# Defects by Points

Aishwarya Singhai, Surya Perumalsamy, Geethan Karthikeyan,
Jake Brodnitzki, Vignesh Subramani, and Chelan West

TE533 - Lean Six Sigma
North Carolina State University
19 April 2024

**Executive Summary**

The Elevate Textiles Finishing Plant has recently faced challenges, with an average of 8.31 defect points per 100 yards of fabric per week leading to increased production of off-quality rolls and significant financial losses. Consequently, the project was initiated with the mission of reducing off-quality production by 5% by identifying key defect categories and underlying trends, with the aim of achieving substantial cost savings. The approach involved analyzing defect data using statistical methods to pinpoint primary defect categories. This analysis focused on product attributes such as style, finish, and color to understand their relationship with defect occurrences. The project also entailed collaborative efforts among teams to analyze trends and establish recommendations for process improvements. Expected outcomes included the identification of primary defect categories, insights into the relationship between product attributes and defect occurrences, and data-driven recommendations for process improvements. The methodology involved utilizing JMP's fit Y by X models to analyze the relationship between product attributes and defect points, brainstorming potential relationships between product attributes and defect occurrences, and using time series analysis to understand temporal trends of defect occurrences and product attributes. Through leveraging statistical techniques and collaborative analysis, the project aimed to optimize quality control processes, minimize off-quality output and ensure profitability and customer satisfaction at Elevate Textiles Finishing Plant.

**Overview**

Defects Definers team comprises Aishwarya Singhai, Surya Perumalsamy, Geethan Kerthikeyan, Jake Brodnitzki, Vignesh Subramani, and Chelan West from the class of TE 533. This project is centered on the analysis of defect data based on points assigned to defects on a scale of 1-4, where each point represents the length of the defect. The total defect points are aggregated without distinguishing between frequency and severity. Within the fabric processing industry, errors are commonplace due to the repetitive nature of the work. Each yard of fabric consists of numerous warp and weft yarns that are susceptible to breakage or incorrect threading. Additionally, errors during processing and transportation between plants can exacerbate defects within a fabric roll. The Elevate Textiles Finishing Plant aims to analyze the defect points recorded in their final inspection department to enact upstream changes, thereby addressing the defects as mentioned earlier. The substantial volume of defects in a roll result in significant revenue loss as products are classified as second quality or scrap. This presents an opportunity for the company to identify the defects most adversely affecting the product and implement upstream or company-wide changes to reduce the quantity of second-quality fabric. As a team, we visited the plant and formulated the following problem and mission statements.

> **Problem Statement** - The Elevate Textiles Finishing Plant experiencing an average of 8.31 defect points per 100 yards of fabric over the 2023-2024 fiscal year faces challenges in accurately deciphering the trends for the top contributing defect data points, contributing to a rise in the production of off-quality rolls/fabric.
>
> **Mission Statement** - Aiming to identify the key categories of defects based on the sum of defect points and uncover any underlying factors or relationships/trends, will reduce the production of off-quality rolls in 2024 by 5%.

## Define Stage

In the define stage, incorporating insights from the professor, our primary objective was to refine the problem and mission statements to accurately capture the core challenges and objectives of the project. Drawing from the professor's valuable input, the revised problem and mission statement are as follows,

> **Problem Statement** - The Elevate Textiles Finishing Plant experiencing an average of 8.31 defect points per 100 yards of fabric per week over the 2023-2024 fiscal year faces challenges in accurately deciphering the trends for the top contributing defect data points, contributing to a rise in the production of off-quality rolls/fabric, resulting in X amount of loss.
>
> **Mission Statement** - Identify the key categories of defects based on the sum of defect points and uncover any underlying factors or relationship/trends, which will reduce the production of off-quality rolls in 2024 by 5%, resulting in saving X amount.

Moreover, during this stage, we developed a comprehensive project plan detailing tasks, responsibilities, and timelines from the first week of March 2024 to the third week of April 2024. This plan ensures a structured approach to the project execution, facilitating effective coordination and monitoring of progress toward achieving our defined objectives. The project plan is listed in detail in **Table 1.** below.

**Table 1**. Project Plan - Tasks and Responsibilities.

| Week | Tasks and Responsibilities |
|---|---|
| **Week 1** | **All Team Members** - Site visit to gain a deeper insight into the inspection procedures and defect data collection process at the plant |
| **Week 2** | **Chelan** - Coordinate data acquisition with Elevate Textiles<br>**Surya, Geethan, Jake, Vignesh, Aishwarya** - Review data quality |
| **Week 3** | **All Team Members** - Define problem and mission statements<br>**Surya** - Devise a project plan |
| **Week 4** | **All Team Members** - Refine problem and mission statements drawing the professor's insights<br>**Vighnesh, Surya** - Perform data analysis, identify trends with respect to Style, Product<br>**Geethan, Aishwarya** - Perform data analysis, identify trends with respect to Color<br>**Jake, Chelan** - Perform data analysis, and identify trends with respect to Finish & Defect Code |
| **Week 5** | **All Team Members** - Collaborate to analyze findings and brainstorm recommendations<br>**All Team Members** - Review and refine recommendations |
| **Week 6** | **All Team Members** - Prepare technical report and presentation slides<br>**All Team Members** - Review and refine the report & presentation |
| **Week 7** | **All Team Members** - Present findings to the class<br>**All Team Members** - Answer to post-presentation inquiries<br>**Chelan** - Submit the report and presentation in Moodle |

**Measurement Stage**

For this project, we were provided with the DefectPoints.xlsx dataset by Ben Tompkins, the Process Improvement Leader at the Elevate Textiles Finishing Plant. This dataset encompasses data spanning from 2023 week 1 to 2024 week 7. Notably, our team did not engage in the direct collection of this data. It is imperative to highlight that a crucial aspect, the Operator identification during inspections, was absent in the dataset. This absence hindered our ability to conduct a comprehensive Measurement System Analysis (MSA), particularly in assessing Gauge R&R to ascertain the source of variability—whether attributed to part-to-part differences or the repeatability and reproducibility of the measurement system. Despite this limitation, we proceeded with our analysis utilizing the available dataset. It includes essential parameters such as the production week, product labels, quantities of specific defects, associated defect points, as well as style, finish, and color attributes for each roll.

In terms of approach, the defect data is aggregated solely as total points without distinction based on severity and frequency. This amalgamation poses significant hurdles in isolating specific defect categories pivotal to quality issues. Consequently, our project's primary focus shifted towards employing advanced statistical methodologies to dissect this combined defect data and identify primary defect categories. Our aim is to discern underlying trends and establish correlations with various product attributes.

Throughout the project lifecycle, we will leverage a comprehensive defect point dataset obtained from the Elevate Textiles team. This dataset comprises ten columns, encompassing crucial parameters such as WEEK, PRODUCT, BU, YDS (yards), TOTAL POINTS (sum of defect points for each product-week combination), PTS PER 100 (average number of defect points per 100 yards), DEFECT (description of defect type), DEFECT PT/100 (defect points rate for specific defect), STYLE (first 5 digits of the product code representing the fabric weave), FINISH (second 3 digits of the product code representing the applied chemical finish), and COLOR (fourth 5 digits of the product code representing the fabric color). The richness of this dataset enables a detailed examination of defect occurrences, product characteristics, and production parameters. Leveraging this dataset will facilitate a thorough analysis, empowering us to derive actionable insights to enhance quality control processes within the Elevate Textiles Finishing Plant.

