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Performance Improvement of a Petroleum Refining Process Using Quality Control

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ABSTRACT: *This study was aimed at applying Quality Control techniques in improving the performance of the production process in a Petroleum Refinery. Multiple Linear Regression analysis was employed to develop a Quality Control mathematical model that will improve the production performance of petroleum refining firms in Nigeria. The Linear Regression adopted consisted of dependent and independent variables: the independent variables were Quality Control indices while the dependent variable was the petroleum refinery production performance. Broad based results revealed that all the independent variables have positive coefficients relating to the production performance of the refinery as one unit change in Benchmarking resulted to 0.194 unit improvement in Production Performance, one unit change in Top Management Commitment resulted to 0.220 unit improvement in Production Performance, one unit change in Six Sigma Practice resulted to 0.224 unit improvement in Production Performance, one unit change in Continuous Quality Improvement resulted to 0.228 unit improvement in Production Performance and one unit change in Training resulted to 0.218 unit improvement in Production Performance. Conclusion and Recommendations were made that, Continuous Quality Improvement, Six Sigma Practice and Top Management Commitment, with their t-values > 1.96 of the Z-statistics used to corroborate the Linear Regression results, are more significant improvement predictors as they contribute better to the Production Performance of petroleum refineries in Nigeria.*
KEYWORDS: *Improvement, Performance, Process, Production, Quality Control.*

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I. INTRODUCTION

Quality control or QC for short is a process by which entities review the quality of all factors involved in production (Aft, 2017). Improving performance is a continuous process that increases product availability and reduces production cost. It also reduces the process as well as product quality variation from standards (Lakhal, et. al, 2006). Having considered Having considered the very essence of the concept of Quality Control as a key component in the operational success of Production and Plant Engineering systems, this research has been chosen to apply Quality Control in improving the performance of a petroleum refinery, by case studying the production facilities of refineries in the Niger Delta of Nigeria as case studies by developing a functional mathematical Quality Control model with the ultimate goal of improving their performance of their refining processes.

II. MATERIALS AND METHODS

Eighty (80) structured questionnaires were administered to core practitioners in the petroleum industry. The questionnaires were designed in line with the method adopted by Powell(2005), but were also made to cover various factors influencing the selection and application of QC techniques in petroleum refining companies and the degree to which QC practices is applied by petroleum refining companies in Nigeria.
The data collected were analyzed with the use of descriptive and inferential statistical methods.
The various equations used for th analysis of the data includes:

$$SWV = \sum_{i=1}^{n} Xi\ Y\,i \quad (1)$$

Where: SWV = Summation Weight Value
X_i = number of response to rating ij
y_i= the value of rating i (i = 1 to 5).

$$RII = \frac{SWV}{\sum x_i}$$

(2)
RII = Relative Importance Index
The Standard Deviation is given as

$$\sigma = \sqrt{\frac{\sum(Xi - \bar{x})^2}{N-1}}$$

(3)
where σ = Standard Deviation, $\bar{x}$=mean and N= total number of questionnaires utilized.

$$CM_i = \frac{\sum RII}{NSF}$$

(4) where:
CM = Cumulative Mean of the factors.
RII = mean of each Sub-factor.
NSF= Number of Sub-factors for each QC practice.
(i=1 to 5, j=1 to 5, m=5)

$$R = \frac{N\Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{\left[N\Sigma x^2 - (\Sigma x)^2 \right]}\sqrt{\left[N\Sigma y^2 - (\Sigma y)^2 \right]}} \quad (5)$$

Where
R = Pearson's Correlation Coefficient
N = number of pairs of scores
Σxy = sum of the products of scores
Σx = sum of x scores
Σy = sum of y scores
Σx^2 = sum of squared x scores
Σy^2 = sum of squared y scores

The Linear Regression Model adopted for data analysis is given as:

$$P = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + e \quad (6)$$

where:
P = Production Performance Coefficient
a = the y intercept when x is zero
b_1, b_2, b_3, b_4, b_5 and b_6 are regression weights attached to the variables
$X_1 \ldots X_n$ are the coefficients /indicators
X_1 = value for Benchmarking
X_2 = value for Top Management Commitment
X_3 = value for Six Stigma Practice
X_4 = value Continuous Quality Improvement
X_5 = value for Training
e = Error term.

