Nigerian Research Journal of Engineering and Environmental Sciences 3(1) 2018 pp. 436-444

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

RJEES

Original Research Article

QUALITY CONTROL MEASURE OF A FIRM'S PERFORMANCE: A CASE STUDY OF A CONSTRUCTION COMPANY

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ARTICLE INFORMATION

Article history:
Received 15 May, 2018
Revised 03 June, 2018
Accepted 04 June, 2018
Available online 30 June, 2018

Keywords:
Productivity
Firm performance
Model
Statistical quality control
Control chart

ABSTRACT

Productivity measures how efficiently production inputs, such as labour, capital and material are used in an economy to produce a given level of output. Productivity growth constitutes an important element for modeling the productive capacity of the economy. The objective of this study is to analyze the impact of productivity, while using the inventory of the construction sector of Julius Berger Nigeria Plc as a case study to investigate, measure, plan and control the productivity and performance of the firm. Secondary data were used for this study and was generated through the firm's annual reports and financial statements to assess the productivity of the firm. Results show a low increase in the company productivity. Statistical quality control techniques were used to check the controllability of the system. The control chart of the mean and range chart was employed and the results obtained shows that the construction process was in control. The result of the statistical quality control techniques indicate that the construction process is under control. The investigation revealed that factors in both external and internal work environment as well as the firm's policies are unfavorable to the enhancement of labour productivity.

1. INTRODUCTION

The term productivity has been recognized for its contribution to operational, organizational, industrial, and national competitiveness. Productivity implies how well the resources are utilized for goods and service generation. It is crucial to the welfare of the industrial firm as well as for the economic progress of the country. High productivity refers to doing the work in a shortest possible time, with least expenditure on inputs without sacrificing quality and with minimum wastage of resources (Stephens et al., 2012).

Today the term productivity has acquired a wider meaning. Originally, it was used only to rate the workers according to their skills. The person who produced more either faster or harder were said to have higher productivity. Subsequently, emphasis was laid to improve the hourly output by analyzing and improving upon the techniques applied by different workers. A system of measurement was then evolved to compare the improvement made in relation to the rate of output and in order to improve productivity further, machines were introduced (O'Mahony and Timmer, 2009). Manufacturers of machines started incorporating new features, with the help of latest technological developments.

The term productivity measurement as examined in various fields of study including Economics, Accounting, Management, Psychology, Human Resource Management, and Industrial Engineering. When focusing on the industrial, national, and international levels, the term productivity is used to indicate the level of industrial competitiveness and the ability to maintain low inflation without extensive governmental support (Neely 2000). From the individual and system level, industrial engineers are expected to look for better ways of reducing the use of resources while increasing the outputs that one generates. For individual workforce, the motion and efforts need to be used wisely while, at the system level, the wastes (of time and others) should be minimized. Productivity measurement and analysis have gained more recognition from researchers and higher acceptance from practitioners over the past three decades (Singh et al., 2000). "You cannot manage what you cannot measure", by Deming (1986), has been continuously repeated over the past three decades by the shakers and movers in the field of engineering and management (Slack et al., 1998). This is due to the general belief that the selection of productivity (as well as other performance aspects) measures is one of the greatest single determiners of an organization's effectiveness as a system.

Many organizations have used productivity measurement as a primary tool for communicating future directions, establishing functional and project accountability, defining the roles and responsibilities, allocating the limited resources, monitoring and evaluating the activities, linking among key organizational processes, establishing the targets and benchmarks, and initiating necessary changes to ensure continuous improvement. Interestingly, solving problems related to quality is not sufficiently addressed without applying the specific tools that can help make the right quality decisions. Thus, the need for statistical tool, known as statistical quality control (SQC), which helps in identifying the source of variations in the production process as well as in the finish product itself. Statistical Quality Control is the term used to describe the set of statistical tools used by quality professionals. It is a branch of quality control which involves the collection, analysis and interpretation of data for use in quality control activities. According to Montgomery (2007), the origin of Statistical Quality Control techniques could be traced to Dr. Walter A. Shewhart of Bell Telephone Laboratories in 1924, when he developed a statistical chart for the control of product variables (Shewhart, 1924). Later in the same decade Dodge and Rooming, both of Bell Telephone in 1939 developed the area of acceptance sampling as a substitute of 100% inspection. Shahian et al. (1996), applied statistical quality control to cardiac surgery. They used quality control charts to analyze perioperative morbidity and mortality as well as the length of stay in 1131 non-emergent population. The result which shows that common adverse outcomes appear to follow the laws of statistical fluctuation was statistical in control. Appalasamy et al. (2012), undertook a research on the application of statistical quality control in accessing the quality of wine production using the physio-chemical quality characteristics (Alcohol percentage, haze, original gravity, etc.). From their findings, the wine production process was largely out- of- control across the quality characteristics.

