STUDY ON THE APPLICATION OF STATISTICAL QUALITY CONTROL TECHNIQUES IN SHOE MANUFACTURING FOR QUALITY IMPROVEMENTS

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ABSTRACT

This article presents the application of statistical quality control (SQC) techniques for solving rework/rejection of leather components in footwear manufacturing company by taking Peacock footwear company as a case study. Data were collected by direct data intake from production shop floor and pulled up data from company's database. The observed data were analyzed using SQC tools. Origin 8 and SPSS software's were used for the data analysis. Control charts revealed that the production process of the company is found out-of-control situation as some points outlie control limits. The study also determined the most frequently occurring type of defects using Pareto analysis. Three type of defects (Skipped stitches, Wrinkle not cut and Thread not cut) were identified as the most frequently occurring defects that are accounted for 72% of the total problems. Furthermore, cause & effect diagram is constructed through brainstorming sessions to identify potential causes of the defects. The company needs to alleviate the causes so that overall performance of the company can be improved.
Keywords: Ethiopia, footwear, statistical quality control (SQC), control chart, Pareto diagram.

1. INTRODUCTION

The tannery operation consists of converting the raw skin (a highly putrescible material) into leather (a stable material). The leather material is used for the manufacturing of a wide range of products like footwear, leather cloth, general goods, etc. The orientation of finishing tanneries has altered over the last few decades. Nowadays, tanneries produce leather material mainly for footwear, garments, general goods, furniture manufacturers and automotive upholstery manufacturers. Of which, the footwear subsector has grown considerably fast. About 65% of the world production of leather is estimated to go into leather footwear production (Netsanet, 2014). The production of leather footwear plays a considerable role in the development process of both developing and developed countries (Ulutas and Islier, 2015). The total export of leather footwear in the world is US $47 billion. China is the leading exporter of footwear with total market share of 22% followed by Italy, which accounts a value of 15%. Vietnam, Hong Kong, Germany and Belgium follow with footwear export share of 8%, 7.8%, 4.4%, and 3.9%, respectively. On the contrary, Africa's share of footwear export is mere 1.3% (LIDI, 2012). In general, the total production of leather and leather products in Africa is much lower qualitatively, quantitatively and value-wise (Mwinyihija, 2012). Seizing the global market opportunities has remained the key challenge, irrespective of having large resource endowment to satisfy raw

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material needs. Africa contains 21% of the livestock population in the world (UNIDO, 2010). Reducing the gap between resources and production is critical for the development of the leather-processing countries in Africa. Ethiopia is one of the leading leather processing countries in Africa (Addis et al., 2019). The leather industry in Ethiopia puts at the forefront of the African leather sector in line with its current comparative advantage for the raw material needs. Availability of large livestock population constituted the country's comparative advantages for the development of leather sector in Ethiopia. Ethiopia has the major comparative advantage to satisfy global raw material requirements (1st in Africa and 10th in the world in livestock population) (UNIDO, 2010). The livestock population growth trend (cattle, sheep and goat) also shows potential of the sector to be the main economic source of the country in the future. The livestock population escalated from 54.5 million in 1995/96 to 77.5 million in 2005/06 to 103.5 million in 2012/13 (Leta and Mesele, 2014). This resource potential makes the leather industry to be a good candidate for a concerted effort to expand production and achieve competitiveness at the international level.

Despite the above mentioned indigenous resource potentials, the leather industry of Ethiopia is yet to utilize its resources to appreciable extent. It significantly lags behind many countries that are less abundantly endowed with their indigenous resources (Netsanet, 2014). The tannery and footwear producers operate at 44.97% and 47.6% of the daily production capacity, respectively. For the period of 2005-2009, footwear producers performed, on average, only 27.55% of the planned export value (LIDI, 2012). Also, actual average production of the footwear industry is far below the international benchmark standards. For instance, in 2009, the footwear producing companies perform 4 pairs of shoe/day/person, which characterized low operational performance and production efficiency as compared to best practices (i.e. 16 pairs of shoe/day/person) (Cherkos, 2011). Studies revealed that the industry faces serious problems, both in the production of raw materials and in the manufacturing stages (Addis et al., 2017b). Apart from dozens of issues, quality related problems have been identified as the major obstacle for performance of the industry (Addis et al., 2017a) and sometimes the challenge is referred as "low-quality trap" (Altenburg, 2010, p. 9). In peacock footwear company of Ethiopia, quality related problems are easily identifiable when daily recorded production data is investigated. The company tried to implement quality circle in the production rooms. However, rework and rejections are easily identifiable at every corner of the production departments, which affect the total manufacturing performance. The quality inspection is normally carried out after mass production of footwear is finished. The rework/reject level of the company is 5%, while the international benchmark target is <3% (Chekos, 2011). This arise the need to study stability of the production process and identify causes of quality problems in the company. Accordingly, the main objective of this article is to evaluate quality performances of the company using statistical quality control tools. Specifically, the study set the following objectives: (1) to study process stability of the company, (2) to find the most frequently occurring types of defects, and (3) to identify the potential causes of the defects.