III. RESULTS

The data analysis followed the method adopted by Powell (2005) which considers four (4) criteria for Quality Control researches case studying organizations using questionnaires as statistical tool(s). These criteria are (a) designation of respondents (b) the years of working experience of the respondents (c) the duration the organization has been in operation (d) the number of permanent employees.
The analysis is presented below:

Table 3.1: Analysis of Designation of Respondents

Designation of respondents	Frequency	Percentage	Cumulative Frequency
Supply Managers	30	38.9	38.9
Assistant Supply Managers	18	23.4	62.3
Quality Managers	15	19.5	81.8
Assistant Quality Managers	9	11.7	93.5

Others	5	6.5	100.0
Total	**77**	**100**	

The table above reveals that 93.5% of the respondents were directly engaged in activities related to QC and Sales Management in their respective organizations.

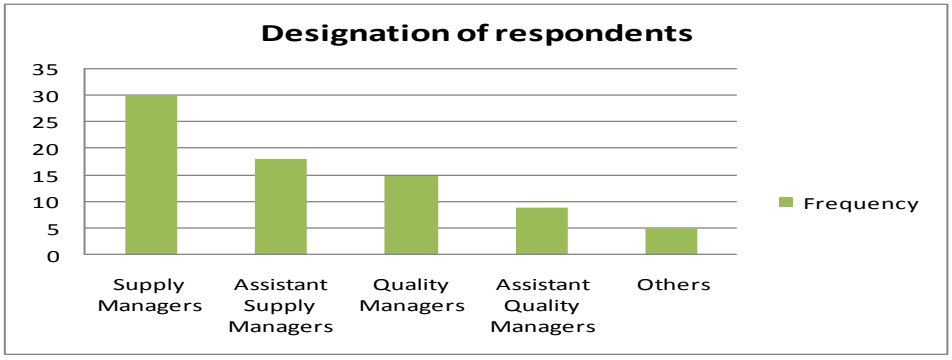


Figure 3.1: Distribution of the Designation of Respondents

Table 4.2: Analysis of Years of Working Experience

Years of working experience	Frequency	Percentage	Cumulative Frequency
Less than 5 years	14	18.2	18.2
5 – 10 years	25	32.5	50.7
11 – 15 years	20	25.9	76.6
Above 15 years	18	23.4	100.0
Total	**77**	**100**	

The results above indicate that 81.8% of the total number of respondents have been working in their current positions for more than 5 years.

Figure 3.2: Distribution of years of working experience

Table 4.3: Analysis of the duration the refinery has been in operation

Duration of Operation	Frequency	Percentage	Cumulative Frequency
More than 10 years	75	97.4	97.4
Missing	2	2.6	100.0
Total	**77**	**100**	

Results in Table 4.3 show that 97.4% of the total number of respondents indicated that their respective organizations have been in operation for more than 10 years.

