.1.2 Age of company (x_2)

The age of the company is the period in years since the company is in existence. Statistical tests prove that age does not follow normality further square root transformation properties of normal distribution were used to get decisive cut-offs. The four quartile cutoffs are considered in the age groups of 0-5, 5-12, 12-26, and 26-70 years, respectively and have been assigned scales from 1 to 4.

3.1.3 Turnover of the company (x_3)

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Turnover is expressed in terms of annual business (in INR.) by a company. Turnover of a company may depend on the volume of sales as well as the unit price of a product. The frequency distribution of the companies' turnover has been categorized in various intervals using appropriate tests. The four quartile cutoffs considered in the turnover categories are 0-32, 32-108, 108-276, and 276-812 (in crores) with scales from 1 to 4. The extreme observations of greater than 812 are given a scale 5.

3.1.4 Employees strength of the company (x_4)

Employees' strength is defined as the total number of employees working in a company, right from the top executive to workers. The distribution of employees in different areas of a company plays a vital role. Statistically driven frequency distribution of the companies in employees' strength interval is derived from the quartile cut-offs. The four quartile cutoffs derive the employee strength of 0-92, 92-475, 475-762, and 762-3505, respectively and have been assigned scales from 1 to 4.

4. Results and findings

The collected responses were converted into valid scores (scale of 0–10). Kruskal-Wallis test is applied to see differentiation among questions (facets) thereby. Appropriate weights are given to each question which is used to give average scores to each company on the respective aspect. These calculated weights were used to find the average score of each company with respect to the aspect of the use of statistical techniques (see table 1).

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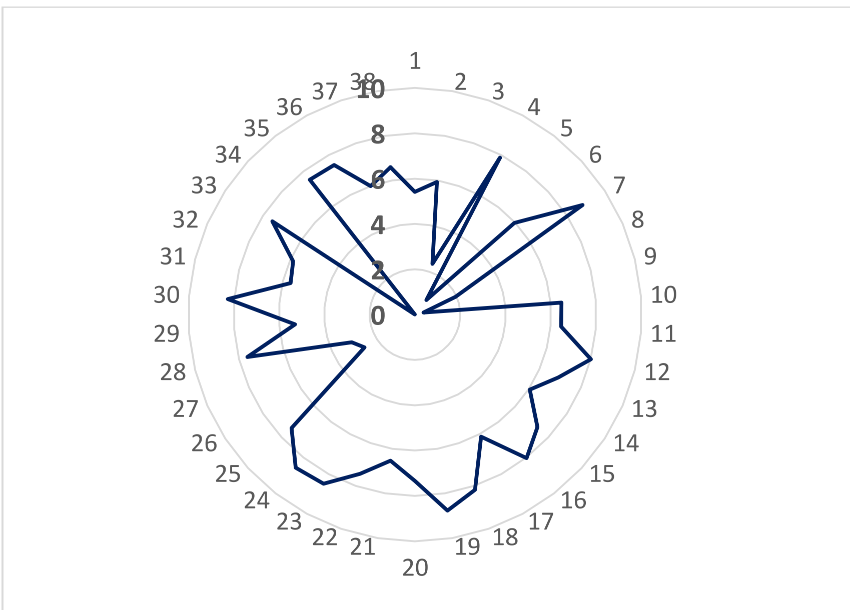
Table 1: Kruskal-Wallis Test: Use of Statistical techniques versus Facets

Facets	N	Median	Ave Rank	Z	Cal. Weights.
1	38	8	143.6	2.97	2.3
2	38	6	106.1	-0.86	1.7
3	38	6	111.7	-0.29	1.79
4	38	6	128.3	1.41	2.06
5	38	2	62.4	-5.33	1
6	38	8	135.0	2.10	2.16
Overall	228		114.5		

H = 37.05 DF = 5 P <0.001

H = 38.93 DF = 5 P <0.001 (adjusted for ties)

