Application of Attribute Quality Control Chart (AQCC) in Brick Industry Clusters (BIC): A Special Reference to Oluvil Brick Manufactory (OBM), Ampara Coastal Belt (ACB) of Sri Lanka

Ismail M.B.M
Senior Lecturer in Management
Department of Management
South Eastern University of Sri Lanka
Sri Lanka
mbmismail1974@gmail.com

Velnampy T
Dean, Faculty of Management Studies & Commerce
University of Jaffna
Sri Lanka
tvnampy@yahoo.co.in

Abstract - Quality control is a process by which entities review the quality of all factors involved in production. Statistical process control (SPC) is the application of statistical methods to the monitoring and control of a process to ensure that it operates at its full potential to produce conforming product. Attribute control chart is one type of the control chart. This research aims at knowing numbers of quality (non-defectives) and defectives manufactured by Oluvil Brick Manufactory and determining 3 sigma levels for Oluvil Brick Manufactory. Oluvil Brick Manufactory is taken a case study. This research is approached by analytical model of graphs i.e. attribute control chart and mathematical equations such as Upper Control Limit (UCL) and Lower Control Limit (LCL) for quality control. This research is based on both exploratory design and conclusive design. It is concluded that Oluvil Brick Manufactory produces 98% non-defectives and 2% of defectives. It produces bricks within 3 sigma levels. Once defectives are removed there can be zero-defective in Oluvil Brick Manufactory. Divisional Secretariat of Addalaichenai can recover its sales of bricks lost in past. This research adds value due to first time application of np chart among Brick Industry Clusters (BIC) in Divisional Secretariat of Addalaichenai.

Index Terms — Attribute Quality Control Chart, Brick Industry Clusters, Ampara Coastal Belt

I. INTRODUCTION

Although there are several definitions defined by several authors all the times the definitions defined by Juran and Crosssby are still valid and widely accepted all over the world. They are: Quality is fitness for use (Juran, 1974) and Quality means conformance to requirements (Crosb, 1979). Quality control is a process by which entities review the quality of all factors involved in production. Statistical process control (SPC) is the application of statistical methods to the monitoring and control of a process to ensure that it operates at its full potential to produce conforming product. Under SPC, a process behaves predictably to produce as much conforming product as possible with the least possible waste. While SPC has been applied most frequently to controlling manufacturing lines, it applies equally well to any process with a measurable output. One of the key tools in SPC is control charts. There are two types of control charts such as variable and attribute control charts incorporating a p chart or an np chart. When number of daily manufactured items is constant or np chart can be applicable. On the other hand, n chart can be used. Brick Industry is one of the Small and Medium Entrepreneurships (SME) which has not been popularized like other SMEs. However, all SMEs contribute to number of establishments, employments and value addition to GDP (Source: Task force for SME sector Development Program, 2002). Succeeding sections of this research describes about statement of the problem, research questions & objectives, review of literature, approach to the research, research design, research methodology, results & discussion of findings, conclusions, limitations & future research avenues, managerial implications and value addition.

A. Statement of the Problem

Researcher discussed with 10 brick buyers (newly built brick householders) in Oluvil. They never preferred block stones. If bricks were not available in Divisional Secretariat of Addalaichenai buyers go for where bricks are manufactured in Ampara Coastal Belt. Buyers' preference is on bricks in place of block stones. They further replied that there are defects in bricks such as break, crack etc. manufactured in Divisional Secretariat of Addalaichenai than other places where bricks are manufactured. Brick buyers are not price sensitive. They
prefer quality bricks without regard to price and place. Researcher interviewed one brick manufacturer. He told that sales of bricks are declining in Divisional Secretariat of Addalaichenai. Sales of brick industry in outside Divisional Secretariat of Addalaichenai increase. But, sale of the Brick Industry has increased. There are a number of brick manufactories which are run in Ampara Coastal Belt. From the above viewpoint of both parties, research problem rests on quality bricks (non-defectives) and the defectives. Researcher raised "Does Oluvil Brick Manufactory manufactures quality (non-defectives) bricks?" as a research issue.

B. Research Questions and Objectives

The above noted research issue is cascaded into two research questions.

1. Whether Oluvil Brick Manufactory manufactures different numbers of quality (non-defectives) and defectives?
2. Does the bricks produced by Oluvil Brick Manufactory fall within 3 sigma levels?

To solve the above two RQs, the following two objectives are set.

1. To find out quality of bricks (lengths of bricks) to identify causes for quality defect and to put forward some suggestions for quality correction.
2. To determine 3 sigma levels for Oluvil Brick Manufactory.

