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Factors Affecting Defects Within the Apparel and Textile Industry

Abstract

The main objective of this report is to ascertain the effect of improvements made to reduce the defect rate in the garments production line and to increase production rate while also decreasing waste. A thorough research was conducted on the major segments of the production process using the data provided by MerchCo Inc. Initially, we looked into different sets of machines, however, the team decided to analyze the embroidery machine production as it produced the highest number of defects. Data was collected for 4 different scenarios: process without any improvements, process with RPM of motor decreased, process with reduced stitch density, process with both reduced stitch density and reduced RPM of motor. The quality characteristic measured and analyzed was the defect rate.

Data was captured and analyzed for all four scenarios. A general increase in quality was observed in the progression from scenario 1 to scenario 4. The team used descriptive statistics tools such as histograms, box plots, scatter plots to compare the effect of improvements made. Moreover, inferential statistics tools such as the p-chart were used for the given data. Furthermore, the team also decided to conduct a design of experiments that involved a factorial design to determine the significance of each improvement made and their interaction. The final results determined that when applying both decrease in RPM and reduction in stitch density (scenario 4), the entire process is under statistical control and the defect rate also reduces from 41 to 23.

Introduction

The organization under investigation is a retail services company. MerchCo Inc. is a manufacturing and distribution business that specializes in graphic t-shirts, embroidery, and stitching services. The facility prides itself on its efficiency and flexibility in t-shirts that are identical to the demand of the customer. With their values and principles very closely aligned with quality, they were quick to provide the team with data on defective units and variation. Data and information was gathered on a single embroidery machine, in order to avoid any nuisance variables, while also having fair replications. The team chose to analyze the total defective units per day over the length of 20 days. From this data, changes to the embroidery machines were recommended and three more scenarios were recorded. With a total of four scenarios, quality characteristics were measured to determine whether there was an improvement in quality over time.

With strategies such as DMAIC, the team was able to organize the collected data in an appropriate manner, and interpret the results in order to assess what steps were necessary to begin improving the systems. The team relied on these strategies for guidance and efficient problem-solving throughout the project.

Softwares such as Minitab and Google Sheets were essential for organizing each data. Google Sheets was used to apply formulas such as sum, average and sample standard deviation. Minitab was used for creating plots such as P-charts, histograms, scatter plots and box plots. Interpreting the data in the form of visual plots allowed for our team to analyze and reduce the percentage of defective units.

Once data from the initial scenario was recorded, the team brainstormed solutions based on the employees suggestions, to increase quality and came up with the ideas to reduce the machine's motor RPM and to reduce the stitch density. The first improvement was implemented by altering the RPM within the stitching machine to increase the stitch speed. The second improvement was implemented by changing the stitching density used in the production process. Both improvements only required changes on the embroidery machines, which also helped with easy implementation into the company. Pictured below in figure A was a snapshot taken of the industrial embroidery machine used for production at Merchco.

Figure A: Embroidery machine

Approach

The purpose of this study will be achieved by looking at the percentage of defects out of the total output production line. Clothing production facilities are equipped with heat presses, stitching machinery, embroidery machines and equipment to produce multiple types of garments. By closely analyzing the faulty garments, the error can be traced back to the type of machine used to produce the product. After determining the machine type, a closer look at the log cycles of the machinery will aid in determining the factors affecting the garments in the production process

Before obtaining sampled data, the project had to be defined. The team initially met to understand and research problems with most retail manufacturers. The discussion led to optimal fixes that have occurred in the past, and concluded with mapping how long each session should last - around 20 days minimum to obtain reasonable results. To gain more insight into the specific company's scope, the team decided to speak to the manager and employees about the most common types of defects. The desire was to identify the main type of defect, which was found to be with embroidery errors, and to identify the main reasons why these errors occurred.

Ahead of the visit to the downtown Toronto facility, the team phoned ahead to get an initial understanding of the manufacturing process. Upon visiting the facility, certain characteristics like operator and operation time were noted, as well as mudas like unnecessary transportation were identified. Through studying the manufacturing system, the bigger problems of lower quality were identified by speaking with employees and analyzing the operations in real-time. The team figured one of the best sources of identifying problems was by speaking directly to those who experience each issue several times every day. Through understanding the point of view of the operator, when it came time to implement fixes to quality problems, our analysis could be done with an empathetic point of view and there was less worker resistance when adding in changes to the machines. Overall, the workers already had excellent solutions, our team just helped in communicating those with the owner. After the trip to the facility, the plan was defined in full with multiple primary and secondary sources to justify the project Roadmap.