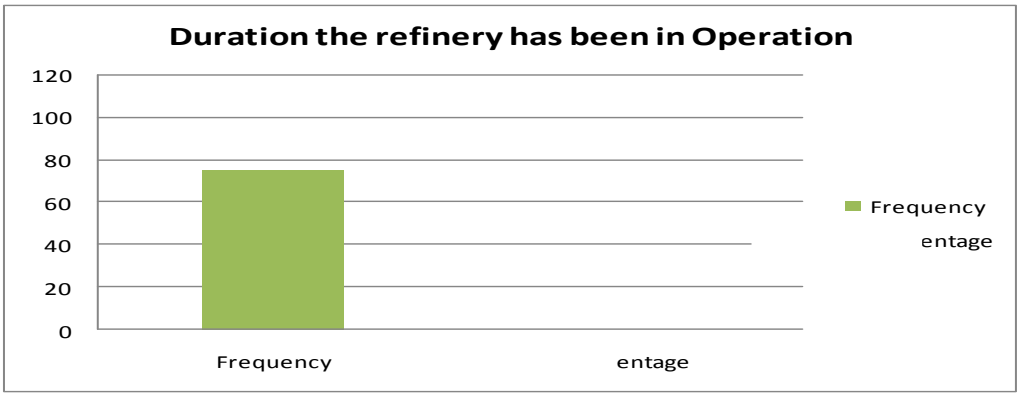


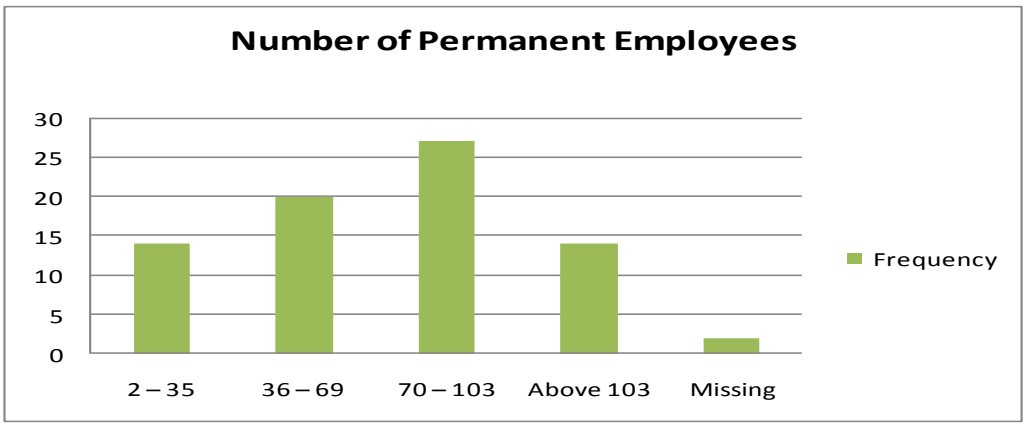
Figure 3.3: Distribution of the Duration the refinery has been in Operation

Table 4.4: Analysis of the Number of Permanent Employees

Number of Permanent employees	Frequency	Percentage	Cumulative Frequency
2–35	14	18.2	18.2
36 – 69	20	25.9	44.1
70 – 103	27	35.1	79.2
Above 103	14	18.2	97.4
Missing	2	2.6	100.0
Total	**77**	**100**	

Results from Table 4.4 above shows that 74.2% of the respondents indicated that they have more than 35 permanent employees, thus indicating that their respective organizations have a wider area of operations

Figure 3.4: Distribution of the Number of Permanent Employee



3.1 Result Of Objective 1

The result of first objective of this research reveals that eight (8) factors influence the selection and application of QC techniques in petroleum refining companies in Nigeria. Table 4.5 below displays the factors and their analysis.

Table 4.5:Analysis of the Factors influencing the selection and application of Quality Control techniques in petroleum refining companies in Nigeria

S/N	Factors	SA (5)	A (4)	N (3)	D (2)	SD (1)	SWV $\Sigma x_i y_i$	=	RII= $\frac{\Sigma x_i y}{\Sigma x_i}$	Ranking
1	Multi-faceted layers in management levels leads to duplication of duties.	23	21	14	9	10	269		3.4935	1
2	Top Management lack of commitment on quality control implementation.	16	10	15	6	30	207		2.6883	2
3	Acute competition at the expense of implementation.	12	13	12	10	30	198		2.5714	3
4	Socio-economic and Cultural dynamism.	14	11	7	8	37	194		2.519	4
5	Poor leadership by senior management hinder quality control implementation.	13	9	10	14	31	190		2.4675	5
6	Inadequate resources for implementing Quality Control practices.	9	8	15	10	35	177		2.2987	6
7	Little attention to quality control practices.	9	8	13	12	35	175		2.2727	7
8	Lack of effective and adequate training on Quality Control	9	7	10	11	40	165		2.1429	8

Continuous Likert Scale: SA= Strongly Agree, A= Agree, N= Neither Agree nor Disagree, D= Disagree, SD = Strongly Disagree.