II. REVIEW OF LITERATURE

Previous literatures are found in Sri Lanka with different industries and different time frames and in foreign countries. There are few literatures in this respect in Sri Lanka. There was a research in Divisional Secretariat of Addalaichenai of Ampara Districts, Eastern Province of Sri Lanka for the first time i.e. Srilankan context using characteristics (variable) control chart by the same author (Ismail, 2011). Objectives were to find out quality of bricks (lengths of bricks), to identify causes for quality defect and to put forward some suggestions for quality correction. Brick manufacturers had been selected using stratified sampling. Simple random sampling was used for sampling bricks. Participatory observation method was used to collect data. Industry was Small and medium Brick Industry (SMBI). There was another research done by Cooray and Ruwine (2010) with the objective of facilitating the development of SMEs of Sri Lanka through sustainable consumption and production. Case study was used. Industry was Brass Industry. Previous literatures were available in different countries like Netherland, UK, UAE, USA, China, Thailand and Singapore. They had different objectives, methodology, data analysis, conclusion, Industry, Country and the source. This research is a geographical extension covering Ampara Coastal Belt. Further, this is an attribute quality control charts covering np. So, this research enhances the existing literature in the application area of attribute quality in Brick Industry.

A. Brick Making Process in Ampara Coastal Belt

Brick Making Process in Ampara Coastal Belt is analyzed in input and process level. Inputs are 5Ms such as Manpower, Machinery, Material, Money and Methods. Brick making consist of 15 sequential steps as indicated below.

1. Unseasoned clay is brought from Pallakkadu, Neinakkadu and Kuduwil
2. Seasoning (Pathanidal) occurs.
3. Unseasoned clay is spread over the land in a circle.
4. It is watered inside the circle considering the nature of the clay.
5. It is waited for a while.
6. Unseasoned clay is mixed with water thrice (Koththippurarathatal).
7. Wet clay is rounded.
8. Moulding starts.
9. Land is leveled neatly before putting the moulded brick onto the land.
10. Moulded bricks are dried for about two weeks.
11. After two weeks, dried bricks are put in rows in furnace (Soolhai).
12. An outer lining is made for dried bricks to put the husk (umi).
13. Husk is put on inside the rows of the dried bricks and outer lining and set fire to husk. Fourteenth, furnace is set fire to 3 days continuously.
14. After three days, ash (saampal) is removed and furnace is cleaned.
15. Brick is termed as fired brick.

(Source: Interview of brick cutter)

III. APPROACHES TO THE RESEARCH

This research is approached by analytical model incorporating graphs and mathematical models. Graphs are attribute control chart. Mathematical formulas are equations such as Upper Control Limit (UCL) and Lower Control Limit (LCL) for quality control. This proposed research uses np chart formulas for Oluvil Brick Manufactory. These formulae have been adopted from Grant and Leavenworth (2000).

A. np chart formulas for Oluvil Brick Manufactory

If subgroup size (Number of daily manufactured brick) is constant the chart for actual number of defectives can be used. Such chart is called as np or pn chart. Fraction defective –P. is calculated by dividing actual number of defectives by subgroup size (Number of daily manufactured brick). Actual
number of defectives -np- may therefore be quantity that, divided by n, gives p. Standard deviation of number of occurrences in n trials of an event with a constant probability of occurrence p in other words standard deviation of number of defectives is $\sqrt{np(1-p)/n}$. Standard deviation of the proportion of occurrences in other words the fraction defectives is $\sqrt{p(1-p)/n}$. The appropriate model for 3 sigma control limits on an np chart is given below.

$$UCL_{np} = np + 3\sqrt{np(1-p)}$$

(5.1.1)

$$LCL_{np} = np - 3\sqrt{np(1-p)}$$

(5.1.2)

B. Research Design

This research is based on exploratory design and conclusive design. Research problem is defined by exploratory design. Researcher discussed with brick buyers and interviewed brick manufacturer in Oluvil. In other words, research problem is qualitative. This qualitative research problem is quantified for arriving at conclusion for the research. Conclusive research design covers descriptive design. i.e. cross sectional research is designed. Record sheets are used to collect data from population at one point in time. Descriptive design is carried out in this research with the use of descriptive statistics.