Root Cause Analysis

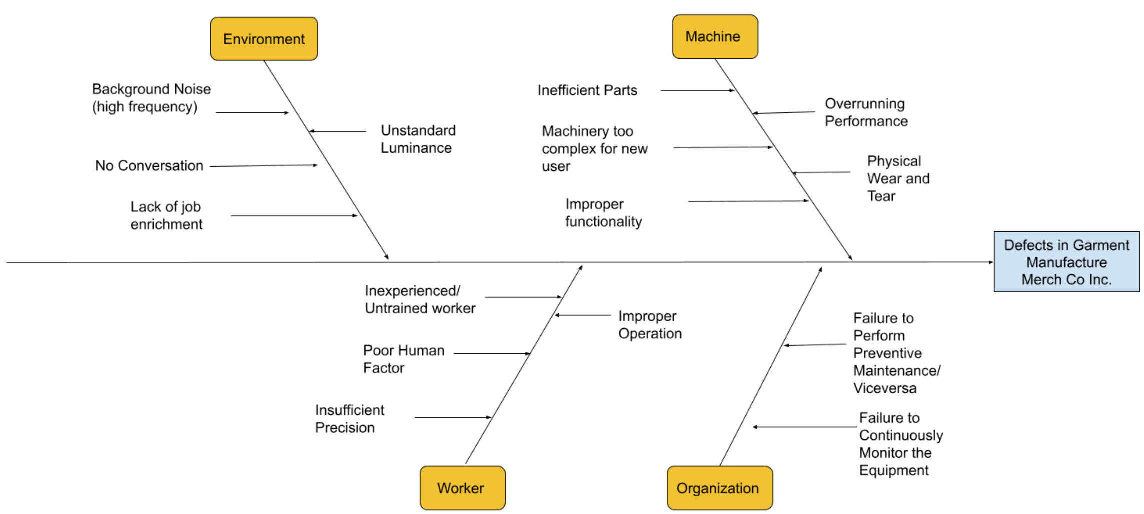

Figure B: Root cause analysis of defects in garment manufacturing

As part of the define process, a comprehensive root cause analysis diagram was created to identify the most relevant assignable causes. In referring back to the facility tour, it was concluded that the best fix would be to focus on the machine aspect of the operation by improving machine precision and decreasing material feed. To be more specific, the two solutions to assignable causes were: decreasing the embroidery machine RPM and decreasing the string density input. The first improvement became scenario 2. The second improvement became scenario 3. These fixes were put to the test throughout the measure phase to identify the effect on process performance.

Inferential Statistics Analysis

The data was recorded in 4 intervals of 2 hours every day - totalling 8 hours a day.

P-Charts

One of the first and most useful plots for measuring performance was the P-chart. With this chart, the variability was assessed relative to the ideal standard variability and the frequency of problems was identified. Four P charts were created with the use of Minitab. One P chart was created for each scenario. The chart was used to analyze the ratio of total nonconforming items to the total number of population items. The x-axis of the graphs represented the days while the y-axis represented the proportion of nonconforming items to total items. To analyze the defective output data, control charts for attributes were created. A P-chart with appropriate control limits was created for every scenario. Figure 1 demonstrates that Scenario 1 has 5 points that are beyond the 3 sigma limits and is therefore out of statistical control with a high variability in defective units. Using Scenario 2 it is shown that only 1 point exceeds the 3 sigma limit on the control chart while having a medium variability. In Scenario 3 it is observed that data points are more present within the 2 sigma limit demonstrating a lower variability in defects while also having 4 points beyond the 3 sigma limit. Finally in setting 4 it is evident that only 1 point is exceeding the control limits and the variability is substantially lower than that of in scenario 3 which is why the P-chart suggests that scenario 4 has the highest improvement.