3.2 Result of Objective 2

The result of the second objective of this research reveals that QC practices are applied to a large degree by the petroleum refining companies in Nigeria. Table 4.6 below displays the QC practices and their analysis:

Table 3.6: Result of Objective 2

S/N	Quality Control Practices	VLD (5)	LD (4)	MD (3)	SD (2)	VSD (1)	∑RII	NSF	CM = ∑RII/NSF	RK
1.	Benchmarking	63	96	93	41	15	13.961	4	3.49023	5
2.	Top Management Commitment	108	112	99	43	17	18.416	5	3.68310	4
3.	Six Sigma Practice	114	110	122	22	17	18.584	5	3.71686	3
4.	Continuous Quality Improvement	130	117	86	28	24	18.909	5	3.78180	1
5.	Training	101	104	136	30	14	18.74	5	3.74804	2

Continuous Likert Scale: 1= Very Small Degree, 2= Small Degree, 3=Moderate Degree, 4= Large Degree, 5= Very Large Degree.
Cumulative Mean Scale: (0 ≤ V.S.D. ≤ 1.4), (1.5≤ S.D. ≤ 2.4),(2.5 ≤M.D. ≤3.4),(3.5 ≤L.D.≤4.4),(4.5 ≤V.L.D. ≤5.0)
The results indicated that Quality Control practices have been practiced to a Large Degree by the refining firms.

3.3 Result of Objective 3

The mathematical model developed for this research which is aimed at improving the production performance of the Petroleum refining companies in Nigeria is given as:

$P = 0.100 + 0.194\ X_1 + 0.220\ X_2 + 0.224\ X_3 + 0.228\ X_4 + 0.218\ X_5$

An hypothetical simulation was generated for 5 iterations for the developed model in MATLAB, results of which showed a significant increase in the value of the production performance coefficient.

P = 3.8357, 3.9819, 4.30035, 4.1249, 4.1456.

Table 3.7: Result of Objective 3

Model	Unstandardized coefficients (B)	Std error	Standardized coefficients	T	Sig.
Constant	0.100	0.124		0.811	0.423
Benchmarking	0.194	0.070	0.216	2.844	0.208
Top management commitment	0.220	0.073	0.202	2.969	0.306
Six Sigma Practice	0.224	0.065	0.064	1.082	0.287
Continuous Quality Improvement	0.228	0.101	0.191	1.990	0.062
Training	0.218	0.083	0.151	1.927	0.063

3.4 Result of Objective 4

The regression model results above reveals that there is a positive relationship between dependent variable (Production Process Performance Coefficient) and independent variables (Benchmarking, Top management Commitment, Six Sigma practice, Continuous Quality Improvement and Training).

Thus an increase/decrease in any of the Quality Control Practices will result in a corresponding increase/ decrease in the production process performance. This is as illustrated by the graphs shown below which were generated by MS Excel software application.