The rest of the paper has been organized as follows. Sections 2 presents the concept of control charts. Section 3 presents the research methodology, followed by data analysis and discussion in Section 4. Subsequently, conclusion is presented in Section 5.

2. CONCEPT OF QUALITY CONTROL CHARTS

Quality is seen as a strategic issue of any organizations. Organizations should consider effective tool to maintain quality and win their competitors. Statistical quality control (SQC) deals with the questions how to monitor, control and improve the quality of products and manufacturing processes by means of statistical methods. SQC and improvement includes, primarily, the areas of statistical control charts, acceptance sampling and Pareto diagram (Smith, 1994). Control charts are commonly used in production environments to analyze process parameters to determine if a process is actually within or out of control. The control chart for industrial SQC was invented by Dr. Walter A Shewhart in 1924. Recognizing that all production processes will show variation in product, Shewhart described two sources of variation; namely: variation due to chance causes (called common causes) and variation due to assignable causes (called special causes). Chance causes are inherent of a production process and caused by regular sources within the process or its environment; whereas, assignable causes, if they exist, can be traced to a particular machine, a particular worker or a particular material (Benneyan, 1998). According to Shewart, if variation in product is only due to chance causes, then the process is said to be in statistical control (Smith, 1994). The term 'statistical control' refers to the stability and predictability of a process over time and to the type of variability that exists.

Control charts are based on the Central Limit Theorem, which means the sampling distribution follows the normal distribution. Once normality of the measurements has been confirmed, the trial control limits for the individual values are commonly established. The control limits are then usually set equal to the centerline plus three (upper control limit (UCL)) and minus three (lower control limit (LCL)) theoretical standard deviations of the plotted values (Benneyan, 1998). A basic form of a control chart can be shown in Figure 1. The construction of control charts is based upon statistical principles. The charts used in this research require normal distribution of data. The centerline in Figure 1 could represent an estimate of the mean, standard deviation or other statistics. The curve to the left of the vertical axis should be viewed relative to the upper and lower control limits. There is very little area under the curve below the LCL and UCL. This is desirable as areas under a curve for a continuous distribution represent probabilities. Since a process or a property is out of statistical control when a value is outside the control limits, quality control requires that the probability for such an event to occur be small.

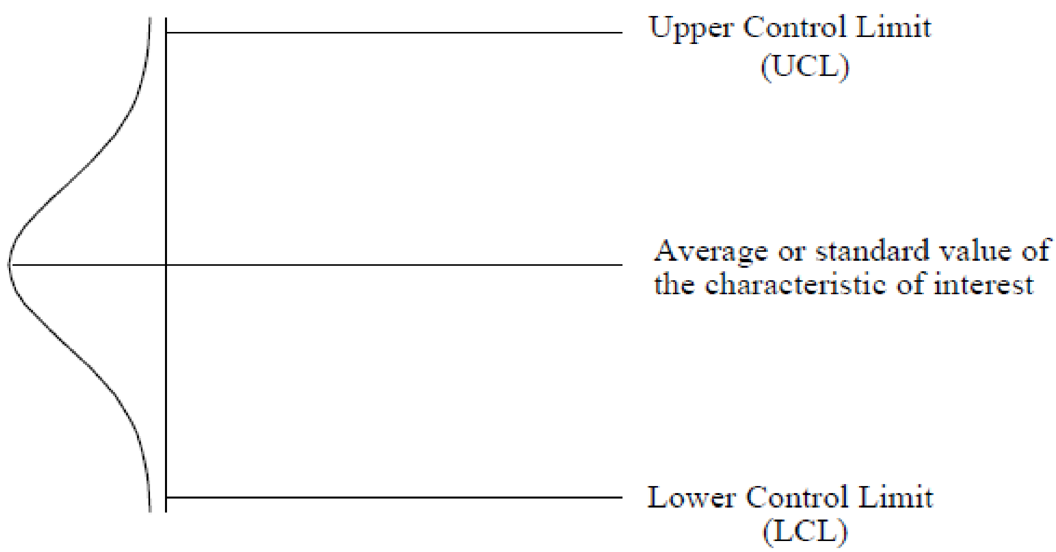

Figure 1: Basic form of a control chart (David, 2003)

A process is considered to be in statistical control if all of the plotted values are fall between the UCL and LCL over a sufficient span of time (Corbett and Pan, 2002). The idea of the control chart is 'proactive', in the sense that it is intended to monitor processes, signal when they go 'out of control' and thereby ensure quality products. Any out-of-control points for which assignable causes can be found should be removed or eliminated. When a process does go out of control, it is wise to have a rational method of detecting this, so that the situation can be corrected as soon as possible. Consequently, supplementary rules were invented to increase the chances of detecting out of control situations (see Table 1). (Stuart et al., 1996). The long-term objectives are to tighten the control limits by reducing process variation and to move the centerline so that the process is operating closer to some target value (Benneyan, 1998).