Figure 1: Radar Chart showing average scores on Use of Statistical Techniques by all 38 companies



The median 6.56 of all scores are taken into consideration as data lacks normality (see figure 2). Wilcoxon-signed rank test is applied as shown

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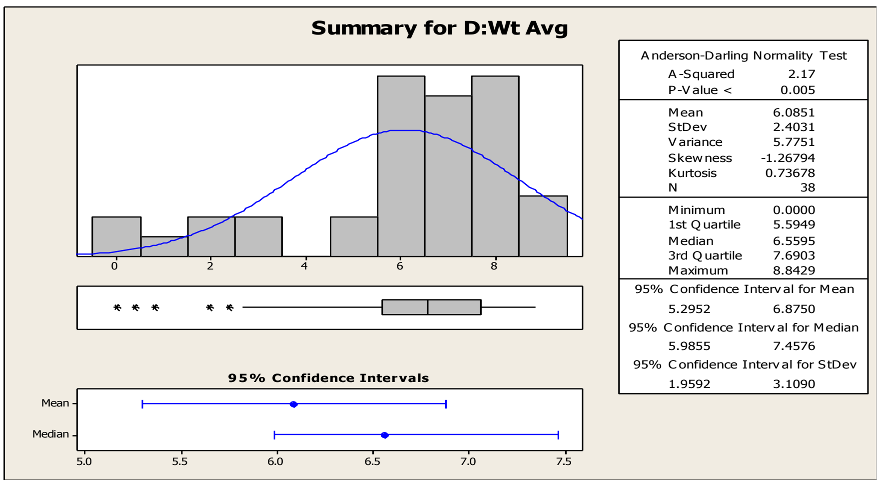
below to study further whether all the companies may be ranked equally to this score or they are statistically different.

Table 2: Wilcoxon signed rank CI: Wt. Avg

N	Est. median	Achieved confidence	Confidence interval	
			Upper	Lower
38	6.61	95.0	5.52	7.12

Figure 2: Normality check for frequency distribution



A sensitivity analysis for the 95% C.I. region is done on the median score. The result of the test in this region is given below shows median at level of 6.61 is insignificant but significant at a level of 7.0 (benchmark).

Table 3: Wilcoxon signed rank test: Wt. Avg

Test of median	N	Wilcoxon statistic	p-value	Ext. Median
Median <6.61	38	370.0	0.500	6.606
Median<7.00	38	270.0	0.073	6.606

A mathematical model has been presented in section 4.1 to find out factor propensity to improve with respect to the aspect at the current as well as at

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significant benchmark higher level. The analysis is shown in the next section.

4.1 Binary Logistic Regression Analysis for the response on the use of statistical Techniques

The analysis will give the effects of multiple explanatory variables on the outcome variable using model

$$y = f(x_1, x_2, x_3, x_4)$$

where y is a response aspect status which is a function of four factors viz. type of company (x1), age of the company (x2), turnover the company (x3), and the strength of the employees (x4). The study has developed this model to examine the relative importanceof each factor in achieving certain degree of response on this aspect. The results of binary logistic regression done at the estimated median level (6.61) (see table 4).

Table 4: Results of Binary logistic regression at median level (6.61)

Variable	**Value Count**			
Response binary	1	18		
	0	20		
Total		38		
Logistic Regression Table				
Predictor	Coef	SE Coef	Z	P
Constant	-2.83143	1.43516	-1.97	0.049
x_1	0.738757	0.460294	1.6	0.109
x_2	0.241746	0.443074	0.55	0.585
x_3	0.436643	0.406869	1.07	0.283
x_4	-0.301281	0.503769	-0.6	0.55
Log-Likelihood = -23.085				
Test that all slopes are zero: G = 6.404, DF = 4, P-Value = 0.171				
Measures of Association:(Between the Response Variable and Predicted Probabilities)				
Pairs	Number	Percent		