Setting 1

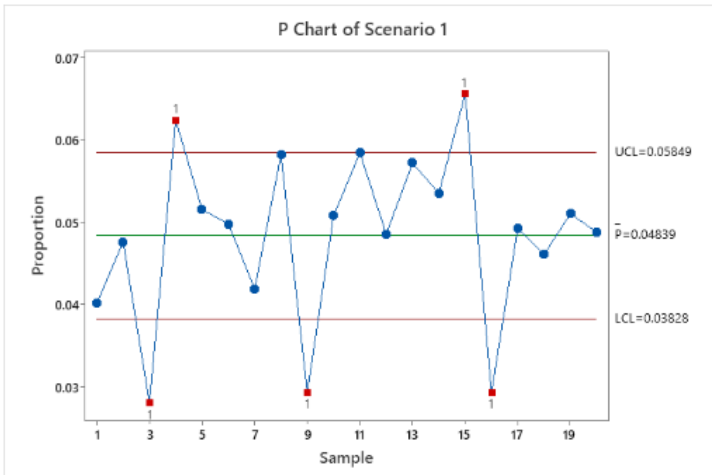

Figure 1: P Chart of Scenario 1

Setting 2

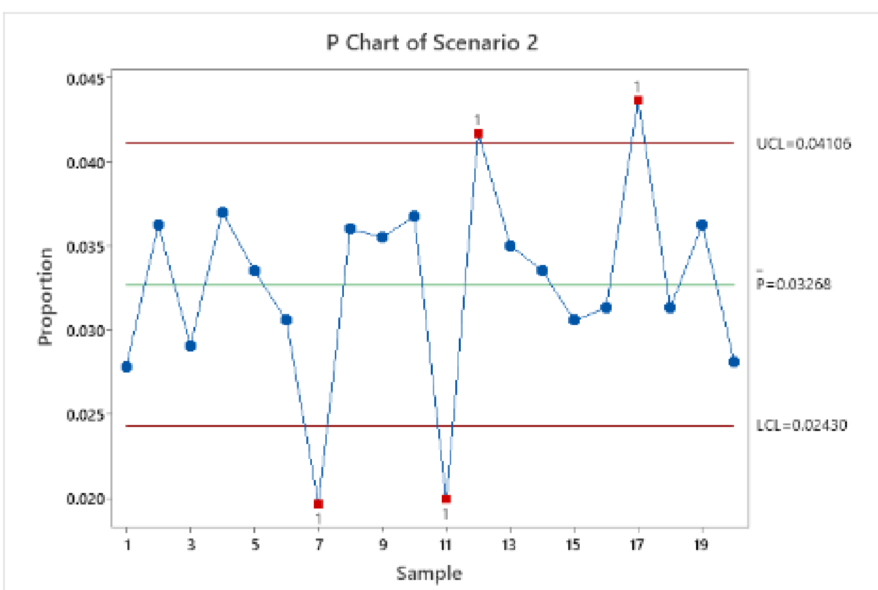

Figure 2: P Chart of Scenario 2

Setting 3

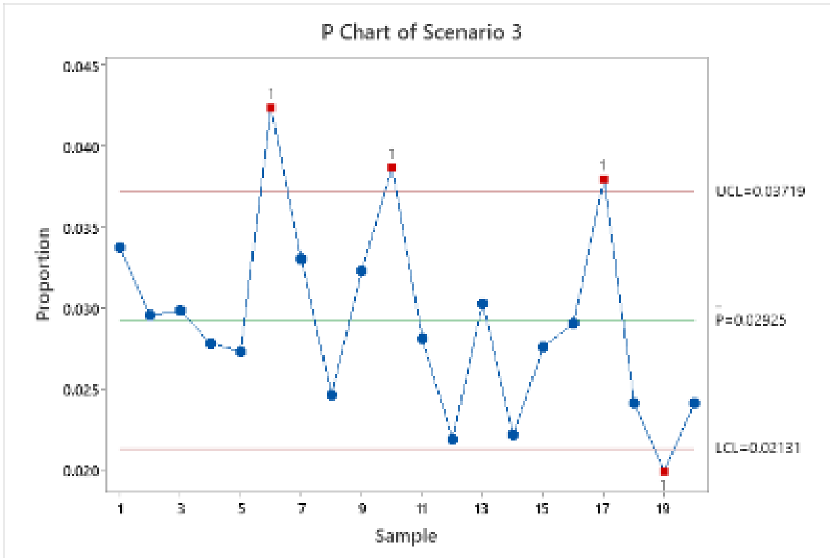

Figure 3: P Chart of Scenario 3

Setting 4

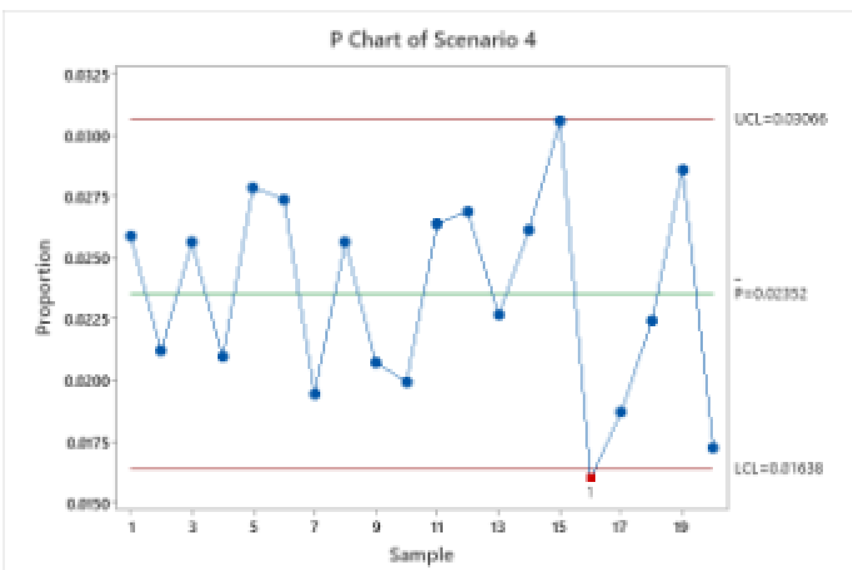

Figure 4: P Chart of Scenario 4

Descriptive Statistics Analysis

Scatter Plots

To measure the relationship between the day and the total number of defects, scatter plots were used as another form of quality visualization. The data started out fairly widespread and random in scenario 1 on a range from 0-85. As changes of factor a, factor b, and factor ab were applied to the original data set, the variability decreased greatly. In analyzing the process over four scenarios, scenario 2 saw a shift in defect rate on an interval from 0-65. Scenario 3 saw a shift in defect rate on an interval from 0-68. Scenario 4 saw a shift in defect rate on an interval from 10-43. The range of values shifted much closer together in scenario 4 when compared to scenario 1. The increased quality was also evident as the value points in scenario 4 are much more accurate with the centerline, compared to scenario 1. In scenario 2 and 3, the quality was equally improved and a similar reduction in variability was observed. Evidently, the biggest improvement in quality came from scenario 4 which combined factors a and b.