Table 1: Criteria for not being in a state of statistical control

S.N.	Control chart out-of-control signals
1	Any single subgroup value outside either control limit
2	Eight consecutive subgroups on one particular side of the centerline (CL)
3	Twelve of fourteen consecutive subgroups on one particular side of the centerline
4	Three consecutive subgroups beyond 2 standard deviations on a particular side of the CL
5	Five consecutive subgroups beyond 1 standard deviation on a particular side of the CL
6	Thirteen consecutive subgroups within +1 standard deviation (on both sides) of the CL
7	Six consecutive subgroups with either an increasing or decreasing trend
8	Cyclical or periodic behavior

There are different types of control charts. The most frequently used charts are the *X-bar* chart and *p*-charts. All of the other types of control charts are derivatives of these charts. The present study will focus on *np* chart. The *np* chart is used to evaluate process stability when counting the number of defectives. The *np* chart is useful to track the number of defective units in a sample of units (rather than the proportion of defective units). The *np* chart always requires a fixed sample size. Formulas for *np* chart are given in Equation 1, Equation 2 and Equation 3. Once the control limits (i.e. UCL, CL and LCL) are established for the *np* chart, these limits may be used to monitor the number nonconforming going forward. When a point is outside these control limits, it indicates that the number of nonconforming units of the process is out-of-control. An assignable cause is suspected whenever the control chart indicates an out-of-control process.

$$UCL = n\overline{p} + 3\sqrt{n\overline{p}(1-\overline{p})} \qquad (1)$$

$$CL = n\overline{p} \qquad (2)$$

$$LCL = n\overline{p} - 3\sqrt{n\overline{p}(1-\overline{p})} \qquad (3)$$

where, n is the sample size and $\overline{p}$ is the number of defective units in a sample of units.

3. METHODOLOGY

The study considered Peacock footwear company in Ethiopia. The company was selected because it represents large to medium sized footwear companies and a major shoe exporter in Ethiopia. Specifically, the study focused on one product model, i.e. *Bades shoe model (article number 6104)*. This product model was selected because it is on the production line for the recent past years, a product has high demand and whose data is accessed easily. Data were collected by direct data intake from production shop floor, internal company documentation and pulled up data from company's database. Physical observation of the company was potentially enabled to observe reworks and rejected leather components in the shop floor. Data were collected for leather cutting and stitching departments of the Peacock footwear company. The basic flow chart of leather footwear manufacturing process is shown in Figure 2. The collected data were analyzed using SQC tools such as control chart and Pareto diagram. Origin 8 and SPSS software's were used for the data analysis. In addition, brainstorming sessions were conducted with the production department heads, production planning personnel, benchmarking personnel and general/deputy managers to generate concrete ideas towards identifying the quality related problems and the possible causes. The brainstorming sessions enabled to build a cause-and-effect diagram. Then, a systematic approach of training followed by plan-do-check-act (PDCA) was proposed as an improvement strategy to alleviate causes of the problems.