## Analysis Stage

In the analysis stage, we will delve into a comprehensive examination of various key parameters to gain deeper insights into the quality control dynamics at the Elevate Textiles Finishing Plant. Our analysis will encompass a detailed exploration of defect codes, styles, finishes, colors, products, and their evolution over time. By scrutinizing these critical factors, we aim to uncover underlying trends, identify potential correlations, and pinpoint areas for improvement within the quality control processes.

### 1. Defect Code

The analysis primarily focused on defect points per 100 yards, aiming to discern the key defects contributing significantly to the overall defect points. To achieve this, the initial step involved conducting a one-way analysis of defect points per 100 yards categorized by defect, as illustrated in **Figure 1**. The analysis utilized the Means/ANOVA hotkey, with results sorted by column via number, as depicted in **Table 2.** The top five defects identified were **Mispick, BrokePic, DrtOlGr, SetMark, and KnotWve**, which collectively accounted for the highest defect occurrences. Notably, Mispick was observed to be the most prevalent, likely due to its association with yarns in the warp direction of the fabric, thereby potentially accruing higher defect point values more frequently than other defects. It is noteworthy that four out of the top five defects are likely linked to the weaving process rather than the finishing plant. The defect **DrtOlGr, signifying dirt, oil, and grime**, emerged as the most prominent finishing plant-related defect, with a total of **2712 defect points**.

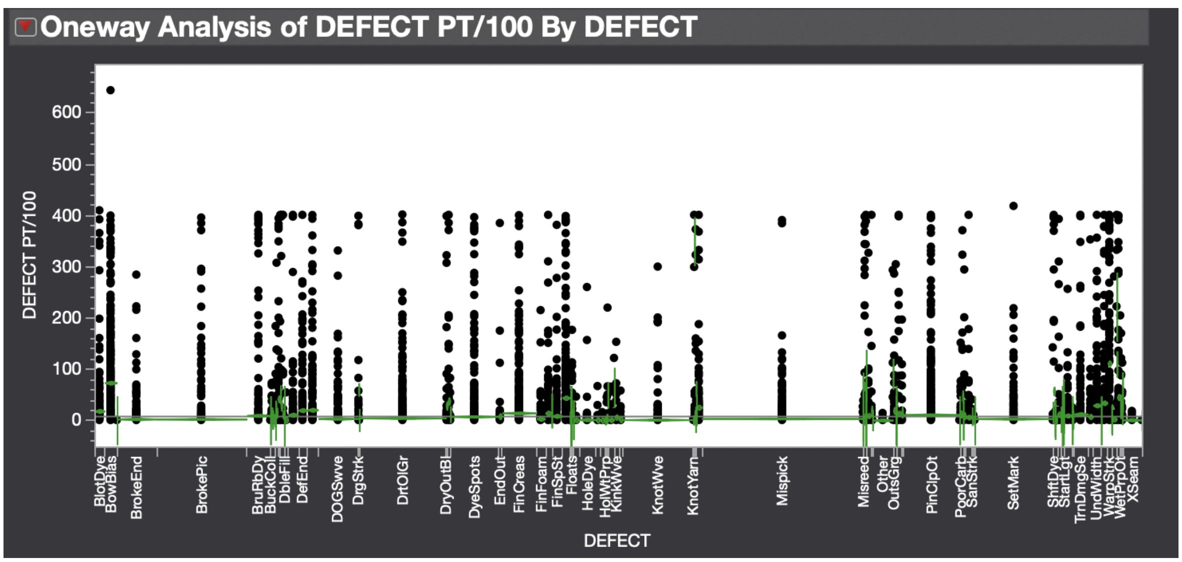


**Figure 1.** One way Analysis of Defect Points per 100 yards by defect.

**Table 2.** Total Defect Points / 100 yards of Top 5 defects.

| Defect | Total Defect Points / 100 Yards |
|---|---|
| Mispick | 5060 |
| BrokePic | 2842 |
| DrtOlGr | 2712 |
| SetMark | 2448 |
| KnotWve | 2190 |

While acknowledging this correlation, further analysis was imperative, leveraging the provided Finish, Style, Color, and Product data to gain deeper insights.

## 2. Finish

During the initial analysis of various finishes, we examined the mean defect points per 100 yards of fabric per finish code to discern their impact on quality control. **Figure 2.** illustrates the distribution of defect points per finish code, highlighting variations in frequency. **Figure 3.** displays a run chart of finish codes experiencing low, medium, and high occurrences and their relationship with defect points/100 yards. Different finish codes present differently in terms of defect points, meaning their peak intensity is relative to their individual application. Subsequently, **Figure 4.** showcases finishes with the highest mean defect points, namely finish codes **061, NFZ, 18A, and 04A**, each exhibiting mean defect points per 100 yards of fabric over 50, with values of **113.76, 71.14, 61.73, and 59.62** respectively. However, it's essential to note that these finishes had significantly fewer occurrences compared to others, with respective numbers of runs being 3, 6, 12, and 4, while some finishes recurred more than 8000 times. Therefore, normalizing the data becomes critical, as higher mean defect points may not necessarily translate to a substantial impact on the company's performance over the fiscal year.

**Table 3.** presents the normalized mean values for finish codes, highlighting the top 5 finishes contributing to normalized mean defect points. Additionally, **Figure 5.** displays the normalized mean value distribution. Notably, finishes **075, PF0, 018, 060, and 055** emerged as the key defect contributors, while also occurring the most frequently. Elevate Textiles may need to closely monitor these specific finishes due to their significant impact on defect points per 100 yards. This relationship is further supported in **Figure 6.** for the non-normalized and normalized mean defect points/100 yards by occurrence. The normalized data clearly shows the importance of normalizing the data, where a linear relationship is established, providing a value of r = 0.97723.

While the normalized data emphasizes certain finishes, it's pertinent to acknowledge that finishes with fewer occurrences also exhibit high defect points per 100 yards. For instance, Finish **061**, occurring only 3 times, displayed a mean defect points/100 yards of fabric of **113.767**. Similarly, all successive finishes in the top 5 occurred fewer than 100 times in total.