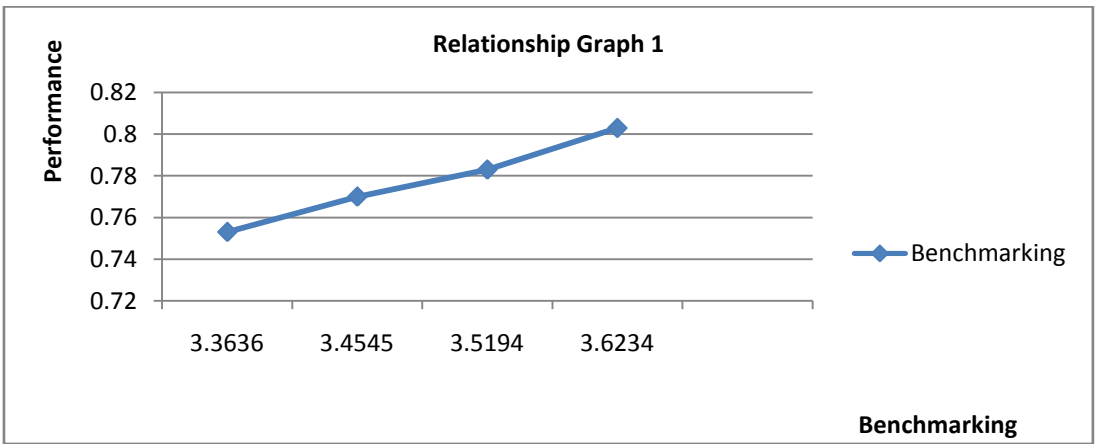


Figure 3.5: Performance Vs Benchmarking

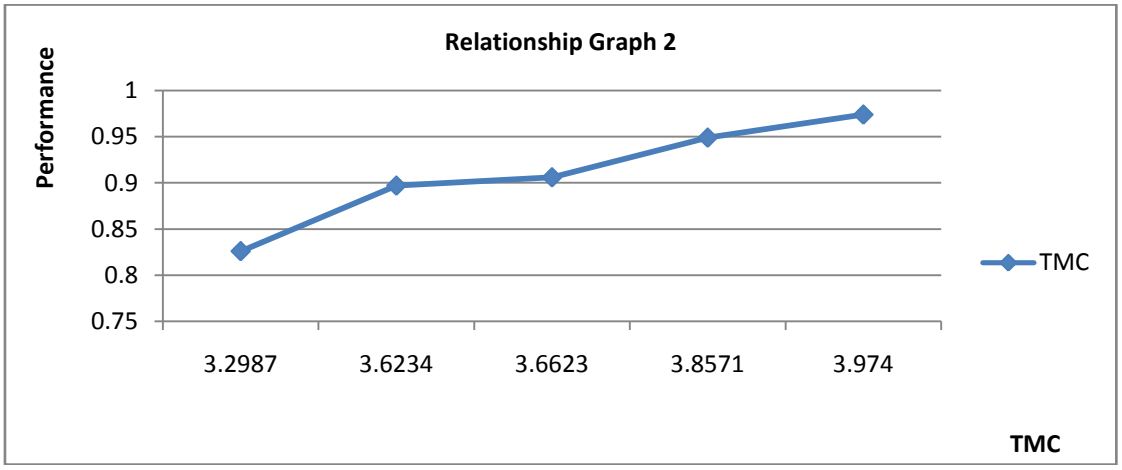


Figure 3.6: Performance Vs TMC

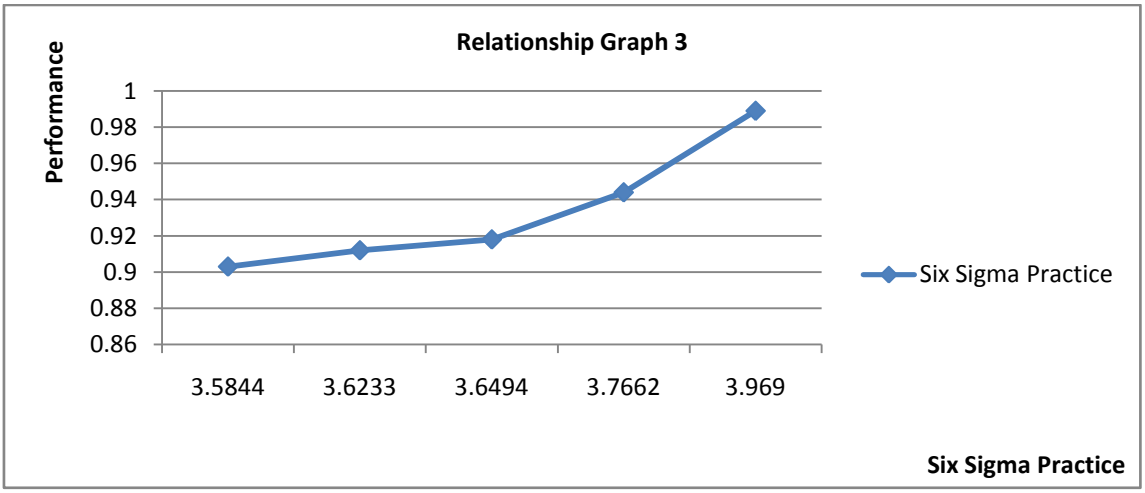


Figure 3.7: Performance Vs Six Sigma Practice

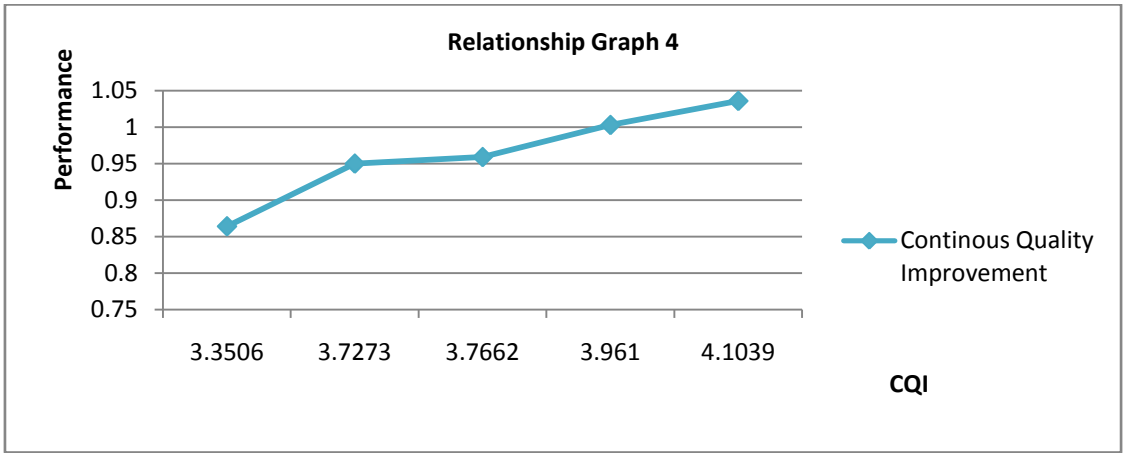


Figure 3.8: Performance Vs CQI

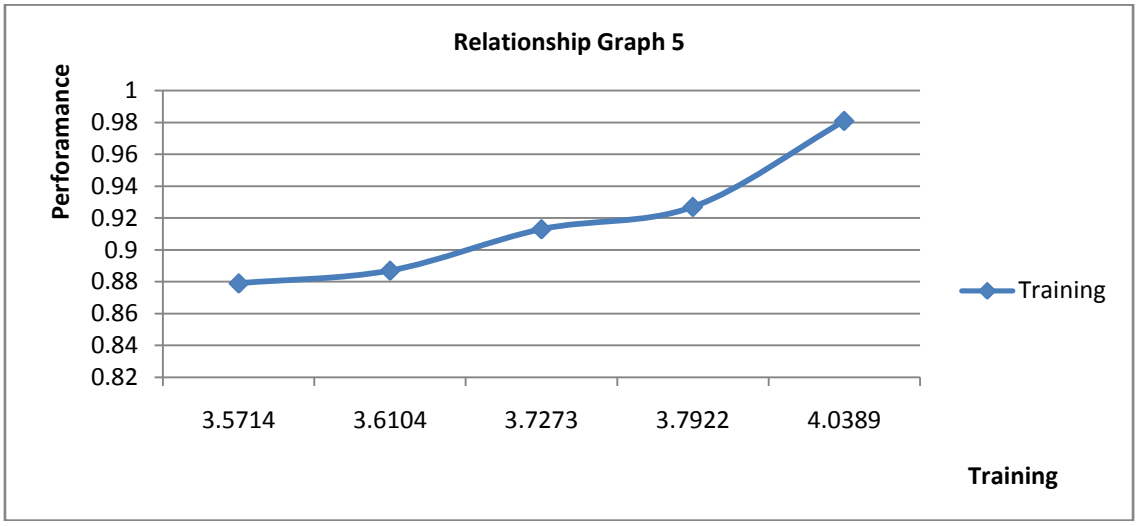


Figure 3.9: Performance Vs Training

IV. CONCLUSION

The aim of this research is to apply Quality Control technique in improving the performance of the production process in a petroleum refinery, using the Port Harcourt refinery as a case study. The regression model was used to propose a Quality Control model for improving the performance of the production process in petroleum refineries in Nigeria.

Data relating to the first objective of this study, which was to identify the factors influencing the selection and application of Quality Control techniques in petroleum refining companies in Nigeria, was analyzed using descriptive statistics. Data relating to the second objective of the study, which was to determine the degree to which Quality Control practices is applied by petroleum refining companies in Nigeria, was established using descriptive statistics also. Data for the third objective, which was to propose a model that improves the performance of the production process in a petroleum refinery, was analyzed using regression analysis.

