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Proportion Defective Chart to Monitor Apparel Production Process

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Abstract— *Quality management is a mechanism in apparel manufacturing that ensures customers obtain goods that are defect free and meet their needs. Each finished items of apparel industry has one or more quality characteristics that must be inspected during the production process. The objective of the study was to apply proportion defective chart (p-chart) to monitor the fraction of nonconforming apparel products. The variation in the production of apparel was examined from day one to day twenty-five. The p-chart was used to monitor the proportion of defective items in 25 numbers of samples with sample size 50 from the apparel production process. The sample proportion defectives remained within the upper and lower control limits of p-chart and revealed that the production process was in statistical control. On average, every day there was about 4% of the apparel production with defectives. On any given day, the defectives may be as high as 8.5% or as low as 0.94%. The apparel manufacturing process with defectives is not acceptable. Hence, the production department should employ other quality inspection tools and quality assurance methods to minimize the defectives in the production process.*

Keywords— ***Proportion defective chart, quality management, apparel manufacturing, defective, statistical quality control.***

I. INTRODUCTION

In the fashion world, the quality of apparel is a combination of the design and materials of the items that are needed for the intended use and target market. The fashion industry has a complicated supply chain, with manufacturers sourcing fabrics, sewing apparels, and selling them to retailers. Quality apparels meet end users all over the world through buyers and retailers. No one would purchase apparel that is of low quality and has obvious flaws. As a result, customers and retailers will not purchase a product that does not meet the quality standard. It is difficult for apparel manufacturers to disregard the importance of manufacturing high-quality goods.

The global textile industry began in the early twentieth century. The garment industry in Nepal began in the early 1980s. When Indian textile exporters began flocking to Nepal to avoid quota restriction in India, this industry exploded [1]. Nepal's textile and apparel industries make a major contribution to the country's manufacturing sector. This industry is a significant source of jobs and revenue, and it has aided the development of industries and businesses. The number of apparel industry establishments hopped from 86 to 234 between 1986/87 and 1991/92 in Nepal but actually declined from 1991/992 to 1996/97 [2, 3]. Nepal's garment industry reached a new peak in the year 2017/18. The major readymade garments are located in Kathmandu, Lalitpur, Morang, and Sunsari. Nepal exported readymade garments worth NRs. 5.97 billion in fiscal year 2017/18. It had been more or less constant over the last five years. More than 95% of the garment items were exported to the international market in 2017/18 [4].

The apparel manufacturing industry's outputs must go through a quality control process to sell in the target market and to export the product to the international market. Each finished items has one or more quality characteristics that must be inspected at the same time. The ratio of the number of defective items in a population to the total number of items in that population is called proportion defective. The product is considered defective if at least one of the characteristics does not meet the requirements. Whether performed by operators, supervisors, press operators, apparel packers, checker, or inspector, quality must be monitored during apparel production process [5].

Quality control is defined as the process of evaluating goods for quality after they have been produced and sorted into appropriate and unacceptable categories [6]. Statistical process control tool can be selected to monitor whether the apparel manufacturing, quality, or other aspects of the process are under control. Variations are unavoidable in any process since no process can run in perfect conditions for an extended period of time. The control charts aid in the management and recognition of certain variables and defectives [7].

The most common control charts for attribute data include the P (or np) and C (or U) charts. The P-chart is employed to monitor the fraction of nonconforming items. The items might have several characteristics that are inspected or evaluated, but in the end, the item is classified as good or bad [8, 9]. The study aims to apply proportion defective chart (p-chart) to monitor the fraction of nonconforming

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apparel products in the apparel manufacturing industry, Lalitpur.

II. METHOD

The cross-sectional study adopted a descriptive research design and focused on the quality control process of the medium-scale apparel industry located in Lalitpur, Nepal. The major finished products of the apparel industry are men's wear, women's wear, and children's wear. The study takes into consideration of women's wear for the study.