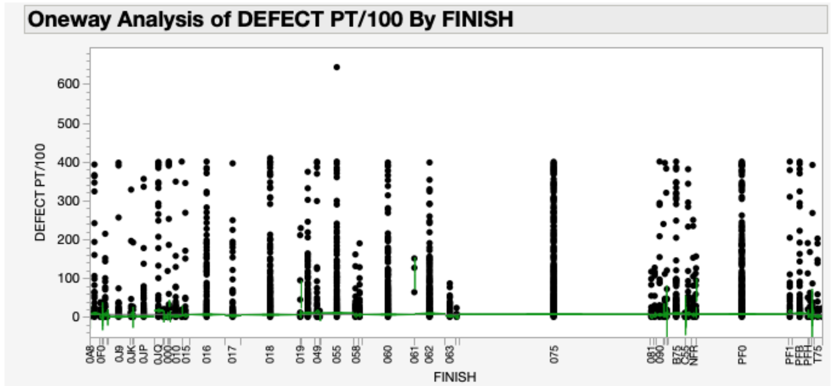


**Figure 2.** Defect Points Distribution per 100 yards by Finish.

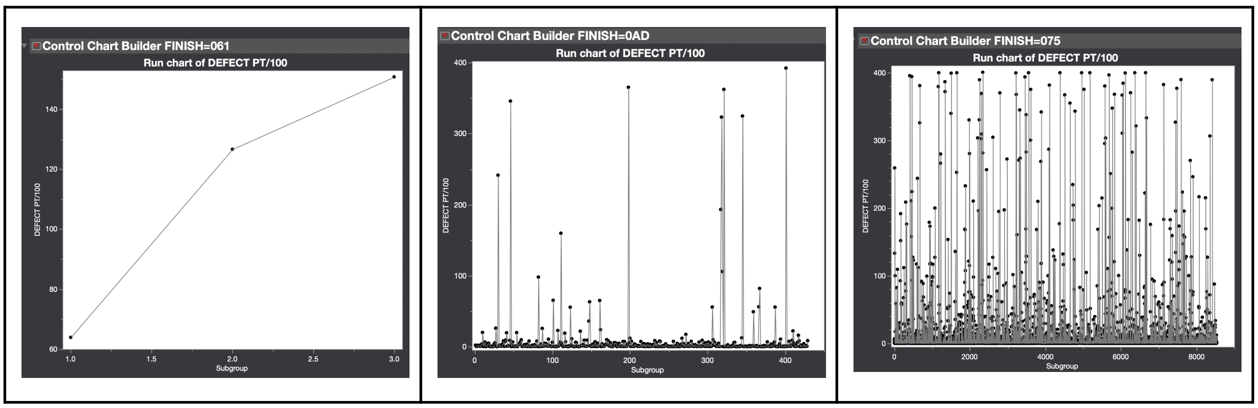


**Figure 3.** Run charts for finish codes with low, medium, and high occurrences.

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 061 | 3 | 113.767 | 21.152 | 72.31 | 155.22 |
| NFZ | 6 | 71.140 | 14.956 | 41.82 | 100.46 |
| 18A | 12 | 61.733 | 10.576 | 41.00 | 82.46 |
| 04A | 4 | 59.628 | 18.318 | 23.72 | 95.53 |
| 002 | 62 | 36.344 | 4.653 | 27.22 | 45.46 |
| 095 | 15 | 18.285 | 9.459 | -0.26 | 36.83 |
| 0JQ | 416 | 18.184 | 1.796 | 14.66 | 21.70 |
| 012 | 28 | 16.919 | 6.924 | 3.35 | 30.49 |
| PF1 | 205 | 15.437 | 2.559 | 10.42 | 20.45 |
| 049 | 197 | 14.844 | 2.610 | 9.73 | 19.96 |
| T55 | 65 | 13.856 | 4.544 | 4.95 | 22.76 |
| NFW | 27 | 12.598 | 7.051 | -1.22 | 26.42 |
| 055 | 1475 | 11.723 | 0.954 | 9.85 | 13.59 |
| 044 | 626 | 11.625 | 1.464 | 8.75 | 14.49 |
| PFB | 680 | 10.915 | 1.405 | 8.16 | 13.67 |
| B75 | 786 | 10.674 | 1.307 | 8.11 | 13.24 |
| 0AD | 429 | 10.517 | 1.769 | 7.05 | 13.98 |
| 062 | 1362 | 10.327 | 0.993 | 8.38 | 12.27 |
| FFB | 250 | 10.080 | 2.317 | 5.54 | 14.62 |
| PFH | 44 | 9.675 | 5.523 | -1.15 | 20.50 |
| PF0 | 4093 | 9.019 | 0.573 | 7.90 | 10.14 |
| 019 | 48 | 8.983 | 5.288 | -1.38 | 19.35 |
| WPZ | 5 | 8.888 | 16.384 | -23.23 | 41.00 |
| 44E | 44 | 8.868 | 5.523 | -1.96 | 19.69 |
| 075 | 8544 | 8.680 | 0.396 | 7.90 | 9.46 |
| 0J3 | 166 | 8.128 | 2.843 | 2.55 | 13.70 |
| 060 | 2362 | 7.874 | 0.754 | 6.40 | 9.35 |
| 016 | 1614 | 7.760 | 0.912 | 5.97 | 9.55 |
| 096 | 112 | 7.505 | 3.462 | 0.72 | 14.29 |
| 018 | 2642 | 7.399 | 0.713 | 6.00 | 8.80 |
| NFR | 202 | 7.265 | 2.578 | 2.21 | 12.32 |
| 0JK | 117 | 7.203 | 3.387 | 0.56 | 13.84 |
| 090 | 333 | 7.133 | 2.008 | 3.20 | 11.07 |
| SB9 | 6 | 7.047 | 14.956 | -22.27 | 36.36 |
| 059 | 178 | 6.990 | 2.746 | 1.61 | 12.37 |
| 082 | 106 | 6.679 | 3.558 | -0.30 | 13.65 |
| 058 | 194 | 6.138 | 2.630 | 0.98 | 11.29 |
| 0JM | 49 | 6.092 | 5.234 | -4.17 | 16.35 |
| C55 | 2 | 5.760 | 25.905 | -45.02 | 56.54 |
| 015 | 293 | 5.660 | 2.140 | 1.46 | 9.85 |
| 017 | 718 | 4.862 | 1.367 | 2.18 | 7.54 |
| 063 | 452 | 4.167 | 1.723 | 0.79 | 7.54 |
| PFN | 149 | 4.025 | 3.001 | -1.86 | 9.91 |
| 010 | 511 | 3.889 | 1.621 | 0.71 | 7.07 |
| 0IB | 4 | 3.555 | 18.318 | -32.35 | 39.46 |
| 0A8 | 5 | 3.478 | 16.384 | -28.64 | 35.59 |
| 000 | 45 | 3.395 | 5.461 | -7.31 | 14.10 |
| C75 | 8 | 3.335 | 12.953 | -22.05 | 28.72 |
| 003 | 23 | 3.274 | 7.639 | -11.70 | 18.25 |
| 081 | 199 | 3.217 | 2.597 | -1.87 | 8.31 |
| T75 | 390 | 3.125 | 1.855 | -0.51 | 6.76 |
| 0JZ | 22 | 2.801 | 7.811 | -12.51 | 18.11 |
| 0JP | 898 | 2.796 | 1.223 | 0.40 | 5.19 |
| 0F0 | 114 | 2.693 | 3.431 | -4.03 | 9.42 |
| PFZ | 1 | 2.520 | 36.636 | -69.29 | 74.33 |
| 0J9 | 1007 | 2.412 | 1.154 | 0.15 | 4.68 |
| 0J1 | 58 | 1.965 | 4.811 | -7.46 | 11.39 |
| 0P8 | 162 | 1.636 | 2.878 | -4.01 | 7.28 |
| 064 | 155 | 1.462 | 2.943 | -4.31 | 7.23 |
| 051 | 52 | 1.239 | 5.080 | -8.72 | 11.20 |
| 0F8 | 10 | 0.977 | 11.585 | -21.73 | 23.68 |
| 0JL | 7 | 0.907 | 13.847 | -26.23 | 28.05 |
| 18B | 1 | 0.880 | 36.636 | -70.93 | 72.69 |
| 0J7 | 12 | 0.583 | 10.576 | -20.15 | 21.31 |
| CNZ | 7 | 0.540 | 13.847 | -26.60 | 27.68 |

Std Error uses a pooled estimate of error variance

**Figure 4.** Defect Points per 100 yards by Finish (Mean sorted in descending order), representing 69 discrete finish codes.