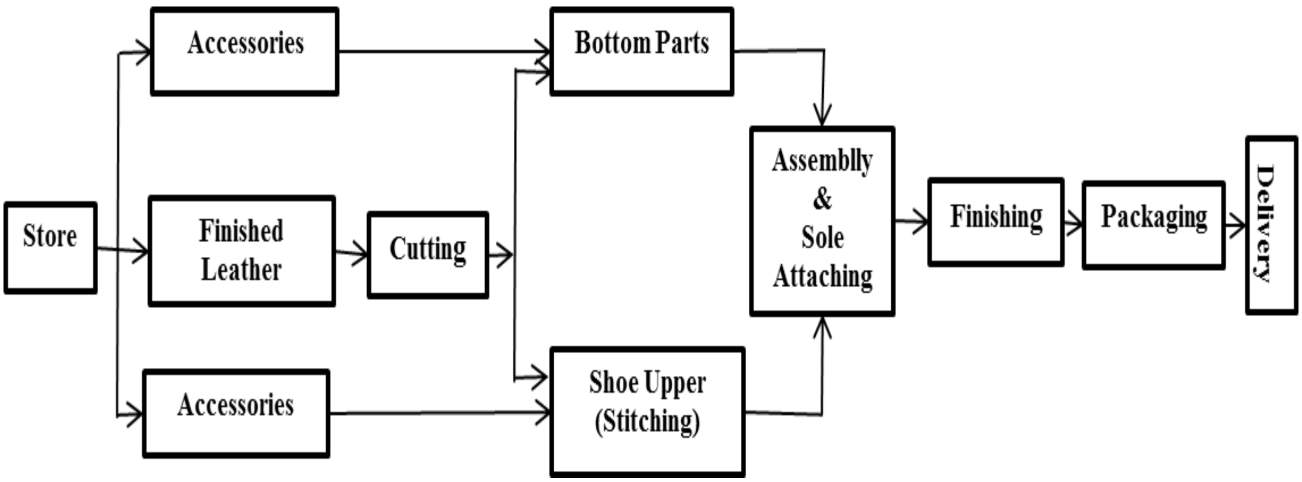

Figure 2: Basic flow chart of leather footwear manufacturing process

4. ANALYSIS AND DISCUSSION

In this section, a step-by-step procedure is described for applying control charts. The procedure is illustrated using data from the cutting and stitching departments of Peacock leather footwear manufacturing company.

4.1 Control chart for cutting department

Step 1. Collect the data using an appropriate data sheet

The quality indicator to be monitored and controlled is rework/rejects in the production process. Taking a constant sample size of 100, rework/reject data were taken for 26 days and trial limits were developed. The data is presented in Table 2, with the UCL & LCL (±3 sigma limits) and warning lines (±2 sigma limits).

Table 2: Rework/reject data in the cutting department

Sample number	Stitching	Rejects	UCL	+2 Sigma	+1 Sigma	Average	-1 Sigma	-2 Sigma	LCL
1	100	11.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
2	100	15.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
3	100	8.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
4	100	9.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
5	100	14.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
6	100	10.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
7	100	9.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
8	100	11.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
9	100	7.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
10	100	19.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
11	100	18.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
12	100	17.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
13	100	15.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
14	100	18.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
15	100	11.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
16	100	16.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
17	100	18.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
18	100	12.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
19	100	19.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
20	100	19.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
21	100	10.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
22	100	8.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
23	100	11.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
24	100	14.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
25	100	12.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
26	100	7.000	23.089	19.726	16.363	13.000	9.637	6.274	2.911
Total		**338**							

Step 2. Examine the distribution of the data and plot the data on np chart

Control chart for the cutting department is shown in Figure 3. The figure shows that all the sample points are randomly scattered and fall in between ±2-sigma limits. According to the out-of-control signals (see Table 1), the production process in the cutting department is statistically in control.