C. Primary Sampling Units (PSUs) and Secondary Sampling Units (SSUs)

Target Universe of Primary Sampling Units (PSU) are all the research sites. i.e. brick manufactories located in Ampara Coastal Belt. Sample size of the PSU is selected by using Probability Proportion to Size (PPS) i.e. Cumulative Total Technique (CTT). SSU is selected from the selected PSUs. Sample size is calculated by the following formulae.

$$n = \frac{62 \cdot z^2}{D^2}$$

Equation (7.1.1)

$$n = \frac{280 \cdot 1.96 \cdot 1.96}{5 \cdot 5} = 43.02592$$

brick manufactories have to be selected as primary sampling unit. Probability Proportion to Size (PPS) i.e. Cumulative Total Techniques (CTT) is applied for calculating PSU as sampling technique. Sample size for PSU is 43. These 43 brick manufactories have to be selected from Ampara Coastal Belt. Researcher selected one of the brick industry leaders in Oluvil. Target Universe of Secondary Sampling Units (SSU) are all the respondents i.e. owners of brick manufactories. Since each brick manufactory has a single owner there are 43 brick manufactory owners. Therefore, there is no need to calculate number of SSU (respondents of brick manufactories) statistically. Sample size of SSU is 1 Oluvil Brick Manufacturer using convenience sampling technique for questioning with regard to defectives and non-defectives in their production.

D. Data Collection

Researcher interviewed with brick manufacturer of Oluvil. He has indicated that there are some causes for quality defects. They are adhered big sand, breadth hair stone, etc.; labour, animals’ finger mark; Cadjan, rain cloth mark, etc.; Crack, scrap, etc. and shrunk brick. Researcher coded these causes into the following ways. Causes for defective bricks and codes for them are depicted in table 1.

Table 1 Causes and codes for cause

<table>
<thead>
<tr>
<th>Causes for defective bricks</th>
<th>Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhered big sand, breadth hair stone, etc.</td>
<td>A</td>
</tr>
<tr>
<td>Labour, animals’ finger mark</td>
<td>B</td>
</tr>
<tr>
<td>Cadjan, rain cloth mark, etc.</td>
<td>C</td>
</tr>
<tr>
<td>Crack, scrap, etc.</td>
<td>D</td>
</tr>
<tr>
<td>Shrink in brick</td>
<td>E</td>
</tr>
</tbody>
</table>

(Source: Interview of Oluvil Brick Manufacturer)

Researcher instructed to use these coding when using record sheets. Data with respect to defectives and non-defectives were collected using primary source record sheet for reasons for defectives and record sheet for number of daily manufactured bricks. It took 36 days to fill the record sheet. Researcher used one record keeper for visiting Oluvil Brick Manufactory. Record keeper has been trained on how to develop rapport with owner of Oluvil Brick Manufactory and how to fill record sheet. Record keeper was A/L school leaver of AK/ Al Hamra Maha Vidyalaya of Oluvil. After filling this record sheet, this has been cross checked by the chief researcher for accuracy.

Observation was started on 02nd August, 2010 and ended up with 05th September, 2010. It took around 36 days which was a continuous 6 week sampling. 7 samples were observed each day. 700 bricks were manufactured daily in Oluvil. Since moulded bricks have to dry for two weeks before putting into furnace quality defects are observed in 15th day.

E. Data Presentation and Analysis

Data presentation and analysis for research objectives are shown in table 2.
Table 2 Research objectives, data presentation and analysis

<table>
<thead>
<tr>
<th>Research objectives</th>
<th>Method of data presentation</th>
<th>Method of data analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To know numbers of quality (non-defectives) and defectives manufactured by Oluvil Brick Manufactory</td>
<td>Tables</td>
<td>Ratio analysis</td>
</tr>
<tr>
<td>2. To determine 3 sigma levels for Oluvil Brick Manufactory</td>
<td>Attribute Quality Control Chart</td>
<td>Upper Control Limit (UCL) &amp; Lower Control Limit (LCL) statistics</td>
</tr>
</tbody>
</table>

IV. RESULTS AND DISCUSSION OF FINDINGS

A. Objective 1 - to know numbers of quality (non-defectives) and defectives manufactured by Oluvil Brick Manufactory

Table 4.1 Causes for defectives of Oluvil Brick Manufactory

<table>
<thead>
<tr>
<th>Cause wise total in all weeks</th>
<th>A (Adhered big sand, breadth hair stone, etc.)</th>
<th>B (Labour, animals’ finger mark)</th>
<th>C (Cadjan, rain cloth mark, etc.)</th>
<th>D (Crack, scrap, etc.)</th>
<th>E (Shrink in brick)</th>
<th>Total defectives from all causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total defectives</td>
<td>110</td>
<td>113</td>
<td>112</td>
<td>115</td>
<td>86</td>
<td>536</td>
</tr>
<tr>
<td>Rank</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Survey results)

There are 536 defectives out of 25200 (700 bricks per day * 36 manufacturing days) bricks. Major causes for these defects have been identified in adhered big sand, breadth hair stone, etc.; labour, animals’ finger mark; cadjan, rain cloth mark, etc.) and crack, scrap, etc. Shrink in brick also contributes a moderate cause for defectives in Oluvil Brick Manufactory. Causes for defectives have been found in all five areas of Oluvil Brick Manufactory.