**Table 3.** Normalized Mean Defect Points/100 yards for Finish

| Finish | Number of Occurrences | Mean Defect points/100 yards | Normalized Mean Defect points/100 yards |
|---|---|---|---|
| 075 | 8544 | 8.68 | 2.260207241 |
| PF0 | 4093 | 9.019 | 1.125038614 |
| 018 | 2642 | 7.399 | 0.595762465 |
| 060 | 2362 | 7.874 | 0.5668166524 |
| 055 | 1475 | 11.723 | 0.5269847921 |

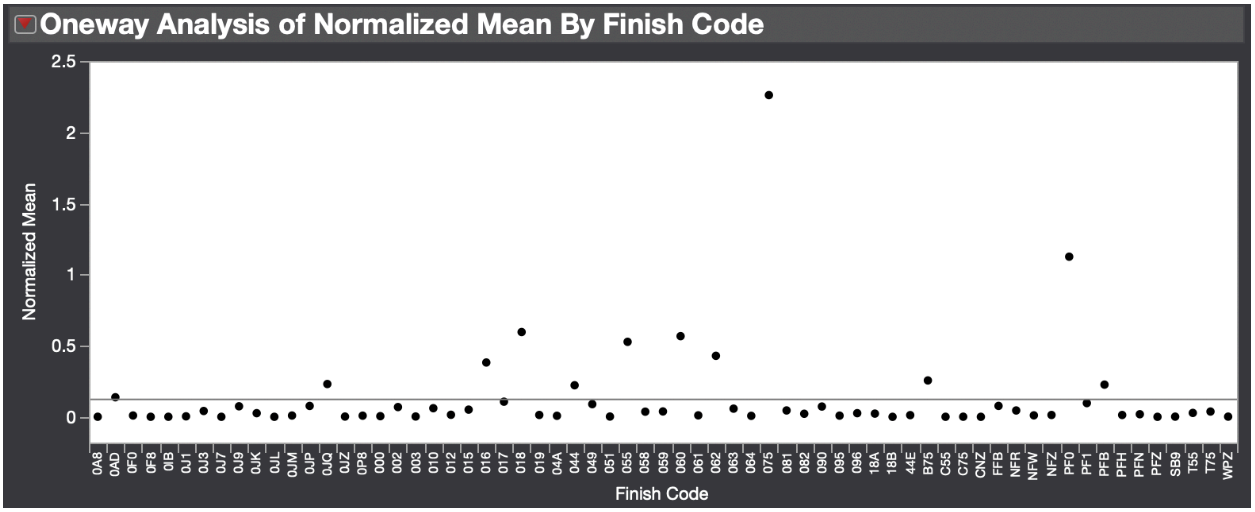


**Figure 5.** Oneway Analysis of Normalized Mean by Finish Code.

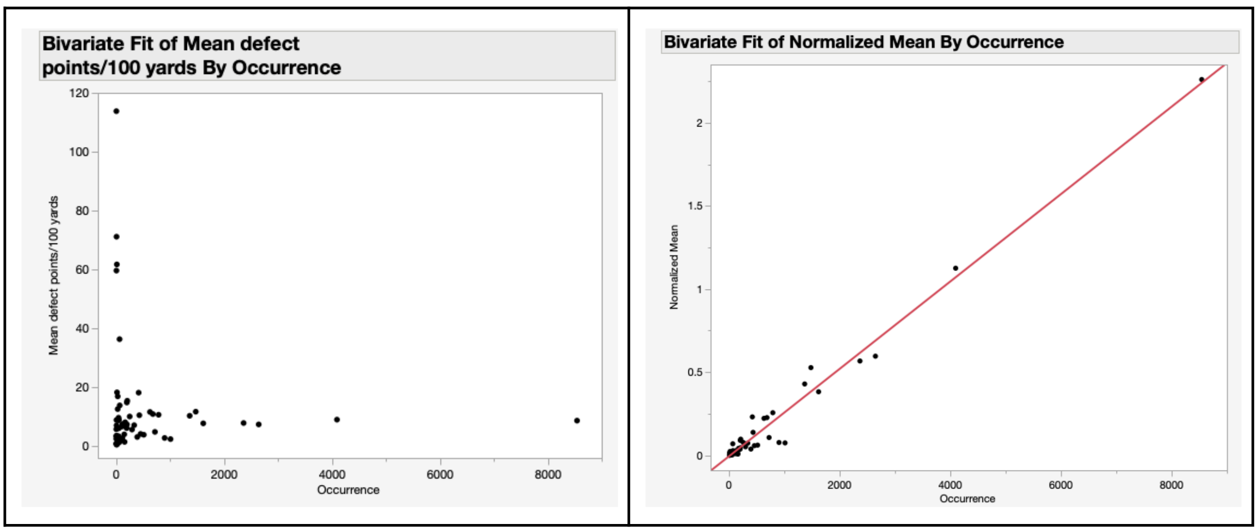


**Figure 6.** Mean Defect Points/100 Yards and Normalized Mean Defect Points/100 Yards by Occurrence.

This analysis confirms that finishes with higher occurrences tend to have a greater impact on the number of defects per 100 yards of fabric. Although their mean defect points/100 yards may align closely with the average of all finishes, their higher frequency necessitates attention. As a recommendation, we suggest Elevate Textiles examine upstream processes to mitigate mean defect points/100 yards. However, the absence of specific information correlating finish codes prevented us from making precise recommendations based on the type and application method of finishes.

## 3. Style

Using regression analysis, we assessed the mean defect points per 100 yards of fabric per style. **Figure 7.** displays the distribution of defect points per style based on the number of data points, highlighting styles with the highest mean defect points. Styles like 0B976, 0C967, 0B974, and X2847 showed mean defect points over 150, with values of 289.18, 232.58, 160.92, and 152.45.

Although these styles had high defect points on average, their occurrence frequencies were lower compared to others. Consequently, we normalized the data, introducing a column of normalized mean. **Table 4.** reveals the top 5 styles with the highest normalized mean defect points, namely **03011, 04043, 04423, 06132, and 03630**, which also have the highest occurrence rates, necessitating close monitoring.

It's noteworthy that even styles with minimal occurrences exhibit high defect points per 100 yards. For instance, style **0B976** occurred only 2 times but had a mean of **289.18**.