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Concordant	260	72.2		
Discordant	96	26.7		
Ties	4	1.1		
Total	360	100.0		

The above analysis on binary logistic regression shows a moderate concordance of 72.2%. The p-value = 0.17 for the model says the model is not significant at 10% level but still not very high value and may predicts small significance at later stage of analysis. It can be seen that one of the regressor coefficient x4, having negative sign with p= 0.55 the corresponding variable being insignificant, at 10% level of significance, is dropped. With the remaining factors, rerun of the analysis with different combination was done. It was found that variable x1 (type of company) is significant with p=0.04 at 5% level of significance and model is also significant with p-value of 0.03, whereas model concordance is low at 48.9%. Binary logistic regression analysis results are presented in table 5.

Table 5: Results of Binary logistic regression at median level (6.61)

Predictor	**Coef**	**SE Coef**	**Z**	**P**
Constant	-2.0753	1.0492	-1.98	0.048
x_1	0.8452	0.4136	2.04	0.041
Log-Likelihood = -23.937				
Test that all slopes are zero: G = 4.700, DF = 1, P-Value = 0.030				
Measures of Association: (Between the Response Variable and Predicted Probabilities)				
Pairs	Number	Percent		
Concordant	176	48.9		
Discordant	44	12.2		
Ties	140	38.9		
Total	360	100.0		

The result shows x1, type of company is significant factor and substituted for the predicted response model may be given by:

$$Y = -2.08 + 0.85 * X_1$$

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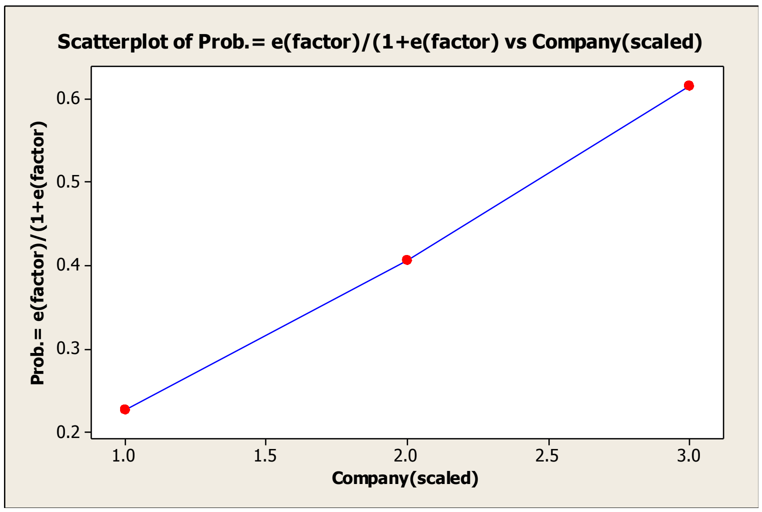
The relation is developed on the above model is depicted by a scatter plot shown below in fig. 2.2. Using the developed predictive response model given by eq.2.2 the predictive probabilities to improve with respect to type of company are also worked out and are shown below under the scatter plot.

Figure 3: Scatter plot- Type of company Vs Propensity to improve



The study summarizes the following inferences from the response model at the estimated median level:

- A general nature company has very low probability of 22.6% to move up, above the estimated level of median 6.61.
- Electronic companies have also low probability of 40.6% to move up, above the estimated level of median 6.61.
- Automobile companies have high probability of 61.5% to rise up from the estimated level of median 6.61.