Table 4.2 Ratio of Oluvil Brick Manufactory

<table>
<thead>
<tr>
<th>Brick Manufactory</th>
<th>Total number of daily manufactured brick taken as Lot Size and variable size n for 36 days</th>
<th>Total number of daily defectives for 36 days</th>
<th>Ratio: Total number of daily defectives for 36 days/ Total number of daily manufactured brick taken as Lot Size n for 36 days</th>
<th>% of ratio</th>
<th>Ω</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oluvil</td>
<td>25200</td>
<td>536</td>
<td>0.02127</td>
<td>2.126984</td>
<td>2</td>
</tr>
</tbody>
</table>

(Source: Survey results)

Oluvil Brick Manufactory has, for every 100 bricks manufactured, there are 2 defectives and 98 non-defectives (quality bricks).
B. Objective 2- to determine 3 sigma levels for Oluvil Brick Manufactory

Figure 4.1 Attribute control chart of Oluvil Brick manufactory based on 1 sigma level.

Figure 4.1

Attribute Control Chart

Brick Manufactory - Oluvil

Mean is around 15. UCL is around 19. LCL is around 11 is within 1 sigma. This refers to Oluvil Brick Manufactory produces around 15 defective bricks each week. However, there are chances up to a maximum of 19 defective bricks and up to a minimum of 11 defective bricks each week. Figure 4.1 shows that there are two out of UCL points and one out of LCL point. This means there are more than 19 defective bricks in two weeks (17th & 22nd week) and less than 11 defects in one week (15th week). Since there are two out of control UCLs and one out of control LCL, there is a need to calculate 2 sigma and 3 sigma levels. These 2 & 3 sigma levels are calculated and tabulated in table 4.1.

Table 4.3 Attribute control chart of Oluvil Brick manufactory based on 2 & 3 sigma levels

<table>
<thead>
<tr>
<th>Brick Manufactory: Oluvil</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UCL</strong></td>
<td>N</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--</td>
</tr>
<tr>
<td>UCL1</td>
<td>700</td>
</tr>
<tr>
<td>UCL2</td>
<td>700</td>
</tr>
<tr>
<td>UCL3</td>
<td>700</td>
</tr>
<tr>
<td>LCL1</td>
<td>700</td>
</tr>
<tr>
<td>LCL2</td>
<td>700</td>
</tr>
<tr>
<td>LCL3</td>
<td>700</td>
</tr>
</tbody>
</table>

(Source: Survey results)
Mean is around 15. UCL is around 23. LCL is around 7 is within 2 sigma. This refers to Oluvil Brick Manufactory produces around 15 defective bricks each week. However, there are chances up to a maximum of 23 defective bricks and up to a minimum of 7 defective bricks each week. Figure 4.3 shows that there is one out of UCL point. This means there is more than 23 defective bricks in one week (22nd week). Since there is one out of control UCL there is a need to calculate 3 sigma levels. This 3 sigma level is calculated and tabulated in table 4.3. Mean is around 15. UCL is around 26. LCL is around 3 is within 3 sigma. This refers to Oluvil Brick Manufactory produces around 15 defective bricks each week. However, there are chances up to a maximum of 26 defective bricks and up to a minimum of 3 defective bricks each week.

In a nutshell, it can be said that Oluvil Brick Manufactory has 3 out of control levels within 1 sigma level. It has 1 out of control limit within 2 sigma levels. It has no out of control within 3 sigma levels. It is tabulated in table 4.4.

<table>
<thead>
<tr>
<th>B- Sigma</th>
<th>Number of out of control brick production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick Manufactory- Oluvil</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

V. CONCLUSIONS

Oluvil Brick Manufactory manufactures 2 defective bricks for every 100 bricks. In other words, it produces 98 % non-defectives and 2 % of defectives. Oluvil Brick Manufactory produces bricks within 3 sigma levels.

A. Limitations and Future Research Avenues

It is a case study approach. Findings cannot be generalised to all manufactories. Albeit, findings can be generalized among brick manufactories that operate within Ampara Coastal Belt and brick manufactories having the same size and market structure. This research is geographically constrained with Ampara Coastal Belt (ACB). This research is only done in brick Industry. Researcher allows other researchers to expand this research in other geographical area or island-wide or in other field.

B. Managerial Implications

Once the above identified causes are removed there can be zero-defective in Oluvil Brick Manufactory. Divisional Secretariat of Addalaichenai can recover its sales of bricks lost in past.

C. Value Addition

Since Oluvil Brick Manufactory has stable daily production np chart can be applied among Brick Industry Clusters (BIC) in Divisional Secretariat of Addalaichenai. Attribute Quality Control Chart is for the first time applied in Divisional Secretariat of Addalaichenai in Brick Industry.

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REFERENCES