Raheem et al. (2016) developed quality schemes to monitor the operation of Champion Brewery Plc using variable control charts. From their findings, the process was largely out- of – control. The aim of this work is to evaluate, plan and control the productivity and performance of Julius Berger Nigeria Plc using statistical quality control technique.

2. METHODOLOGY

Statistical quality control methods were employed for the analysis of data. This study was carried out using Julius Berger Nigeria Plc as a case study. The data obtained from the company's annual reports and financial statements was converted into productivity ratios and subjected to various mathematical manipulations to measure and determine the relevance of productivity on the firm's performance, and the various factors affecting it. Statistical quality control methods were chosen because of the ability to group data into dependent and independent variables. In the proceeding sections, we explained the mathematical platform on which the statistical quality control methods were developed, how data was visibly manipulated and the way this translates into interpretable results.

2.1. Statistical Quality Control

Statistical quality control methods enable us to monitor and maintain the ongoing construction process. This Statistical process control, uses graphical displays known as control charts to determine whether a process should be continued or should be adjusted to achieve the desired quality. This control chart provides a basis for deciding whether the variation in the output of a process is due to common causes (randomly occurring variations) or to out-of-the-ordinary assignable causes. For the purpose of this work, the Quality Control Charts was adopted.

2.2. Quality Control Charts

The control chart enables the determination of the control limit. The chart contains a center line (CL) that represents the average value of the quality characteristic corresponding to the in-control state. Two other horizontal lines, called the upper control limit (UCL) and the lower control limit (LCL), are also placed on the chart. These control limits are chosen so that if the process is in control, nearly all of the sample points will fall between them. In general, as long as the points plotted are within the control limits, the process is assumed to be in control, and no action is necessary. However, a point that plots outside of the control limits is interpreted as evidence that the process is out of control, and investigation and corrective action are required to find and eliminate the assignable cause or causes responsible for this behaviour. The appropriate process control charts, the variable control charts adopted are discussed as follows.

2.2.1. Constructing the mean chart

The Mean chart is based on the mean of a sample taken from the process under study. The sample contains five observations. To construct a Mean chart the centre line of the chart is first constructed. This is done by calculating the means of each sample. The centre line of the chart is then computed as the mean of all k samples means, where k represents the number of samples.

$$\text{Grand Mean } \overline{\overline{X}} = \frac{\sum of\ the\ means\ of\ the\ sub\ group}{Number\ of\ sample\ means} = \frac{\sum \overline{X}}{k} \qquad (1)$$

The standard error of the distribution of the sample means is designated by S_x It was determined as follows:

$$S_{\overline{X}} = \frac{S}{\sqrt{n}} \qquad (2)$$

Where S is an estimate of the standard deviation of the population, n is sample size (number of observations per sample).

These relationships allow limits to be set up around the sample means show how much variation can be expected for a given sample size. These expected limits are called the upper control limit (UCL) and the lower control limit (LCL). To construct the upper and lower control limits of the chart, Equation (3) was used.

$$UCL = \overline{\overline{X}} + A_2 \overline{R} \tag{3a}$$

$$LCL = \overline{\overline{X}} - A_2 \overline{R} \tag{3b}$$

Where: A_2 is a constant used in computing the upper and the lower control limits. It is based on the average range, $\overline{R}$. The factors for various sample sizes can be found in the table of factors for Control Charts, (Note: n in this table refers to the number in the sample). A portion of this table is shown in Table 1.