The primary data were collected through interviews with the supervisors of the apparel industry. The production process of the apparel was observed during the field visit to the industry in the month of November 2018. The overall production procedure had been observed along with quality management procedure, technology employed, maintenance, inventory, and marketing policy. There were many tools employed for the quality management system in the production department of the industry. The statistical process control chart was one of them.

There were few quality related problems in apparel manufacturing that should not be overlooked such as raw material defects, sewing defects, color defects, sizing defects, and other defects. Out of these, the study had considered one defect that is sizing defects. The standard or designed length of women's wear was 34 inches. The length of women's wear was measured using cloth-measuring tape available in the production department of the industry. The apparel women's wear that had measured exactly 34 inches were considered as not defective product and the women's wear that was measured less or more than 34 inches were considered as the defective manufacturing product. The production process unit was monitored for 25 days continuously with sample size 50 each day. The collected data were tabulated and analyzed using MS Excel. The defectives in the produced apparel were analyzed using proportion defective chart. The p-chart was used to determine the difference between standard measure and the actual measure of the apparel.

2.1 Proportion Defective Chart (p-chart)

P-charts are used to measure the proportion of items in a sample that are defective. P-charts are appropriate when both the number of defectives measured and the size of the total sample can be counted.

Let us assume that the apparel manufacturing process operates in a good working order. Let p be the probability that a given unit will not conform to specifications. The fraction (proportion) may be expressed as a decimal or as a percentage when multiplied by 100. The binomial distribution underpins the statistical principles of a control chart for proportion defective. It is also assumed that the successive units of attire produced are independent. Each unit of produced attire is a realization of a Bernoulli random variable with parameter 'p'.

Let 'n' be the random sample of selected units of apparel products and D be the number of units that are defective. Then D follows a binomial distribution with parameters 'n' and 'p' such that

$$P(D = x) = \binom{n}{x} p^x (1-p)^{n-x}, x = 0, 1, \ldots\ldots, n$$

where, nCx is the combination referring to n items taken x at a time.

The mean of the variable D is 'np' and the variance is npq or np(1-p). The sample proportion defective is the ratio of the number of defective items in the sample, D, to the sample size 'n', and is given by $\hat{P} = \frac{D}{n}$. The mean of this estimator is $\mu = \bar{p}$ and the variance is $\sigma^2_{\hat{p}} = \frac{\bar{p}(1-\bar{p})}{n}$.

If the true proportion conforming 'p' is known, then the control limits of the p-chart is given by

$$Upper\ Control\ Limit, UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$\text{Center Line, (CL)} = \bar{p}$$

$$Lower\ Control\ Limit, LCL = \max\left[0, \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}\right]$$

If the proportion 'p' is unknown, it can be estimated from the available data. The data is obtained by selecting 'm' preliminary samples, each of size n [8-10].

If there are Di defectives in sample 'i', the proportion defective in sample 'i' is $\hat{p}_i = \frac{D_i}{n}$, $i = 1, 2, \ldots, m$ and the average of these individuals sample fractions is

$$Average\ Proportion\ Defective,\ \bar{p} = \frac{\sum_{i=1}^{m} D_i}{m\ n} = \frac{\sum_{i=1}^{m} \hat{p}_i}{m}$$

III. RESULT

3.1 Production Process of Women's Wear

The inputs to the production process were labor, machines and mainly raw materials such as fabric, thread, fastener, embroidery, thread lease, wool, beads, elastic, etc. The various machines used by the apparel industry were for stitching, embroidery, cutting, printing, dying, and ironing. The stitching machines were imported from Japan and China; the embroidery machines were imported from India, and cutting machines from America and China. The printing and dying was done manually through outsourcing. The maintenance of the machine was done frequently. At the time of machine breakdown, a special

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maintenance people will be appointed to repair the machines and as per the requirement repair or replace, the parts will be decided. The production process of the apparel manufacturing had a sequence of a process that included cutting, stitching, printing, embroidery, dying, ironing, and packaging. The production of the product will be done as per the order of the customer. The customer selects the fabric, color, design, and embroidery and then places order of the product.