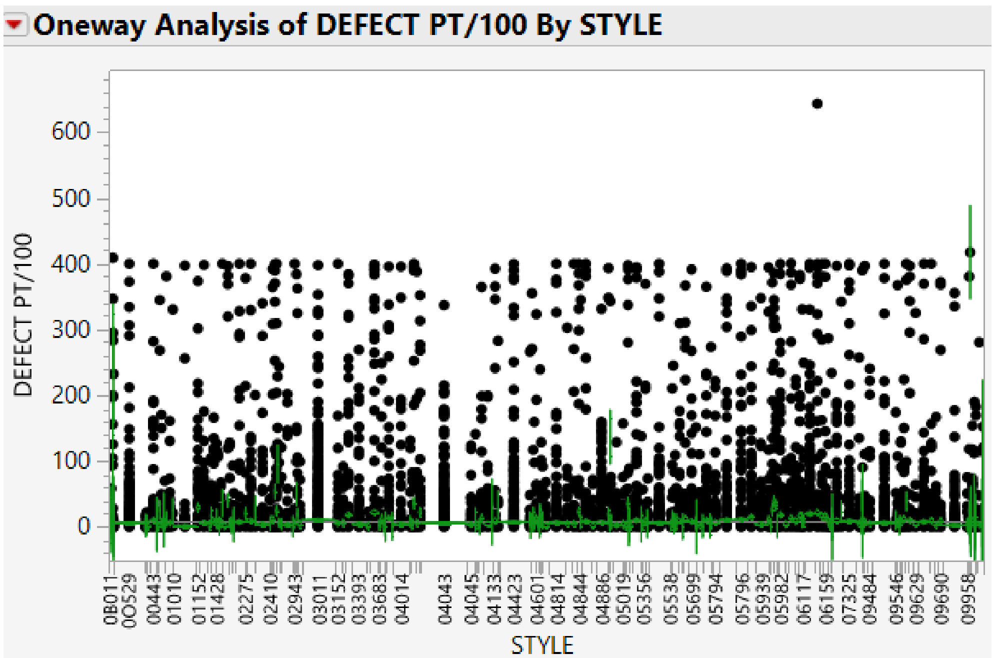


**Figure 7.** Defect Points Distribution per 100 yards by Style.

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 0B976 | 2 | 289.180 | 25.580 | 239.0 | 339.32 |
| 0C967 | 1 | 232.580 | 36.176 | 161.7 | 303.49 |
| 0B974 | 6 | 160.928 | 14.769 | 132.0 | 189.88 |
| X2859 | 1 | 152.450 | 36.176 | 81.5 | 223.36 |
| 04942 | 3 | 136.890 | 20.886 | 96.0 | 177.83 |
| X2847 | 1 | 120.910 | 36.176 | 50.0 | 191.82 |
| 0B972 | 2 | 103.180 | 25.580 | 53.0 | 153.32 |
| 02835 | 6 | 95.977 | 14.769 | 67.0 | 124.92 |
| 0B971 | 2 | 86.310 | 25.580 | 36.2 | 136.45 |
| 0B973 | 3 | 82.857 | 20.886 | 41.9 | 123.79 |
| 02787 | 39 | 53.970 | 5.793 | 42.6 | 65.32 |
| 02960 | 16 | 50.656 | 9.044 | 32.9 | 68.38 |
| 08149 | 9 | 48.401 | 12.059 | 24.8 | 72.04 |
| 01535 | 43 | 40.240 | 5.517 | 29.4 | 51.05 |
| 09625 | 24 | 38.993 | 7.384 | 24.5 | 53.47 |
| 05965 | 75 | 38.969 | 4.177 | 30.8 | 47.16 |
| HV100 | 3 | 38.750 | 20.886 | -2.2 | 79.69 |
| 0B968 | 3 | 36.967 | 20.886 | -4.0 | 77.90 |
| 01504 | 12 | 36.586 | 10.443 | 16.1 | 57.05 |
| 04033 | 62 | 36.344 | 4.594 | 27.3 | 45.35 |
| 05072 | 60 | 35.883 | 4.670 | 26.7 | 45.04 |
| 04159 | 11 | 33.810 | 10.907 | 12.4 | 55.19 |
| 05966 | 73 | 33.731 | 4.234 | 25.4 | 42.03 |
| HV118 | 6 | 32.653 | 14.769 | 3.7 | 61.60 |
| 01152 | 105 | 29.434 | 3.530 | 22.5 | 36.35 |
| 05961 | 56 | 26.327 | 4.834 | 16.9 | 35.80 |
| 00618 | 25 | 26.122 | 7.235 | 11.9 | 40.30 |
| 01010 | 15 | 25.834 | 9.340 | 7.5 | 44.14 |
| 05735 | 16 | 1.376 | 9.044 | -16.4 | 19.10 |
| 04013 | 11 | 1.349 | 10.907 | -20.0 | 22.73 |
| W1627 | 5 | 1.346 | 16.178 | -30.4 | 33.06 |
| 00K32 | 38 | 1.170 | 5.868 | -10.3 | 12.67 |
| 00617 | 95 | 1.148 | 3.712 | -6.1 | 8.42 |
| 3D468 | 7 | 1.123 | 13.673 | -25.7 | 27.92 |
| X2840 | 2 | 1.120 | 25.580 | -49.0 | 51.26 |
| 04074 | 33 | 1.085 | 6.297 | -11.3 | 13.43 |
| 09244 | 29 | 1.064 | 6.718 | -12.1 | 14.23 |
| 02908 | 20 | 1.008 | 8.089 | -14.8 | 16.86 |
| 04043 | 10 | 0.965 | 11.440 | -21.5 | 23.39 |
| HV214 | 6 | 0.940 | 14.769 | -28.0 | 29.89 |
| 0B970 | 4 | 0.933 | 18.088 | -34.5 | 36.39 |
| 05980 | 17 | 0.909 | 8.774 | -16.3 | 18.11 |
| 05083 | 6 | 0.830 | 14.769 | -28.1 | 29.78 |
| 05685 | 13 | 0.777 | 10.033 | -18.9 | 20.44 |
| 07272 | 2 | 0.760 | 25.580 | -49.4 | 50.90 |
| HV210 | 6 | 0.723 | 14.769 | -28.2 | 29.67 |
| HV216 | 2 | 0.700 | 25.580 | -49.4 | 50.84 |
| 0GORQ | 9 | 0.688 | 12.059 | -22.9 | 24.32 |
| 05729 | 3 | 0.647 | 20.886 | -40.3 | 41.58 |
| HV114 | 3 | 0.613 | 20.886 | -40.3 | 41.55 |
| 03845 | 73 | 0.589 | 4.234 | -7.7 | 8.89 |
| HV212 | 4 | 0.525 | 18.088 | -34.9 | 35.98 |
| 40061 | 19 | 0.395 | 8.299 | -15.9 | 16.66 |
| HV110 | 4 | 0.380 | 18.088 | -35.1 | 35.83 |
| 07199 | 12 | 0.322 | 10.443 | -20.1 | 20.79 |
| HV116 | 1 | 0.170 | 36.176 | -70.7 | 71.08 |

Std Error uses a pooled estimate of error variance

**Figure 8.** Defect Points per 100 yards by Style.

**Table 4.** Normalized Mean Defect Points/100 yards for Style.

| Style | Number of Occurrences | Mean Defect points/100 yards | Normalized Mean Defect points/100 yards |
|---|---|---|---|
| 03011 | 1243 | 11.050 | 0.41858867 |
| 04043 | 1715 | 6.121 | 0.31991939 |
| 04423 | 1169 | 7.692 | 0.27403614 |
| 06132 | 373 | 20.163 | 0.22920181 |
| 03630 | 309 | 22.396 | 0.21090312 |

4. **<u>Color</u>**

Utilizing regression analysis, we conducted an examination of the mean defect points per 100 yards of fabric per color code. The outcomes are illustrated in **Figure 9.**, delineating the distribution of defect points across various color codes based on the frequency of data points. This presentation emphasizes colors exhibiting the highest mean defect points. Notably, color codes such as **09147, 0048H, and 0048G** demonstrated mean defect points exceeding 200, with values of **366.92, 233.33, and 230.18**, respectively.

Despite these colors displaying elevated average defect points, their occurrences were notably lower compared to others, each having just one instance, while certain colors were observed in over 1000 runs. Consequently, we proceeded to normalize the data, similar to our approach for style and finish, by introducing a column of normalized mean values. **Table 5.** showcases the color codes associated with the top 5 normalized mean values. It is apparent that colors contributing the highest normalized mean defect points have transitioned to **0H944, 0D263, 0V183, 0709G, and 00000**. These colors also exhibit the highest occurrence rates, underscoring the imperative for Elevate to closely monitor them.

Nevertheless, it is pertinent to acknowledge that even colors with minimal occurrences demonstrate elevated defect points per 100 yards. For instance, color **09147** was observed only once but displayed a mean of **366.92** defect points per 100 yards.