A Quality Control model was developed for petroleum refining firms using regression analysis. The regression model was used to establish the relationship between Quality Control Practices and production performance of petroleum refining firms in Nigeria. The regression adopted consisted of dependent and independent variables: The independent variables: Quality Control techniques while the dependent variable is Production Process Performance of petroleum refineries in Nigeria. The Multiple Linear Regression Model indicated that all the independent variables have positive coefficient. The regression results above reveals that there is a positive relationship between dependent variable (Production Process Performance) and independent variables (Benchmarking, Top Management Commitment, Six Sigma Practice, Continuous Quality Improvement and Training).

From the findings, one unit change in Benchmarking results to 0.194 unit increase in production process performance. One unit change in Top Management Commitment, results to 0.220 unit increase in Production Process Performance. One unit change in Sigma Practice, results to 0.224 unit increase in Production Process Performance. One unit change in Continuous Quality Improvement, results to 0.228 unit increase in Production Process Performance. One unit change in Training, results to 0.218 unit increase in Production Process Performance.

The significant values represented by S are all >5% (from 0.06 – 0.42) hence this implies that only three out of the predictors used were significant. Similarly, the Z-statistical score test represented by **T** was used since the sample size is more than 30. Three of the **T** values are > 1.96 hence only three values are significant (Bench Marking, Top Management Commitment and Continuous Quality Improvement).