The delivery date will be mentioned to the customer when time required for the production is examined and also based on the customer's preferences. There was a good record maintenance system for customer order and delivery of the product. The criterion for the customer order was based on the quantity. The minimum order quantity should be twenty and the maximum number of product order will be taken as per the availability of the raw materials. The industry will prepare a sample as per the order and design placed by the customer. Mostly the new design or masterpiece will be prepared and sometimes the exiting product design can be developed in a different look on the basis of customer preferences. The color of the product is determined based on the order and availability of the raw material such as thread, and fabric. The financial department estimates the cost of the product. The approved masterpiece of new design with the sample is forwarded to the production department where pattern, grading, and measurement are provided. The produced product will be checked for measurement and quality with the standard design and then after the product is send for packaging as a finished product. The finished product is delivered to the customer. The final report is prepared with customer feedback by the team of marketing department.

3.2 Calculation of Control Limits for P-Chart

Out of 25 samples with sample size 50, the average number of defectives of women's wear was found to be 4.24 with standard deviation 2.38.

The average proportion defective is calculated as:

Average Proportion Defective,

$$\bar{p} = \frac{\sum_{i=1}^{m} D_i}{m\,n} = \frac{106}{25*50} = 0.085 \quad \text{OR}$$

$$\bar{p} = \frac{\sum_{i=1}^{m} P_i}{m} = \frac{2.120}{25} = 0.085$$

The calculation of control limits to construct p- chart are given below:

Upper Control Limit,

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.203$$

Center Line, (CL) = $\bar{p}$ = 0.085

Lower Control Limit,

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = -0.03339 \sim 0.000$$

The lower control limit of the proportion defective chart is calculated as -0.03339, and hence the lower limit is taken as zero for p-chart. The p-chart helps to look at variations in the rate at which defective items are produced. The production of apparel was observed for 25 days with sample size 50 in each day. The apparel was observed for either defective or not defective. The sample proportion of defectives within each lot, **p =D/n** , is computed and presented in the table 1.

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Table 1: Calculation of proportion defective and control limits

Day Number	Sample Size (n)	Number of Defectives (D)	Proportion Defective (p =D/n)	Average Proportion (p-bar)	Upper Control Limit (UCL)	Lower Control Limit (LCL)
1	50	3	0.060	0.085	0.203	0.000
2	50	6	0.120	0.085	0.203	0.000
3	50	2	0.040	0.085	0.203	0.000
4	50	2	0.040	0.085	0.203	0.000
5	50	2	0.040	0.085	0.203	0.000
6	50	7	0.140	0.085	0.203	0.000
7	50	1	0.020	0.085	0.203	0.000
8	50	3	0.060	0.085	0.203	0.000
9	50	2	0.040	0.085	0.203	0.000
10	50	6	0.120	0.085	0.203	0.000
11	50	8	0.160	0.085	0.203	0.000
12	50	1	0.020	0.085	0.203	0.000
13	50	4	0.080	0.085	0.203	0.000
14	50	3	0.060	0.085	0.203	0.000
15	50	9	0.180	0.085	0.203	0.000
16	50	4	0.080	0.085	0.203	0.000
17	50	5	0.100	0.085	0.203	0.000
18	50	8	0.160	0.085	0.203	0.000
19	50	5	0.100	0.085	0.203	0.000
20	50	5	0.100	0.085	0.203	0.000
21	50	4	0.080	0.085	0.203	0.000
22	50	4	0.080	0.085	0.203	0.000
23	50	2	0.040	0.085	0.203	0.000
24	50	8	0.160	0.085	0.203	0.000
25	50	2	0.040	0.085	0.203	0.000
SUM	**1250**	**106**	**2.120**			

3.3 Proportion Defective Chart

The p-chart plots the proportion defectives against sample number. The centerline of the graph is given by $\bar{p}$, which is the defect rate from all samples combined. Control lines for samples are plotted along with the upper control limit and lower control limits.