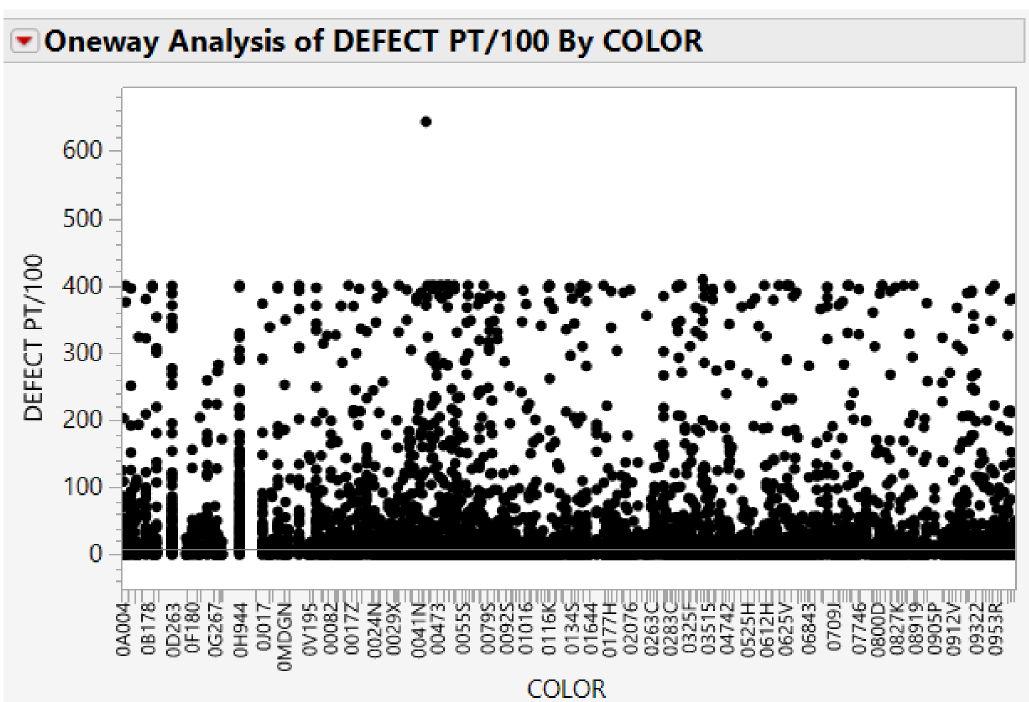


**Figure 9.** Defect Points Distribution per 100 yards by Color.

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 09147 | 1 | 366.920 | 36.010 | 296.3 | 437.50 |
| 0048H | 1 | 233.330 | 36.010 | 162.7 | 303.91 |
| 0048G | 1 | 230.180 | 36.010 | 159.6 | 300.76 |
| 0087V | 2 | 166.770 | 25.463 | 116.9 | 216.68 |
| 08939 | 1 | 146.990 | 36.010 | 76.4 | 217.57 |
| 0047Y | 1 | 144.440 | 36.010 | 73.9 | 215.02 |
| 07185 | 2 | 143.450 | 25.463 | 93.5 | 193.36 |
| 0076Q | 4 | 137.138 | 18.005 | 101.8 | 172.43 |
| 0082X | 5 | 134.084 | 16.104 | 102.5 | 165.65 |
| 0046R | 3 | 133.847 | 20.790 | 93.1 | 174.60 |
| 0953J | 3 | 131.883 | 20.790 | 91.1 | 172.63 |
| 0085Y | 3 | 127.690 | 20.790 | 86.9 | 168.44 |
| 0160L | 4 | 122.303 | 18.005 | 87.0 | 157.59 |
| 0086F | 1 | 120.910 | 36.010 | 50.3 | 191.49 |
| 0STON | 1 | 112.350 | 36.010 | 41.8 | 182.93 |
| 00075 | 3 | 110.093 | 20.790 | 69.3 | 150.84 |
| 08926 | 3 | 109.430 | 20.790 | 68.7 | 150.18 |
| 02951 | 6 | 101.720 | 14.701 | 72.9 | 130.53 |
| 0083Q | 4 | 101.483 | 18.005 | 66.2 | 136.77 |
| 0288V | 1 | 100.000 | 36.010 | 29.4 | 170.58 |
| 0099L | 1 | 98.290 | 36.010 | 27.7 | 168.87 |
| 0046P | 4 | 96.265 | 18.005 | 61.0 | 131.56 |
| 0041R | 9 | 92.954 | 12.003 | 69.4 | 116.48 |
| 0716T | 5 | 91.640 | 16.104 | 60.1 | 123.20 |
| 0054S | 9 | 91.303 | 12.003 | 67.8 | 114.83 |
| 0086Q | 2 | 91.055 | 25.463 | 41.1 | 140.96 |
| 0795E | 4 | 90.755 | 18.005 | 55.5 | 126.05 |

| | | | | | |
|---|---|---|---|---|---|
| 00967 | 2 | 0.320 | 25.463 | -49.6 | 50.23 |
| 0098S | 1 | 0.320 | 36.010 | -70.3 | 70.90 |
| 04194 | 1 | 0.320 | 36.010 | -70.3 | 70.90 |
| 09504 | 1 | 0.320 | 36.010 | -70.3 | 70.90 |
| 0091X | 1 | 0.310 | 36.010 | -70.3 | 70.89 |
| 0099V | 3 | 0.310 | 20.790 | -40.4 | 41.06 |
| 0053T | 6 | 0.307 | 14.701 | -28.5 | 29.12 |
| 09437 | 2 | 0.305 | 25.463 | -49.6 | 50.21 |
| 00912 | 1 | 0.300 | 36.010 | -70.3 | 70.88 |
| 0099Z | 15 | 0.293 | 9.298 | -17.9 | 18.52 |
| 0023M | 7 | 0.290 | 13.610 | -26.4 | 26.97 |
| 04487 | 2 | 0.290 | 25.463 | -49.6 | 50.20 |
| 0140Q | 3 | 0.287 | 20.790 | -40.5 | 41.04 |
| 0393A | 13 | 0.276 | 9.987 | -19.3 | 19.85 |
| 00990 | 2 | 0.270 | 25.463 | -49.6 | 50.18 |
| 0099Y | 3 | 0.250 | 20.790 | -40.5 | 41.00 |
| 0823Y | 3 | 0.250 | 20.790 | -40.5 | 41.00 |
| 0087U | 4 | 0.235 | 18.005 | -35.1 | 35.53 |
| 0912R | 11 | 0.235 | 10.857 | -21.0 | 21.52 |
| 00740 | 2 | 0.190 | 25.463 | -49.7 | 50.10 |
| 0A175 | 5 | 0.188 | 16.104 | -31.4 | 31.75 |
| 0089V | 1 | 0.180 | 36.010 | -70.4 | 70.76 |
| 0098Z | 2 | 0.180 | 25.463 | -49.7 | 50.09 |
| 0100X | 2 | 0.180 | 25.463 | -49.7 | 50.09 |
| 07727 | 2 | 0.170 | 25.463 | -49.7 | 50.08 |
| 0041D | 6 | 0.133 | 14.701 | -28.7 | 28.95 |
| 0059U | 1 | 0.130 | 36.010 | -70.5 | 70.71 |
| 0R290 | 2 | 0.100 | 25.463 | -49.8 | 50.01 |

Std Error uses a pooled estimate of error variance

**Figure 10.** Means of Defect Points per 100 yards categorized by Color Code, representing two subsets of 1637 color codes.