Setting 1

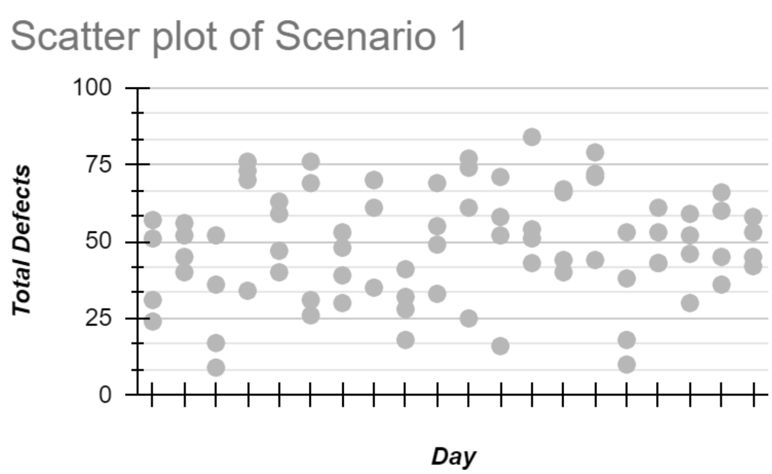

Figure 5: Scatter Plot of Scenario 1

Setting 2

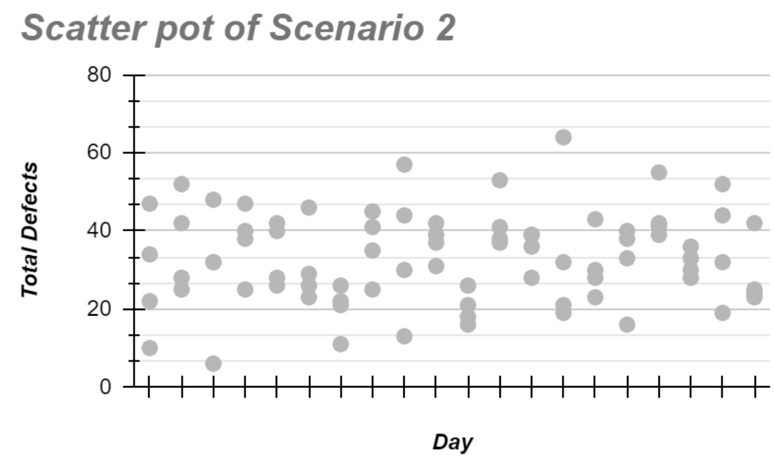

Figure 6: Scatter Plot of Scenario 2

Setting 3

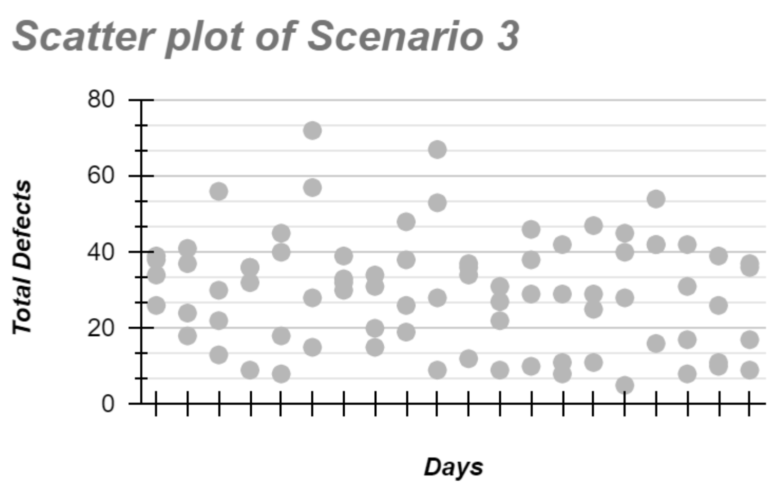

Figure 7: Scatter Plot of Scenario 3

Setting 4

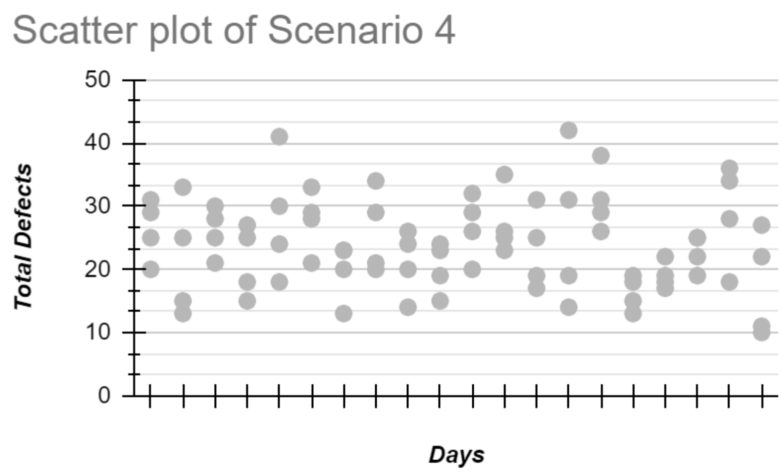

Figure 8: Scatter Plot of Scenario 4

Box and Whisker Plot

Box and Whisker Plot were measured to contribute in visualizing detailed information of spread and locality in order to indicate the variation in the set of data collected for each scenario. Each Box represents one scenario respectively, and displays a summary of the five numbers within the set of data, which are Minimum, Lower Quartile(Q1), Median, Upper Quartile(Q3), and Maximum. The Interquartile Range can be identified as the box length(25th to 75th percentile) which is Q3-Q1.