Table 1: Table of factors for Control charts

N	A_2	D_2	D_3	D_4
2	1.880	1.128	0	3.267
3	1.023	1.693	0	2.575
4	0.729	2.059	0	2.282
5	0.577	2.326	0	2.115
6	0.483	2.534	0	2.004

The control limits can be constructed by using the sample range as an estimate of the variability of the process. The control limits for the range R (max-value – min-value in the sample is given as;

$$\text{Grand (average) Range, } \overline{R} = \frac{\sum of\ the\ ranges\ of\ the\ subgroup}{Number\ of sample\ ranges} = \frac{\sum R}{k} \tag{4}$$

2.2.2. Constructing the range (R) chart

The R-chart is constructed in a manner similar to mean chart. The centre line of the control chat is the Grand(average) range, and the upper and lower control limits are computed as follows:

$$\text{UCL} = D_4 \overline{R} \tag{5a}$$

$$\text{LCL} = D_3 \overline{R} \tag{5b}$$

The values for D_3 and D_4, which reflect the usual three σ (sigma) limits for various sample sizes, are found in the Table of Factors for control charts.

3. RESULTS AND DISCUSSION

The obtained inventory of the construction sector of Julius Berger Nigeria Plc is shown in Table 2.

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Table 2: Inventory of the construction sector of Julius Berger Nigeria Plc

Particulars	Year				
	2011	2012	2013	2014	2015
Output					
Construction and maintenance					
i. Civil works	101,383,428	120,375,160	101,762,935	109,333,628	122,437,567
ii. Building works	65,889,534	76,307,591	82,165,087	70,386,981	46,633,975
iii. Services	125,761	271,962	284,163	258,098	170,999
Total output	167,398,723	196,954,713	184,212,185	179,978,707	169,242,541
Inputs					
Labour					
i. Wages and salaries	36,895,835	43,025,869	41,682,863	44,401,611	30,109,505
ii. Social security costs	387,061	410,629	468,087	1,211,930	-
iii. Defined benefit plans	3,707,244	1,449,205	844,939	325,215	407,270
iv. Defined contribution (pension schemes)	993,344	1,199,607	1,276,404	1,483,844	694,152
Materials					
i. Construction materials	3,498,050	3,226,126	3,299,342	2,850,488	2,589,532
ii. Consumables	2,269,159	2,089,625	2,272,197	2,026,787	1,481,724
iii. Spares	4,339,151	4,336,454	4,075,700	4,453,449	4,484,729
iv. Others	543,690	536,718	609,792	544,138	445,486
Capital					
Property, plant and equipment	54,650,926	56,172,990	66,542,850	66,711,736	55,470,657
Energy costs	1,946,713	2,708,783	2,942,892	4,593,487	6,148,772
Other expenses					
i. Marketing expenses	91,479	152,155	101,537	116,276	66,355
ii. Administrative expenses	21,998,911	27,066,902	26,750,656	26,829,104	30,650,717
iii. Audit fees	36,000	70,000	70,000	56,000	56,000
iv. Income tax expense	5,461,817	3,772,925	6,242,816	3,298,407	3,397,666
Total input	136,819,380	146,217,988	157,180,075	158,902,472	136,002,565

Note: All units are in Naira

3.1. Analysis of Data

3.1.1 Productivity measures

Assuming 2011 is the base year:

$$\text{Deflator for the year} = \frac{Current\ year\ price}{Base\ year\ price} \quad (6)$$

Calculations for the year 2011

Total Output = 167,398,723

Calculations for productivity measures were done as shown in Equations (7) to (12).

$$\text{Total Productivity Measure} = \frac{Total\ Output}{Total\ Input} \quad (7)$$

$$\text{Labour Productivity} = \frac{Output}{Labour\ Input} \quad (8)$$

$$\text{Material Productivity} = \frac{Output}{Material\ Input} \quad (9)$$

$$\text{Capital Productivity} = \frac{Output}{Capital\ Input} \quad (10)$$

$$\text{Energy Productivity} = \frac{Output}{Energy\ Input} \quad (11)$$

$$\text{Other Expenses Productivity} = \frac{Output}{Other\ expenses\ input} \quad (12)$$

The productivity index was calculated using Equation (13).

$$\text{Productivity Index} = \frac{productivity\ ratio\ in\ the\ current\ year}{productivity\ ratio\ in\ the\ base\ year} \quad (13)$$

The same calculations were done for the other years and the results are presented in Tables 3 and 4.