**Table 5.** Normalized Mean Defect Points/100 yards for Color.

| Color Code | Number of Occurrences | Mean Defect points/100 yards | Normalized Mean Defect points/100 yards |
|---|---|---|---|
| 0H944 | 1277 | 11.633 | 0.4527411008 |
| 0D263 | 1027 | 8.333 | 0.2608189382 |
| 0V183 | 632 | 6.604 | 0.1272012678 |
| 0709G | 380 | 10.539 | 0.1220535170 |
| 00000 | 334 | 11.168 | 0.1136813361 |

The analysis underscores the critical importance of focusing on the top defect-contributing colors. These colors exhibit notably high mean defect points per 100 yards of fabric, indicating significant quality issues. Despite varying occurrence frequencies, the identified colors consistently demonstrate elevated defect rates, necessitating prioritized attention in quality control efforts. By closely monitoring and addressing defects in these key colors, Elevate Textiles can mitigate off-quality production, enhance product quality, and minimize associated costs.

## 5. <u>Product</u>

In our analysis, we utilized regression analysis to investigate the correlation between individual products and the mean defect points per 100 yards of fabric. The findings, illustrated in **Figure 11.**, delineate the distribution of defect points per product, emphasizing those exhibiting the highest mean defect points. Notably, certain products demonstrate mean defect points exceeding 200, such as **05698 075 US 09147 053, 00618 015 US 0058S 06Q, and 0B976 FFB US 00472 03G**, albeit with varying occurrence frequencies. **Table 6.** presents the top 5 products characterized by the highest normalized mean defect points, underscoring the importance of comprehensive quality control measures across all products, even those with limited occurrences.

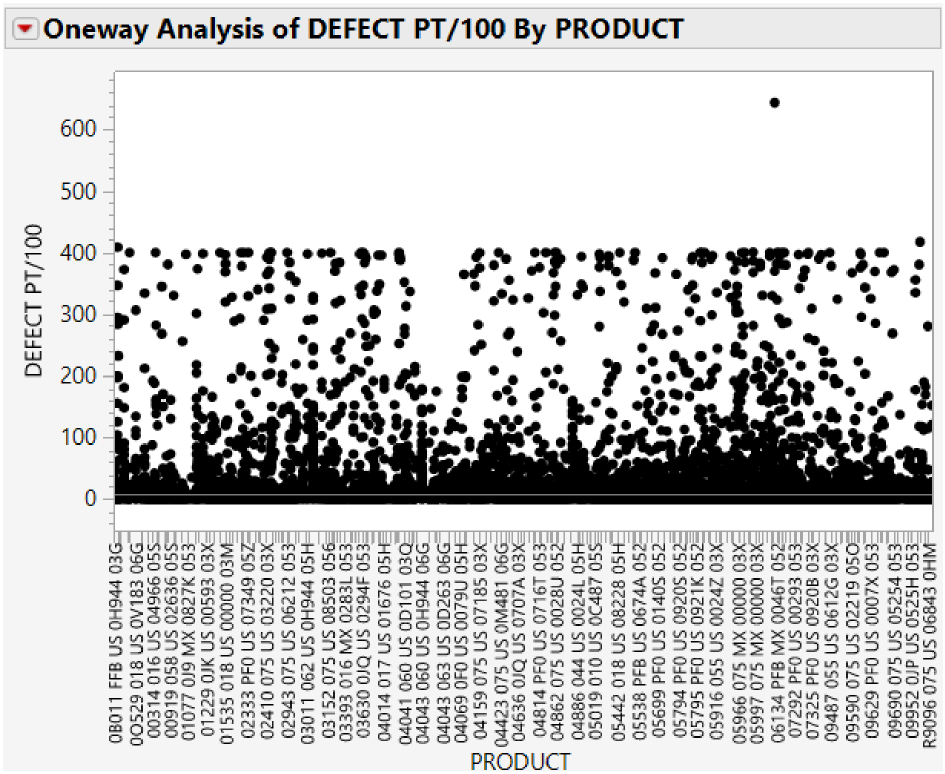


**Figure 11.** Defect Points Distribution per 100 yards by Product.

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 430 | 1 | 417.350 | 35.468 | 347.8 | 486.87 |
| 05698 075 US 09147 053 | 1 | 366.920 | 35.468 | 297.4 | 436.44 |
| 00618 015 US 0058S 06Q | 2 | 306.565 | 25.079 | 257.4 | 355.72 |
| 0B976 FFB US 00472 03G | 2 | 289.180 | 25.079 | 240.0 | 338.34 |
| 03838 017 US 00000 03M | 1 | 249.100 | 35.468 | 179.6 | 318.62 |
| 06329 NFR US 0055P 03G | 1 | 234.090 | 35.468 | 164.6 | 303.61 |
| 05737 PF0 MX 0048H 03X | 1 | 233.330 | 35.468 | 163.8 | 302.85 |
| 0C967 FFB US 0024L 03G | 1 | 232.580 | 35.468 | 163.1 | 302.10 |
| 05737 PF0 MX 0048G 03X | 1 | 230.180 | 35.468 | 160.7 | 299.70 |
| 05795 PF0 MX 0953J 052 | 2 | 196.665 | 25.079 | 147.5 | 245.82 |
| 05961 0JM MX 0083V 052 | 1 | 191.880 | 35.468 | 122.4 | 261.40 |
| 01535 049 US 0709G 05H | 2 | 185.885 | 25.079 | 136.7 | 235.04 |
| 05795 PF0 MX 0953K 052 | 2 | 182.020 | 25.079 | 132.9 | 231.18 |
| 01010 075 US 0087V 03X | 2 | 166.770 | 25.079 | 117.6 | 215.93 |
| 09629 PF0 US 00075 053 | 2 | 163.455 | 25.079 | 114.3 | 212.61 |
| 05965 B75 MX 0082X 052 | 4 | 161.998 | 17.734 | 127.2 | 196.76 |
| 0B974 018 US 03433 03G | 6 | 160.928 | 14.480 | 132.5 | 189.31 |
| X2859 NFR MX 0055P 03G | 1 | 152.450 | 35.468 | 82.9 | 221.97 |
| 06134 PFB MX 00468 052 | 7 | 151.671 | 13.406 | 125.4 | 177.95 |
| 02835 061 US 0085Y 03G | 1 | 150.760 | 35.468 | 81.2 | 220.28 |
| 02907 T75 MX 08939 05Y | 1 | 146.990 | 35.468 | 77.5 | 216.51 |
| 05737 PF0 MX 0047Y 03X | 1 | 144.440 | 35.468 | 74.9 | 213.96 |
| 04159 075 US 07185 03X | 2 | 143.450 | 25.079 | 94.3 | 192.61 |
| 06159 B75 MX 0076Q 03X | 4 | 137.138 | 17.734 | 102.4 | 171.90 |
| 04942 FFB US 00000 03M | 3 | 136.890 | 20.477 | 96.8 | 177.03 |
| 06134 PFB MX 0046R 052 | 3 | 133.847 | 20.477 | 93.7 | 173.98 |
| 06134 055 MX 00467 052 | 2 | 132.515 | 25.079 | 83.4 | 181.67 |
| 02833 PF1 MX 0160L 05Y | 4 | 122.303 | 17.734 | 87.5 | 157.06 |
| X2847 B75 MX 0086F 03X | 1 | 120.910 | 35.468 | 51.4 | 190.43 |
| 02835 04A US 0085Y 03M | 2 | 116.155 | 25.079 | 67.0 | 165.31 |
| HV100 PFH US 0STON 03G | 1 | 112.350 | 35.468 | 42.8 | 181.87 |
| 04814 075 US 0009Z 053 | 3 | 110.027 | 20.477 | 69.9 | 150.16 |
| 02907 T75 MX 08926 05Y | 3 | 109.430 | 20.477 | 69.3 | 149.57 |
| 04011 075 US 0H944 05H | 3 | 108.910 | 20.477 | 68.8 | 149.05 |
| 02275 0J3 US 09658 03X | 2 | 107.670 | 25.079 | 58.5 | 156.83 |
| 0B972 075 US 00000 03X | 2 | 103.180 | 25.079 | 54.0 | 152.34 |
| 05795 055 US 0921L 052 | 3 | 102.950 | 20.477 | 62.8 | 143.09 |
| 04828 055 US 02951 05O | 6 | 101.720 | 14.480 | 73.3 | 130.10 |
| 05965 B75 MX 0083Q 052 | 4 | 101.483 | 17.734 | 66.7 | 136.24 |
| 05509 055 MX 0822F 03X | 4 | 100.483 | 17.734 | 65.7 | 135.24 |
| 04423 075 US 0288V 039 | 1 | 100.000 | 35.468 | 30.5 | 169.52 |
| 05509 B75 MX 0099L 03X | 1 | 98.290 | 35.468 | 28.8 | 167.81 |
| 05698 075 MX 0H158 03X | 3 | 96.603 | 20.477 | 56.5 | 136.74 |
| 06134 PFB MX 0046P 052 | 4 | 96.265 | 17.734 | 61.5 | 131.02 |
| 02835 061 US 00000 03M | 2 | 95.270 | 25.079 | 46.1 | 144.43 |
| 06113 075 US 0041R 03X | 9 | 92.954 | 11.823 | 69.8 | 116.13 |
| 04033 002 MX 0B923 05H | 9 | 92.452 | 11.823 | 69.3 | 115.62 |
| 04814 PF0 US 0716T 053 | 5 | 91.640 | 15.862 | 60.6 | 122.73 |
| 06132 075 MX 0054S 053 | 9 | 91.303 | 11.823 | 68.1 | 114.48 |
| 03291 016 MX 0086Q 03G | 2 | 91.055 | 25.079 | 41.9 | 140.21 |
| 05965 B75 MX 0083S 052 | 4 | 90.913 | 17.734 | 56.2 | 125.67 |
| 07325 055 US 0795E 03X | 4 | 90.755 | 17.734 | 56.0 | 125.51 |
| 04825 075 US 0181V 052 | 1 | 88.890 | 35.468 | 19.4 | 158.41 |
| 06134 055 MX 0046C 052 | 12 | 88.874 | 10.239 | 68.8 | 108.94 |
| 05737 075 MX 00307 03X | 1 | 86.390 | 35.468 | 16.9 | 155.91 |
| 0B971 NFZ US 0F180 03G | 2 | 86.310 | 25.079 | 37.2 | 135.47 |
| 0B973 NFZ US 0A267 03G | 3 | 82.857 | 20.477 | 42.7 | 122.99 |
| 05796 055 US 0635K 03X | 11 | 82.662 | 10.694 | 61.7 | 103.62 |
| 05916 PF0 US 0024T 03X | 3 | 82.477 | 20.477 | 42.3 | 122.61 |
| 05509 PF0 MX 0821R 03X | 5 | 80.526 | 15.862 | 49.4 | 111.62 |
| 05982 075 MX 0049Q 03X | 7 | 80.239 | 13.406 | 54.0 | 106.51 |
| 04033 002 MX 0203K 05H | 5 | 78.864 | 15.862 | 47.8 | 109.95 |
| 02333 055 US 07415 05Z | 6 | 78.532 | 14.480 | 50.2 | 106.91 |
| 09690 075 US 05257 053 | 5 | 76.012 | 15.862 | 44.9 | 107.10 |
| 02275 PF1 US 09658 03X | 11 | 73.271 | 10.694 | 52.3 | 94.23 |
| 06229 075 MX 0092S 053 | 4 | 73.253 | 17.734 | 38.5 | 108.01 |