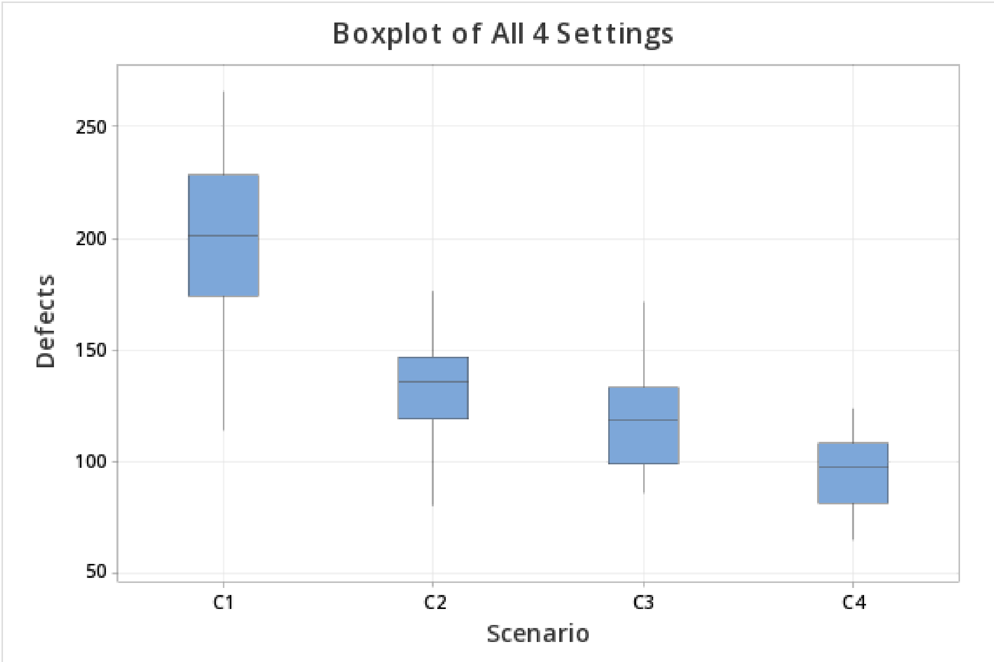

Figure 9: Box and Whisker Plot of All four Scenarios

In analyzing the plot and data, we can identify and calculate each value in the table of summary below:

Measurement	Scenario1	Scenario2	Scenario3	Scenario4
Minimum	114	80	86	65
Lower Quartile(Q1)	175	120	100	82
Median	201	136	119	98
Upper Quartile(Q3)	228	147	133	107

Maximum	266	177	172	124
Interquartile Range	53	27	33	25

Table A: Box and Whisker Plot summary Values

Considering that outliers are not being used and based on the summary, the comparison between the box plots can be made and followings can be illustrated:

A gradual decrease in Median values shows that defects become less on average. Scenario 4 has the lowest median value between the 4 scenarios, so quality has been improved in Scenario 4 since on average there are less defects in comparison with the rest.