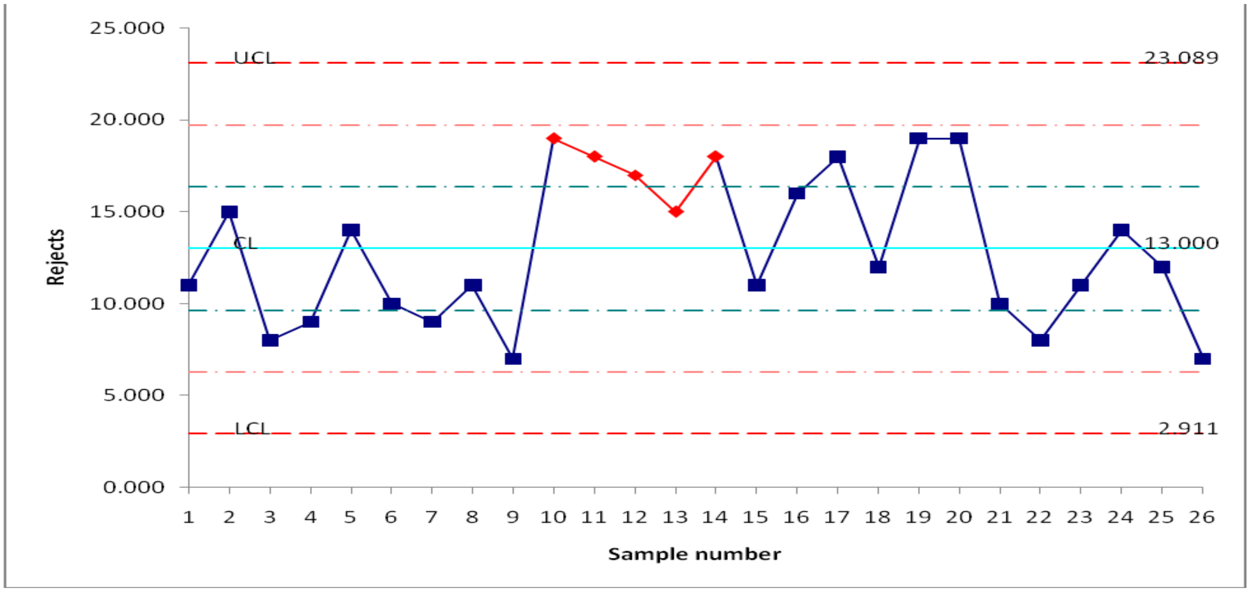

Figure 3: Control chart of cutting department

4.2 Control chart for stitching department

Step 1. Collect the data using an appropriate data sheet

The quality indicator to be monitored and controlled is rework/rejects in the production process. Taking a constant sample size of 100, sample was taken for 26 days. Data for the number of rework/*rejects* in the stitching department are presented in Table 3, with the trial control limits (UCL & LCL) and warning lines (±2 sigma limits).

Table 3: Rework/reject data in the stitching department

Sample number	Sample size	Rejects	UCL	+2 Sigma	+1 Sigma	Average	-1 Sigma	-2 Sigma	LCL
1	100	16.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
2	100	9.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
3	100	12.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
4	100	8.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
5	100	11.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
6	100	7.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
7	100	3.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
8	100	5.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
9	100	8.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
10	100	14.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
11	100	6.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
12	100	11.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
13	100	6.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
14	100	7.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
15	100	9.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
16	100	5.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
17	100	12.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758

18	100	18.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
19	100	20.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
20	100	9.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
21	100	22.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
22	100	20.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
23	100	20.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
24	100	17.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
25	100	10.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
26	100	7.000	20.703	17.546	14.388	11.231	8.073	4.916	1.758
Total		292.000							

Step 2. Examine the distribution of the data and then plot the data on np chart

An out-of-control condition happens either when one or more points fall beyond the control limits, or when the plotted points exhibit some nonrandom pattern of behavior. The control chart for the stitching department is shown in Figure 4. It can be seen that observation 21 is an outlier as it lies above the UCL. Also, six consecutive points (i.e. 21st - 26th observations) shows a decreasing trend. According to the signals presented in Table 1, the process is found in out-of-control condition for which a corrective action has to be taken, and hence step 3 is executed.

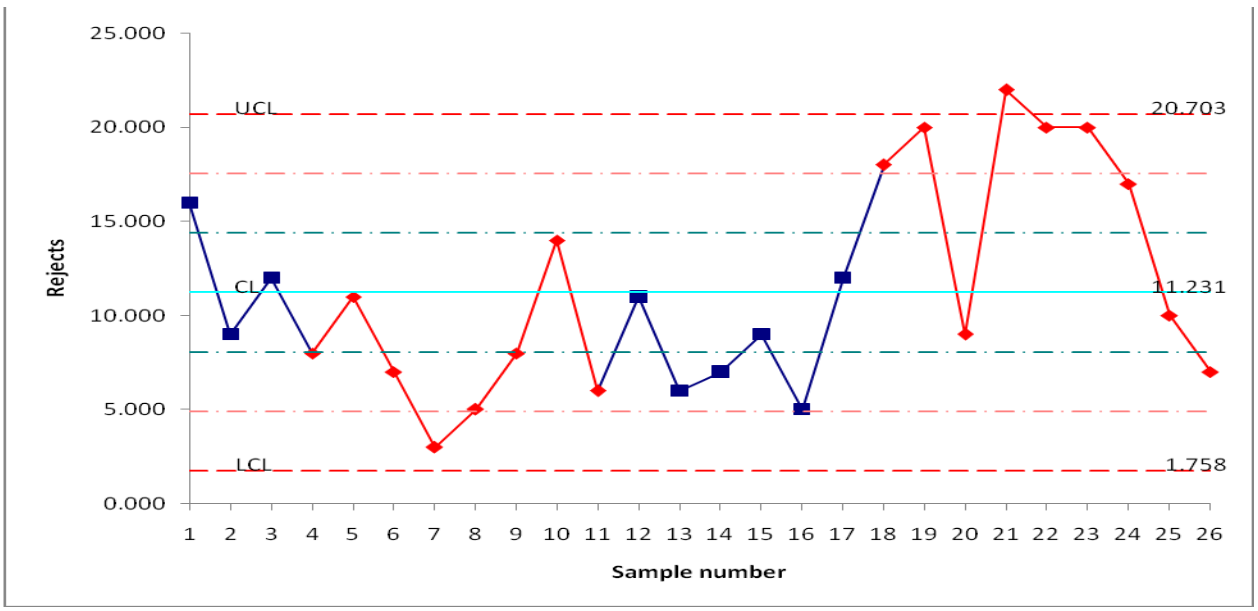

Figure 4: Control chart of stitching department

Step 3. Establish the trial control limits for the np charts by eliminating the out-of-control points

Analysis of out-of-control situations in Step 2 needs to be addressed in order to improve the stability of the process. The out-of-control points should be eliminated to develop trial limits for future monitoring. The revised control chart is shown in Figure 5. After removing the outlier, all points fall within the UCL and LCL. However, still a trend is revealed in the revised control chart. This might be happened because of the reason that same type of defective raw material was used for successive days of the production of leather footwear. The raw material, i.e. leather, might have scratches, cuts or marks, which collectively make the cut components have low quality level.