**Figure 12.** Defect Points per 100 yards by Product.

**Table 6.** Normalized Mean Defect Points/100 yards for Product.

| Product | Number of Occurrences | Mean Defect points/100 yards | Normalized Mean Defect points/100 yards |
|---|---|---|---|
| 03011 062 US 0H944 06G | 365 | 16.886 | 0.18783951 |
| 04043 060 US 0H944 06G | 517 | 7.61 | 0.11990644 |
| 0O529 018 US 0J017 06G | 337 | 7.033 | 0.07223336 |
| 01183 018 US 0709G 033 | 355 | 6.593 | 0.07133107 |
| 04886 044 US 0024L 033 | 298 | 7.436 | 0.06753407 |

## Improvement Stage

### Current Improvement Methods

As of our plant tour on March 8th, only one improvement initiative has been enacted within the inspection department, involving the installation of backlights on select machines. Despite this implementation, no further enhancements have been introduced in other departments. During our tour, we had the opportunity to interview the most experienced inspection worker, who highlighted the significant benefits of the added backlights in fabric inspection. However, the absence of detailed data specifying which machines were equipped with backlights limited our ability to accurately assess the extent to which this enhancement improved the repeatability and reproducibility of fabric inspection and analysis.

### Suggested Improvements Methods

The following recommendations can enhance the continuation of the project into next year.

1. **Timestamp for granular time trend analysis**

   Ensure all data entries include precise timestamps (date and time down to the minute or second if applicable). This granularity allows for more detailed time series analysis and can help identify trends or issues at specific times of the day or week.

2. **External factors analysis**

   Include data on external factors that might affect the metrics, such as weather conditions, economic indicators, or market activities, to understand external influences on trends. This can also help in exploring in depth the relation of different factors on defects.

3. **Operator data**

   Incorporation of data on who performed specific actions or handled operations to analyze performance by individual or team. This can help in establishing various KPIs of performance as well as establish the need for improvement and training. This can also provide the scope to perform MSA analysis.

4. **Data Completeness**

   Aim to minimize missing data, especially in time variables, to ensure consistent and reliable trend analysis.

5. **AI Inspection**

   One prominent improvement extensively discussed during the plant tour involved the acquisition of an AI inspection machine. This machine would enable the consistent analysis of defect points and substantially mitigate human error within the inspection department. The implementation of such technology holds the potential to significantly enhance the accuracy of data collection, facilitating more precise analysis and identification of potential root causes underlying various defects within the production process stream.

### Implemented Improvements

None of the recommended improvements were implemented during the course of our project.

## Control Stage

In the control stage, it is important to note that due to project timeline constraints, control procedures could not be implemented at this juncture. As such, the team did not have the opportunity to engage in this stage currently, and no actions were taken in this regard.

### Controls that could be implemented and tested

Implementing procedural controls, such as establishing Standard Operating Procedures (SOPs) for data collection and analysis in line with the project continuation recommendations, ensures consistency and minimizes data gaps. Introducing regular reviews and feedback loops fosters a culture of ongoing process enhancement. Moreover, implementing data quality controls, including periodic audits, enhances accuracy and identifies areas for improvement effectively.

## Summary

Throughout this project, we've gleaned valuable insights into the intricacies of quality control processes at the Elevate Textiles Finishing Plant. Our analysis underscored the importance of detailed data examination in pinpointing critical defect categories and understanding their impact on product quality. However, in hindsight, a clearer definition of project scope and objectives would have provided a more focused direction for our efforts. Incorporating stakeholder input during project definition could have ensured better alignment with organizational goals. Additionally, our sponsor could have provided more comprehensive data, especially regarding operator identification during inspections and external factors influencing defect occurrences. Despite these challenges, we've successfully identified areas for process improvement. Moving forward, refining project scope and enhancing collaboration with stakeholders will be crucial for driving sustainable improvements in product quality and operational efficiency.