To examine the variability, the Interquartile Ranges for each scenario can be compared, and it can be noticed that Scenario 4 has the least value out of all. The smaller the box length, the less dispersion, which indicates Scenario 4 is less dispersed.

A helpful approach to understand how wide data has been distributed is to compare the range of whisker's endpoints(Minimum and Maximum) between the scenarios. Larger ranges have wider distribution and more scattered data. In this case Scenario 1 has the largest range and widest distribution.

Histograms

In measuring each histogram, the plot which had the closest normal distribution was scenario 3. Scenario 1 had a bell curve shape but a large variability. Scenario 2 resembles a bimodal histogram with its double peaks at intervals 35 and 20. Scenario 4 had a bell-shaped curve but in intervals 20-35 there are multiple peaks - it is therefore deemed multimodal. As quality (resistance of variation) is the priority in analyzing data, the standard deviation of each histogram must be acknowledged in each scenario. In analyzing each histogram, scenario 1 is a multimodal histogram with a large standard deviation and larger frequency values ranging from

30-75. Scenario 2 is a bimodal histogram with a decreased standard deviation, larger frequency values range from 20-45. Scenario 3 is a normal bell-curve distribution, peaking at 35 with a fairly large center of distribution. Scenario 4 is a muti-modal distribution with large frequencies from 20-33, but the center spread of distribution is much smaller in comparison to other scenarios. Although setting 3 has the most normal-looking distribution, setting 4 has the least variance. It can still be concluded that setting 4 has the highest quality.