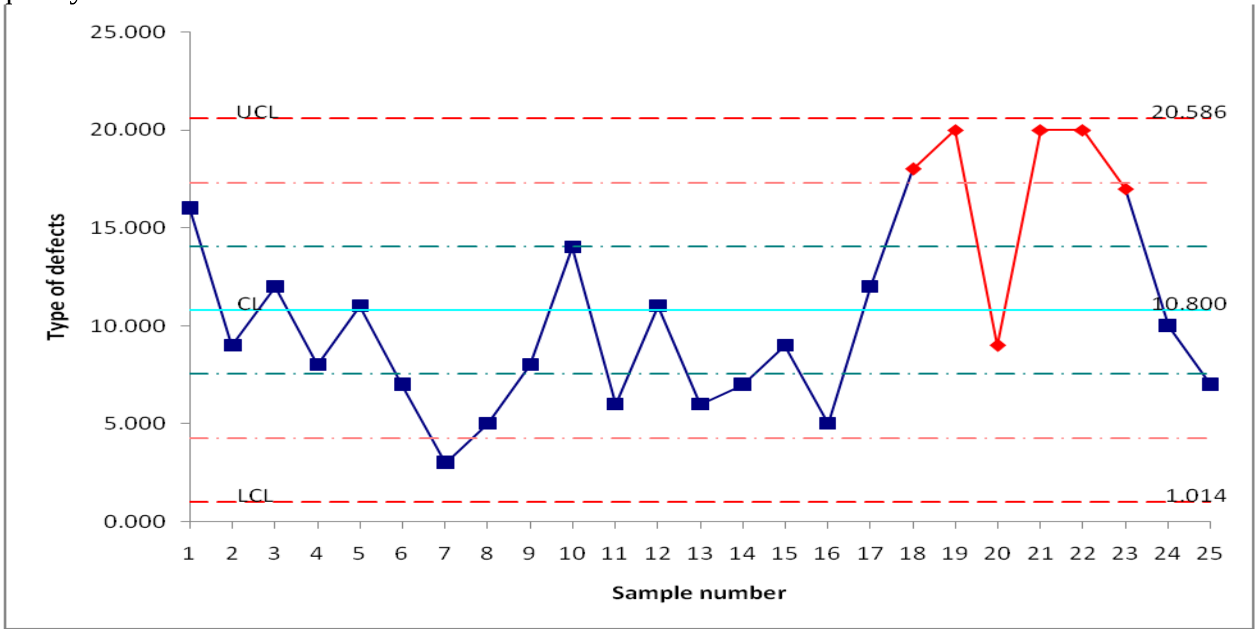

Figure 5: Revised control chart for stitching department

4.3. Pareto analysis

The Pareto principle is a 20/80 rule, which states that: "20 percent of the problems have 80 percent of the impact" (David, 2003). The present study conducted Pareto analysis for the stitching department. Pareto Analysis states that 80% of quality problems in the end product or service are caused by 20% of the problems in the production or service processes. In practice it is beneficial to separate "the vital few" problems from "the trivial many" (Samadhan et al., 2013). The first attempt is to find the most frequently occurring defects and then rank them according to their economic impact. The process in the stitching department were found in out-of-control situation. 12 types of defects were identified that are responsible for the instability of the process in the stitching department. A one-month data of the defects are collected with their frequency of occurrence (see Table 4). The Pareto diagram is shown in Figure 6. It is revealed that the three defect types (*Skipped stitches>1, Wrinkle not cut and Thread not cut)* are the vital few that results 72% of the total problems in the stitching department. In the other words, if these three types of defects are alleviated, the company can resolve 72% of its problems.