In summary, the findings of the empirical study are clear, and suggest several things. Firstly, we can say that Benchmarking, Top Management Commitment, Six Sigma Practices, Continuous Quality Improvement and Training have strong contributions toward QC application. Secondly, there is significant impact of QC on supply and production performance of petroleum refinery in Nigeria.

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NOMENCLATURE

Symbols/Abbreviation	Description
ANOVA	Analysis of Variance
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BPSD	Barrels of oil Per Stream Day
CNC	Computerized Numerical Control
CPM	Critical Path Method
CQI	Continuous Quality Improvement
CTQ	Critical to Quality
FCCU	Fluid Catalytic Cracking Unit
ISO	International Organization for Standardization
KPI	Key Performance Indicators
LPG	Liquefied Petroleum Gas
MATLAB	Matrix Laboratory Application Software
MS	Microsoft
NNPC	Nigerian National Petroleum Corporation
PHRC	Port Harcourt Refining Company
QC	Quality Control
QMS	Quality Management System
RII	Relative Importance Index
SPC	Statistical Process Control
SPSS	Statistical Package for Social Sciences

SQC	Statistical Quality Control
SWV	Summation of Weight Value
TAM	Turn Around Maintenance
TMC	Top Management Commitment
TQC	Total Quality Control
WRPC	Warri Refining Petroleum Company

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