Setting 1

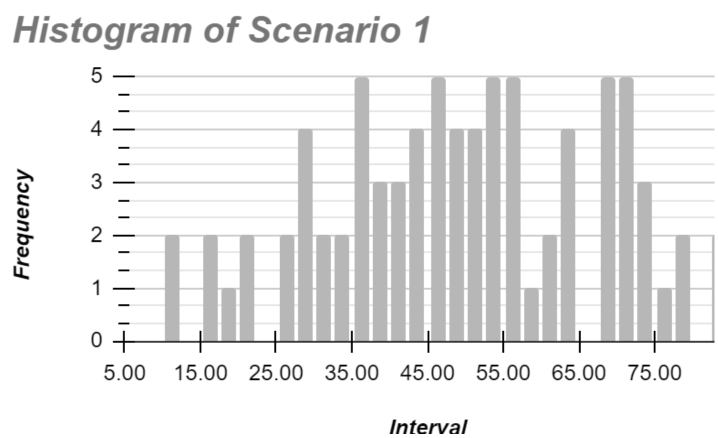

Figure 10: Histogram of Scenario 1

Setting 2

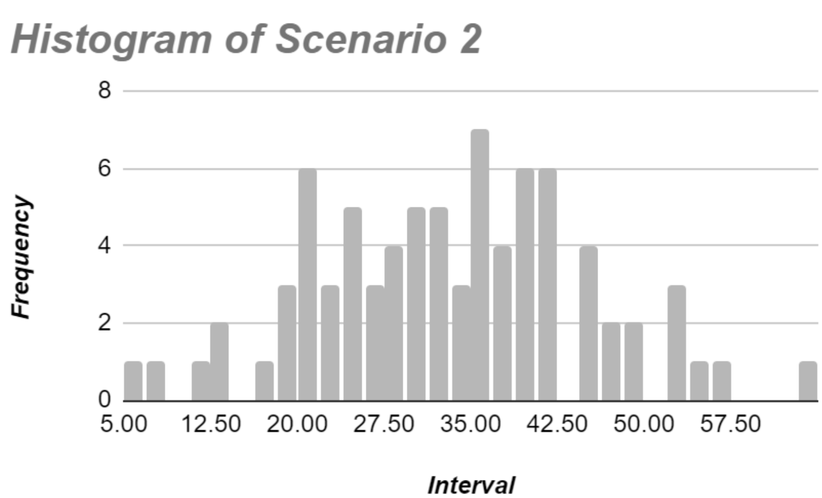

Figure 11: Histogram of Scenario 2

Setting 3

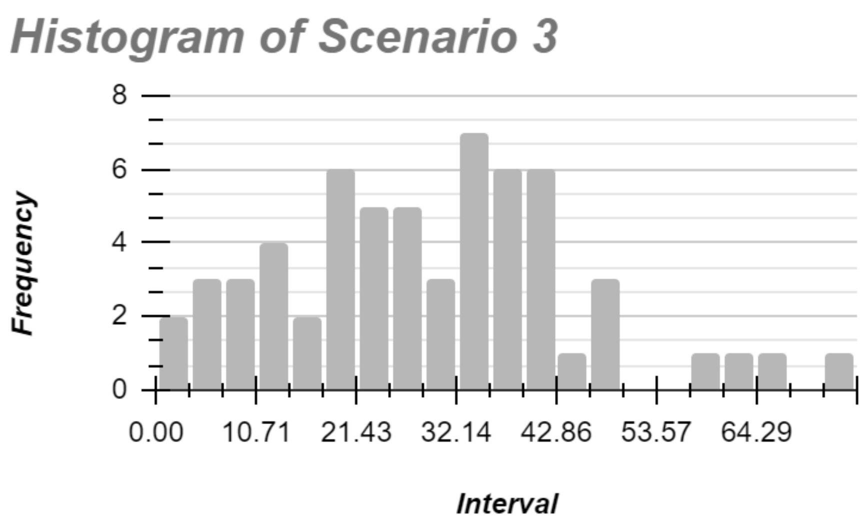

Figure 12: Histogram of Scenario 3

Setting 4

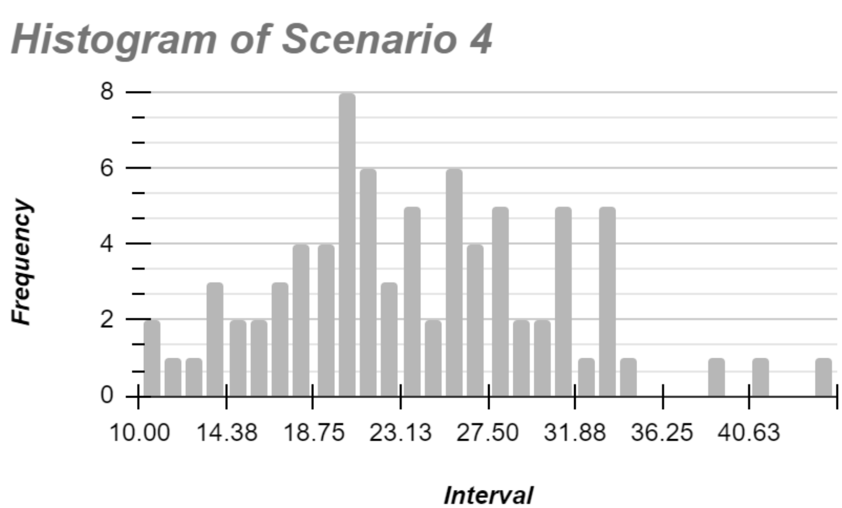

Figure 13: Histogram of Scenario 4

Design of Experiments

For the second stage of the report, it was decided that Using Design of Experiments, we are able to perform analysis on our data set in terms of the number of defective units. Design of Experiments was our tool for the improvement stage of DMAIC as we could numerically see the impact our assignable causes and solutions had on the increase in process performance. For each scenario the effects and contributions for improvement were analyzed. This step was performed using the design of experiments which involves factorial design and ANOVA analysis of the variance. The two factors are Factor A: RPM of stitching machine and Factor B: stitching density. Each factor has two levels to them, a 0 denotes lack of improvement, while + denotes the presence of an improvement. Using factorial design, the effects of our improvements towards response variables could be calculated. This enabled the team to visualize that by implementing the two factors we could reduce the operational waste and achieve a decrease in the average defects.

Table B highlights that the greatest reduction of the response variable occurs in lowering the RPM and stitching density (scenario 4) with an effect of 14.375. Analyzing the improvements on an individual level, the reduction in RPM has a greater impact than reduction in stitching density.

Inorder to ensure that the conclusions drawn from interaction effects are accurate, a one way analysis of variance is conducted. This is initialized by first finding the contrast for every improvement. Next, running an F-test on each treatment in order to examine the variation and significance of waste output. The critical F value was found to be 4.75 using the textbook (Montgomery, 2020). Due to the f-value for factor A and AB being greater than the f-critical, we can draw a strong conclusion that these factors have a significant effect on the manufacturing process and that the mean of each group is not the same. Meanwhile, we cannot draw a conclusion that factor B has a significant effect, as its f value is less than the f critical.