Table 4: Type of defects with their frequency of occurrence in stitching department

No	Type of defects	Frequency	% defective	% cumulative
1	Skipped stitches>1	208	26	26.0%
2	Wrinkle not cut	199	24.8	50.8%
3	Thread not cut	170	21.2	72.0%
4	Uneven stitch length	45	5.61	77.7%
5	Improper skiving leaving impression on upper	40	4.99	82.6%
6	Backer not caught in stitching	32	3.99	86.6%

7	Stitch too far or too close to edges	25	3.12	89.8%
8	Edge colorings after stitching	20	2.49	92.3%
9	Stitch not locked at end	18	2.28	94.5%
10	Stitch not per marking	18	2.28	96.8%
11	Thread not matching lining color	14	1.74	98.5%
12	Broken stitch	12	1.49	100.0%

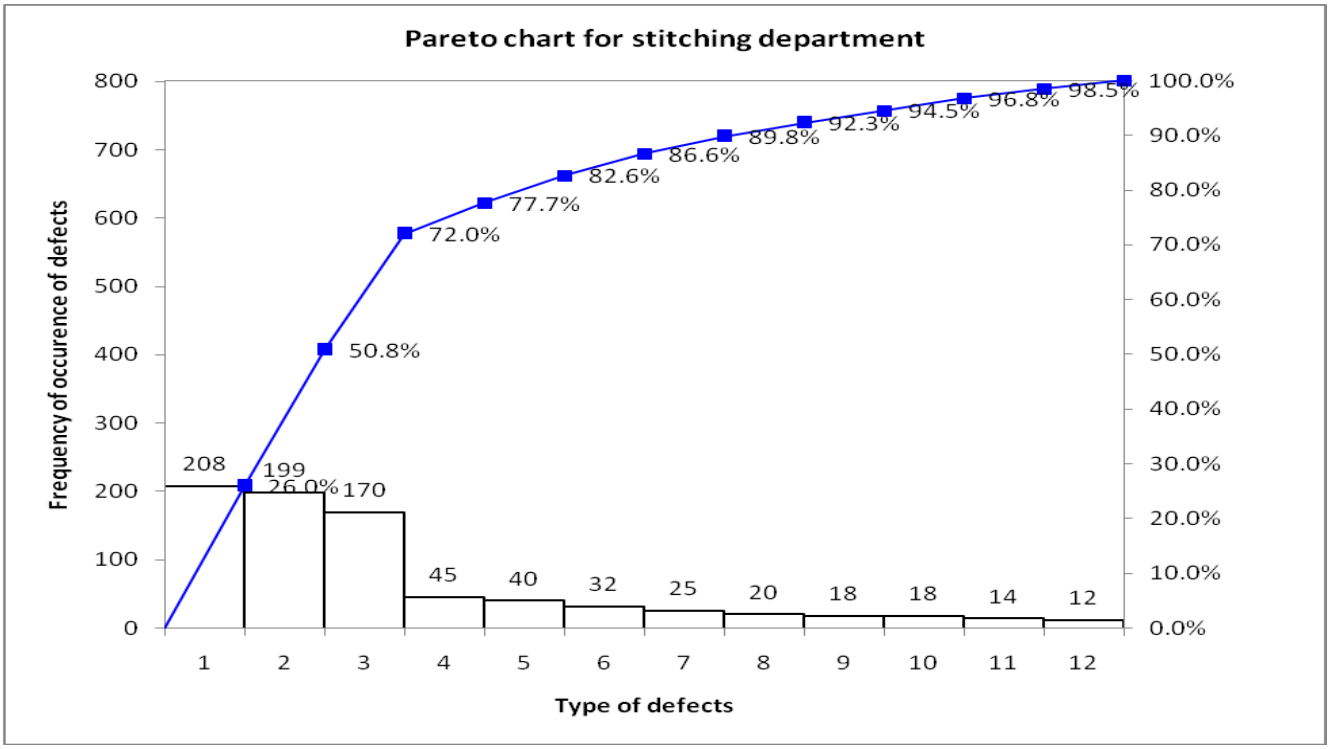

Figure 6: Pareto chart for stitching department

4.4. Cause and effect analysis

Scholars stated that while Pareto analysis helps to prioritize the most pressing problem, the C&E diagram helps to lead to the root cause of that problem (Adrian, 2000). Cause and effect (C&E) analysis usually comes from a brainstorming session, which helps to identify and isolate causes of a problem. Brainstorming is a tool used by teams to bring out the ideas of each individual and present them in an orderly fashion to the rest of the team. The key ingredient is to provide an environment free of criticism for creative and unrestricted exploration alternative solutions to problems (Adrian, 2000). The C&E diagram shown in Figure 7 were constructed by quality improvement team through brainstorming sessions involving all operators taking part in the related production and test activities. The C&E diagram shows major factors that can cause reworks/rejections of leather components in the production process of Peacock shoe factory.