Table 3: Productivity ratios

Particulars	Year				
	2011	2012	2013	2014	2015
Total Productivity Ratio	1.22	1.35	1.17	1.13	1.24
Labour Productivity Ratio	3.99	4.27	4.16	3.79	5.42
Material Productivity Ratio	15.72	19.33	17.96	18.22	18.80
Capital Productivity Ratio	3.06	3.51	2.77	2.70	3.05
Energy Productivity Ratio	85.99	72.71	62.59	39.18	27.52
Other Expenses Productivity Ratio	6.07	6.34	5.55	5.94	4.95

Table 4: Productivity index

Particulars	Year				
	2011	2012	2013	2014	2015
Total Productivity Index	1	1.11	0.96	0.93	1.02
Labour Productivity Index	1	1.07	1.04	0.95	1.36
Material Productivity Index	1	1.23	1.14	1.16	1.20
Capital Productivity Index	1	1.15	0.91	0.88	0.99
Energy Productivity Index	1	0.85	0.73	0.46	0.32
Other Expenses Productivity Index	1	1.04	0.91	0.98	0.81

From Table 4, if the productivity index is greater than 1 it means there is increase in productivity. On the other hand, if the productivity index is less than 1, it means there is decrease in productivity. This analysis is as presented in Table 5. The increase in total productivity was calculated using Equation (14).

$$\text{Increase in Productivity} = \text{Productivity Index} - 1 \quad (14)$$

Table 5: Percentage % Increase or decrease with respect to the Base Year (2011)

Particulars	2012		2013		2014		2015	
	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease
T.P.	11%	-	-	4%	-	7%	2%	-
L.P.	7%	-	4%	-	-	5%	36%	-
M.P.	23%	-	14%	-	16%	-	20%	-
C.P.	15%	-	-	9%	-	12%	1%	-
E.P.	-	15%	-	27%	-	54%	-	68%
O.E.P.	4%	-	-	9%	-	2%	-	19%

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3.2. Analysis of Data using Control Charts

The two types of control chart that were used for this analysis are the Mean Chart and Range Chart.

Table 6: Values of mean and range

S/N	x1	x2	x3	x4	x5	Mean	Range
1	3.99	15.72	3.06	85.99	6.07	22.97	82.93
2	4.27	19.33	3.51	72.71	6.34	21.23	69.20
3	4.16	17.96	2.77	62.59	5.55	18.61	59.82
4	3.79	18.22	2.70	39.18	5.94	13.97	36.48
5	5.42	18.80	3.05	27.52	4.95	11.95	24.47
Σ						88.73	272.90

The grand mean $\overline{\overline{X}} = \frac{\sum \overline{X}}{n} = \frac{88.73}{5} = 17.75$

The grand range $\overline{R} = \frac{\sum R}{n} = \frac{272.90}{5} = 54.58$

For the Mean, $(\overline{X}) - Chart$

The upper control limit (UCL) = $\overline{\overline{X}} + 3\left(\frac{S}{\sqrt{n}}\right) = 17.75 + 3\left(\frac{5.46}{\sqrt{5}}\right) = 25.06$

The centre line for the chart is $\overline{\overline{X}}$ was computed from Equation (1).

The lower control limit (LCL) = $\overline{\overline{X}} - 3\left(\frac{S}{\sqrt{n}}\right) = 17.75 - 3\left(\frac{5.46}{\sqrt{5}}\right) = 25.06$

For the Range (R) – Chart

UCL = $D_4 \overline{R} = 1.712(54.58) = 93.44$

The centre line for the chart $\overline{R}$ was computed from Equation (4).