Calculations

Factor A: RPM of stitching machine

Factor B: Stitching density

n=4

Factors		NU				
Factor A	Factor B	1	2	3	4	Sum
0	0	55	34	45	53	187
0	1	45	42	47	39	173
1	0	19	18	15	12	64
1	1	54	32	23	56	165

Table B: Factorial Design of Experiments

$A = \overline{y}_{At} - \overline{y}_{A^-} = \frac{ab+a}{2n} - \frac{b+(1)}{2n} =$ -11.125

$B = \overline{y}_{B^+} - \overline{y}_{B^-} = \frac{ab+b}{2n} - \frac{a+(1)}{2n} =$ 10.875

$AB = \frac{ab+(1)}{2n} - \frac{a+b}{2n} = 14.375$

Contrast A = $ab + a - b - (1)$ = -131

Contrast B = $ab + b - a - (1)$ = 87

Contrast AB = $ab + (1) - a - b$ = 115

$SS_A = \frac{(Contrast\ A)^2}{2^2 * n}$ =1072.5625

$dF_A = 1$

$MS_A = \frac{SS_A}{dF_A}$ =1072.5625

$SS_B = \frac{(Contrast\ B)^2}{2^2 * n}$ =473.0625

$dF_B = 1$

$MS_B = \frac{SS_B}{dF_B}$ =473.0625

$SS_{AB} = \frac{(Contrast\ AB)^2}{2^2 * n}$ =826.5625

$dF_{AB} = 1$

$MS_{AB} = \frac{SS_{AB}}{dF_{AB}}$ =826.5625

$SS_T = \Sigma(y_{ij} - \bar{y}_{..})^2 = 3596$

$SS_E = SS_T - SS_A - SS_B - SS_{AB}$

$SS_E = 1223.8125$

$df_T = \#\ of\ observ - 1 = 15$

$df_{error} = 12$

Analysis of Variance

$F_0 = \frac{MS_F}{MS_E}$

Sources of variation	Sum of Squares	Degree of Freedom	Mean Square	F_0	P-value
A	1072.5625	1	1072.5625	10.51692968	
B	473.0625	1	473.0625	4.638578214	
AB	826.5625	1	826.5625	8.104795465	

Error	1223.8125	12	101.984375		
Total	3596	15			

Table C: Analysis of variance

F $_{(df_f, df_{error})} = F_{(0.05, 1, 12)} = 4.75$ -> From IND605 Formulae sheet

F $_A > F_{critical}$, $reject\ null\ hypothesis,\ Factor\ A\ has\ a\ significant\ impact$

F $_B > F_{critical}$, $accept\ alternative\ hypothesis,\ Factor\ B\ is\ insignificantt$

F $_{AB} < F_{critical}$, $reject\ null\ hypothesis, Interaction\ of\ AB\ has\ a\ significant\ impact$

Results and Recommendation:

To control the process in its increased efficiency with respect to costs, labor, etc., the following recommendations were concluded. A and AB had the most significant effects based on the created ANOVA tables. According to the tables, A and AB both passed the F-test. To reiterate, variation A had the reduction in RPM of the embroidery machine and variation AB was a combination of variation A and a reduction in sewing string density. While they are both significant in increased process performance, variation AB has a more significant effect however, adding in only factor A is more cost-effective and simpler. Although, referring back to the P-tests, scenario 4 was the only scenario in statistical control with scenario 2 (variation A) being out of control. The group then had to make a decision on whether scenario 2 or scenario 4 was most ideal for MerchCo. The two ultimate deciding factors were the cost of scenario 2 and the statistical control of scenario 4, but it was decided that the cost made scenario 2 much more feasible for the benefit of the company. It is therefore recommended that scenario 2, decreasing the RPM of the embroidery machine should be implemented into Merchco’s facility with the goal of improving quality and considering cost effectiveness.

Conclusion

As a result, the team was able to collaboratively examine the impact and relevance of the improvement scenarios that may be implemented. Upon examining the 4 scenarios, we were able to choose the most beneficial and appropriate one. Inferential and descriptive statistics have been utilized to grasp a better understanding of each production scenario and how the number of erroneous orders have been affected by the implementation of the improvements. The team collectively determined that scenario 2 with variation A was the most successful in decreasing the number of defective units and increasing the process quality. The utilization of scatter plots, histograms and box plots in descriptive statistics has shown a significant decrease in defective units. Using the inferential statistics analysis which includes the P charts, 2 Factorial design and ANOVA testing, it was concluded that the best decision to reduce waste would be to use the scenario 2 that passed the F-test in the most cost-effective manner, even though scenario 4 was the only scenario in complete statistical control. The team prioritized the results of ANOVA testing over the descriptive statistics including box plot, histograms, p-charts and scatter plots mainly because of the cost effectiveness.

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