The variation in the production of apparel was examined from day 1 to day 25. The p-chart reveals the production process was in statistical control. This means that the production process was consistent and predictable. On average, each day there was about 4% of the apparel production with defectives. Some days it may be as high as 8.5% or as low as 0.94%. The chart presented common causes of variation. The sample proportion defectives lie within the upper and lower control limits and it reveals the production process is in statistical control. But this does not mean that the production process is acceptable because 8.5% of apparel with defectives is not acceptable. The p-chart helped to detect the defective in the production process. The production unit should employ other quality inspection tools and methods to minimize the defectives during the production process.

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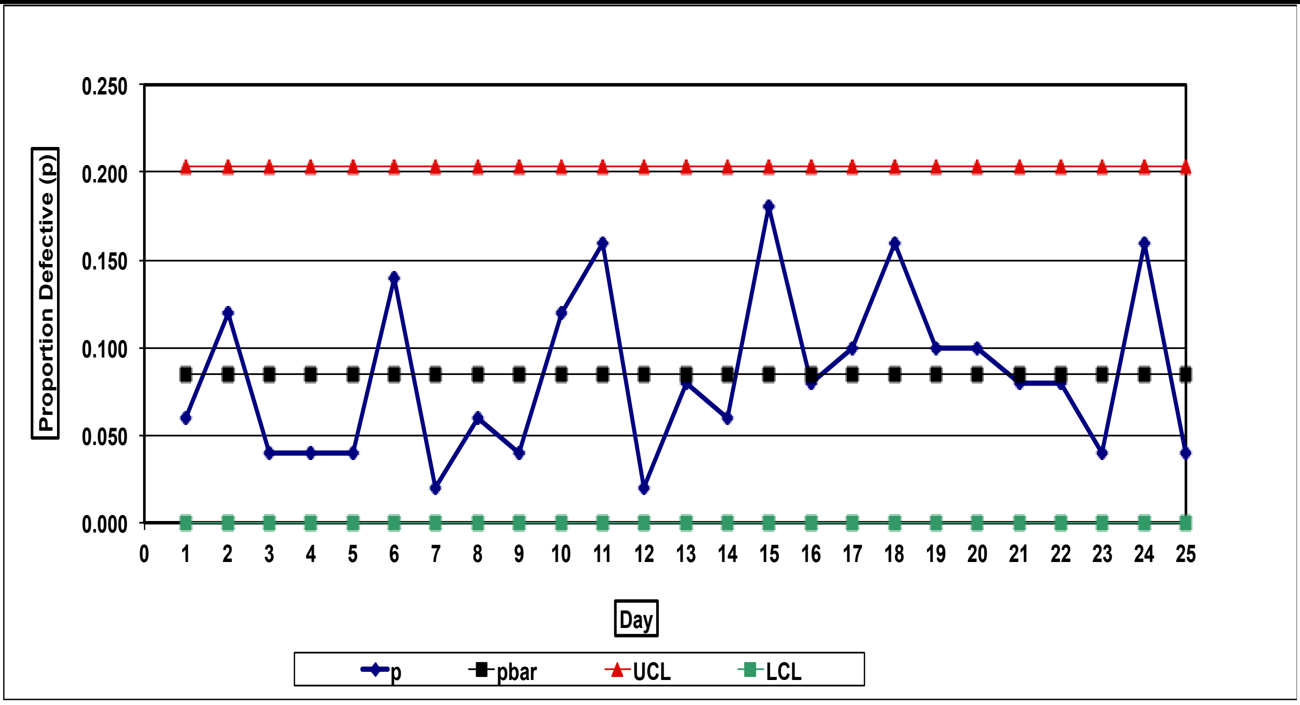

Fig. 1: Proportion Defective Chart (p-chart)

IV. CONCLUSION

The women's wear was the finished product of the apparel industry considered for the study. The length of the apparel was measured, and the fraction of nonconforming was observed. The proportion control chart was used to inspect the defectives. It was found that the proportion defectives are within the control limits and hence the production process of apparel is in statistical control. Nevertheless, the production department should also aim to enhance productivity in order to ensure the consistency in quality of apparel production. Furthermore, future research can be conducted with other quality measures in apparel manufacturing industry.

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