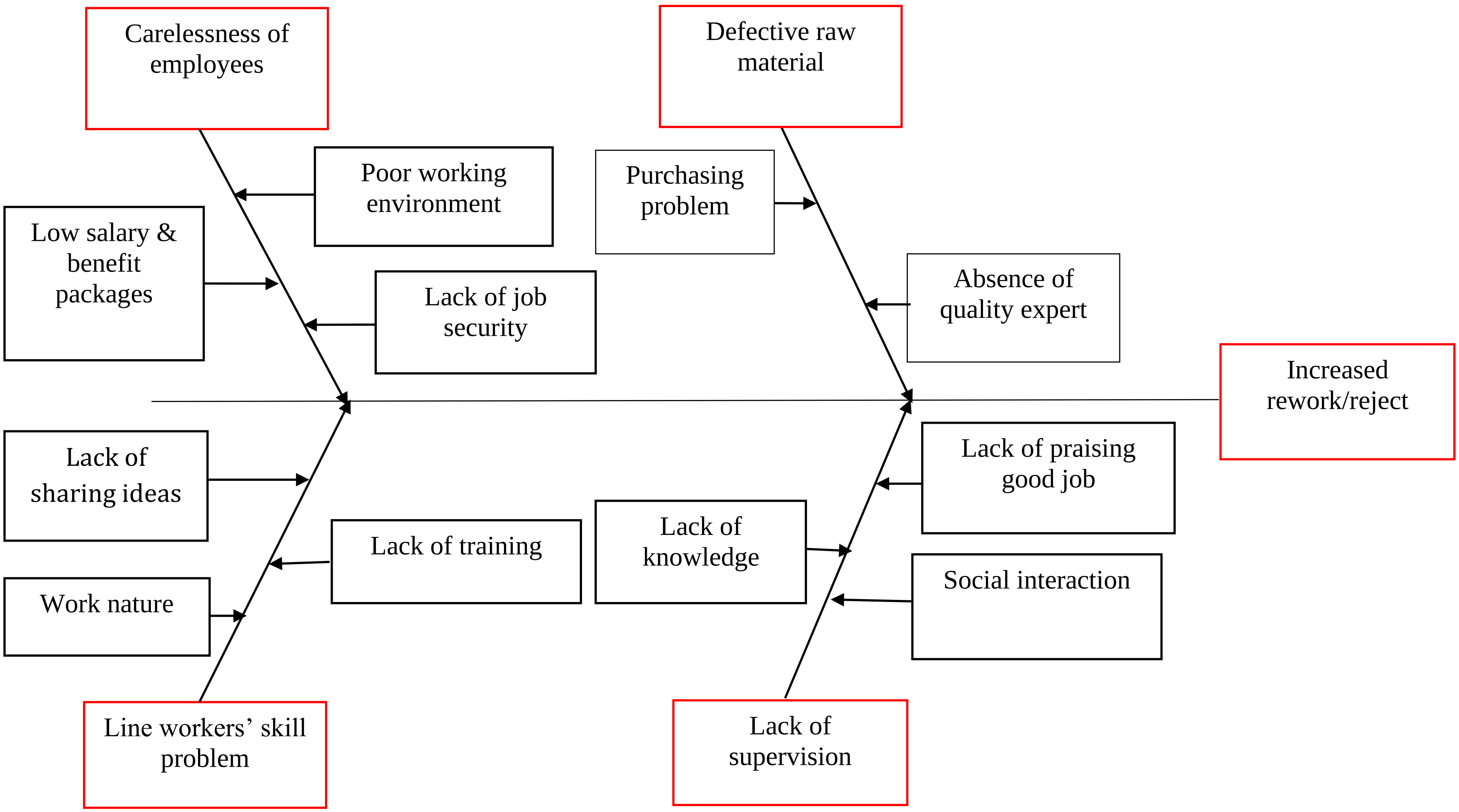

Figure 7: Cause and effect diagram

5. Conclusion

A high frequency of rework/rejections are warnings of quality related problems and if not addressed, may lead customers to find alternatives competitors. Particularly, quality control in leather footwear industry are perhaps difficult because various factors such as scratches and ticks on raw material may affect quality of the finished product. Causes of quality problems have to be identified and eliminated to maintain quality and win competitors in the field. In this study, rework and rejections have been identified as quality problems in Peacock footwear company in Ethiopia. The quality control charts were used to investigate process situations in the cutting and stitching department. It is revealed that the process is out-of-control as some points are found out of the control limits and some trends showed something is wrong in the process. The revised control limits have been determined by eliminating the out-of-control points, and then all the points fall within the UCL and LCL. The study also determined the most frequently occurring type of defects using Pareto analysis. Three type of defects (Skipped stitches, Wrinkle not cut and Thread not cut) are the most frequently occurring defects accounted for 72% of the total problems in that department. Furthermore, cause & effect diagram is constructed through brainstorming sessions to identify potential causes of the defects. The company needs to alleviate the causes so that overall performance of the company can be improved.

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