LCL = $D_3 \overline{R} = 0.2888(54.58) = 15.17$

The control charts are plotted thus:

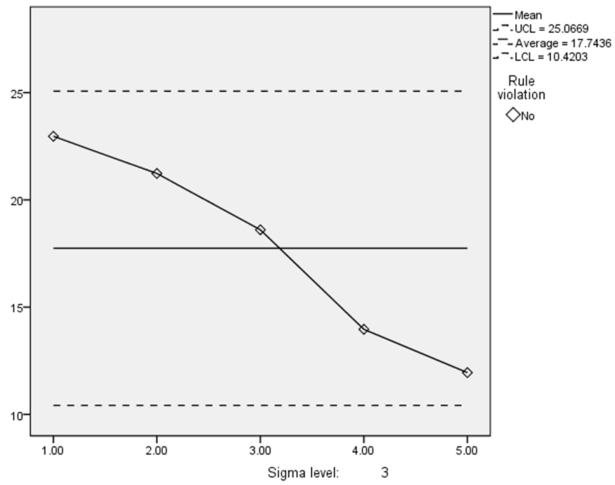

Figure 1: Mean chart

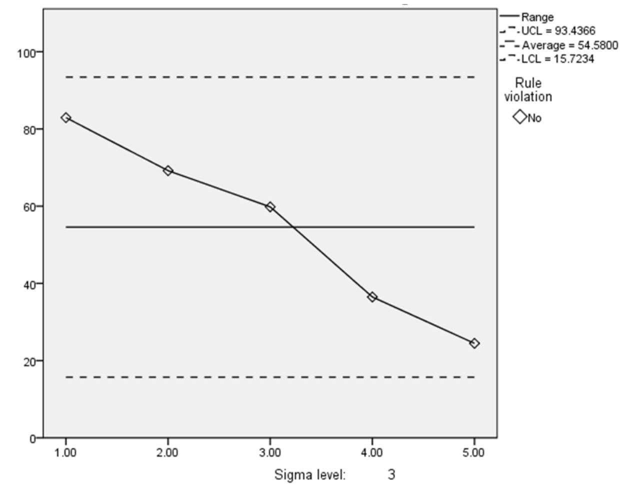

Figure 2: Range chart

The data used for the analysis is presented in Table 1. It is the inventory of the section of the construction company. The productivity ratios and Productivity measures of the firm was computed and the results shows that productivity of a firm could be measure using total productivity rather labour productivity, partial productivity or multifactor productivity. Total productivity represents the actual productivity as presented in Tables 3 and Table 4**.** Productivity of the company from 2011 to 2015 was analyzed using 2011 as a base year in order to measure the productivity level of the company. From the analysis of results there was an increase in total productivity by 11% in 2012 and radial decrease in the total productivity in 2013 and 2014 by 4% and 7% respectively. This radial decrease in total productivity of the company could be as a result of internal and external factors that facilitate the productivity growth.2015 saw an increase in Productivity with a small margin of 2% as presented in Table 5. For The statistical process control, the appropriate process control charts, the variable control charts; the Mean and Range charts were explored. To develop variable control charts for the measurable quality characteristics used during construction given the initial set objectives of this research, which includes: determining if the process of construction is statistically-in-control. To build appropriates attributes control chart for the quality of products and suggesting alternative control schemes for the future in event of out-of- control. It was found that the process based on the observed characteristics, is largely in-control across the five quality characteristics. From the plotted points on the mean chart and range, it could be seen clearly that all the points plotted are under control. If all the points plotted falls within the control limits then the system is in control. Also, if all the points follow random variation it means that the system is in control. For both the mean chart and range chart as shown in Figure 1 and Figure 2 respectively, any point falling outside the control limits indicates that assignable causes had affected the process and the process will be out of control. In the control chart, though all the points fell within the control limits but no sharp shift was observed after the second point and the same is observed after 3rd point till the 5th point plotted. These are the clear indications that the points falling within the control limits and no variation in the process indicating that the process is in control. Both the control charts show that the process is in control. The statistical quality control charts revealed that the system is in-control, but there has been a decrease in the productivity of the firm over the years. Hence, the productivity of the firm has to be worked upon and improved by considering the critical factors (both internal and external) that inhibits or facilitates productivity growth.

4. CONCLUSION

The study has found out that the operating policy of the construction sector of Julius Berger Nig. Plc is under control, but there has been a decrease in the company's productivity and effectiveness over the years. This decline is as a result of some external and internal factors that has affected the growth and productivity of the firm. Therefore, the company's performance and productivity can only be improved and optimize when these critical factors are dealt with. This study has also demonstrated importance of statistical quality control in measuring quality performance in construction company, especially for the companies aiming at producing optimally and at high quality level to the satisfaction of their customers.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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