The above analysis shows that companies at the median level of 6.61 have some significant propensity to the factor type of company (x1) on improvement from the current median score of 6.61 (level ‘0’ to ‘1’). More of the automobile sector are using statistical techniques may be because of

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the need to maintain standards in the international market. To further identify whether type of company or any other factor plays a significant role at the higher benchmark level of 7.0, binary logistic analysis has been carried out and predicted Response Model at benchmark level is given by

$$Y = -1.95 + 0.74 * X_1$$

Using the developed predictive response model the predictive probabilities to improve with respect to type of company at the benchmark level is general nature company has very low probability of 22.97% to move up, Electronic companies have also low probability of 38.5% to move up, whereas Automobile companies have high probability of 56.71% to rise up from the bench mark level of 7.0. In order to analyze this differentiation, data for automobile industries (22 companies) on usage of statistical techniques aspect is also studied. It signifies that within automobile sector, there are no significant factors to which we can contribute the need to use statistical techniques. All the companies make use of statistical techniques in their operations at the same level, which cannot be differentiated up to 90% level of statistical confidence. This could be inferred as, new companies are doing better than old ones or are old companies are doing better than new ones.

5. Conclusions and Recommendations

The survey results show as far as quality measured on the scale of quality certificates is concerned, a large number of companies, even from small-scale industries, are craving and acquiring these certificates. But, survey results show very clearly that statistical techniques per say do not find any usage in the day-to-day industrial applications. The current survey reveals even though a lot of opportunities are available for the use of these techniques as well as sufficient data is generated, the current middle-level management does not seem to have the ability to harness them and put them all in quick response decision-making techniques. This could be one of the reasons why, top management even though on the face of it seems to appreciate these techniques, became apathetic when it comes to time

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management. In order to bridge this gap, a decision support system based on quick response analytical techniques is to be developed, so that top management can see and appreciate the role of these techniques in a much broader sense.

On the other hand, when we view the syllabus to see what is taught in statistics, a detailed study of almost all the topics is done even at the undergraduate level. An undergraduate of statistics from the college affiliated to a university or an institution studies descriptive statistics, sample surveys, design of experiments, operational research, hypothesis testing, statistical inference, and lots of other techniques on data analysis. They are learning computer languages and are working on statistical software also. When we talk about other courses, statistics is taught as a paper in almost all the courses like mathematics, economics, commerce, psychology, computer science, pure science courses as well as professional courses like engineering, management etc. They study the major application statistics topics as per requirement in their courses.

The study recommends a strategic framework and policy for the industries, government and academic institutions to work jointly on this drive for quality enhancement in industries. To facilitate a better decision-making approach in the industry the subject statistics should lead to develop objective decision support system based on quick response analytical techniques are to be developed, so that top management can see and appreciate the role of these techniques in much broader sense.

- Industries should organize specially invited lectures from academic institutions that will explain the use of statistical techniques.
- They can also sponsor projects where academic excellence is required. This will enhance collaborative research, which will be time-bound.
- They can also sponsor some candidates for undergoing a course. Summertime projects can be thought of as a method of promoting

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applications of these techniques. These projects will be done by students of the colleges.

- Award for the industry and the college/university that has jointly done excellent work.
- Promotion of Design of Experiment which the industry has to use.

To disseminate the statistical decision-making approach in the industry, the subject statistics should be explored in an assortment of industrial dimensions, which would help the industry people value and understand the techniques in their day-to-day working.

- A suggestion to include a specialized one-week vocational course on selected statistical techniques can be conducted both at the college level and at the university level. The course design can be modified from time to time as per industry/market requirements.
- There should be at least one industrial course of one-week duration on a monthly basis for selected industries for middle-level executives. The course design can be modified from time to time in consultation with the industrial people. This course may be sponsored by a group of companies like auto-sector, banking sector, service sector, etc.
- Students who are undergoing graduation can be asked to write dissertation projects in industries as part of their curriculum.
- In three years, two/three projects can be taken up by the students during the summertime. These projects must carry a grade and qualifying marks and must be evaluated by a team of professionals comprising of academic and industry persons. A panel of three is suggested consisting of a college representative, industry representative, and a professional who has made an application in various types of projects.
- Colleges should also be encouraged to use real (simulated) data from the industry while they are developing a statistical technique for teaching. A lot of practical sessions can be added to give a fair idea of statistical analysis.

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