Analysis of garment factories productivity

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ABSTRACT

The apparel industry is an important contributor to the global economy, with developing countries like Bangladesh playing a significant role in the industry's growth. To remain competitive, efficient resource allocation and optimal production planning are critical. The use of standard tools like Standard Minute Value (SMV) and assembly line balancing techniques can help increase productivity and reduce costs. Data analysis and visualization can provide valuable insights into production performance, but it is essential to address data quality issues like outliers, missing values, and input errors. Overtime and productivity indicators are also valuable measures to evaluate different departments' performance, and a day of rest like Friday could have a positive impact on overall productivity. These findings can help apparel industries in Bangladesh and other developing countries identify areas for improvement and optimize their production processes. Additionally, the analysis provided an overview of the garment and apparel industry, highlighting its significance as a labor-intensive sector in developing countries, such as Bangladesh. The analysis also showed that proper planning and allocation of resources are critical to optimizing production and increasing productivity. Finally, the analysis revealed the impact of factors such as seasonality, departmental dynamics, and style changes on productivity, emphasizing the importance of considering these factors when evaluating overall performance.

1 INTRODUCTION

The clothing industry encompasses both garments and apparel, with the former referring to a specific piece of clothing and the latter encompassing all types of clothing. While the two terms are used interchangeably in the industry, they both involve the processing of fabrics by combining raw materials from the textile industry. Despite the negative impact of the COVID-19 pandemic on the overall apparel retail industry between 2020-2021, the sector is expected to rebound, with revenue projected to reach $2trillionby2027, upfrom$1.53 trillion in 2022.[7] Despite the proliferation of distribution networks and international trade, many smaller businesses in developing countries still face challenges in competing with larger companies in the apparel industry due to strict standards and regulations set by international markets. The industry, however, remains an important way for these countries to foster economic growth and create much-needed employment opportunities, as labor-intensive activities are often well-suited for their available resources. Additionally, the relatively low barrier to entry in the apparel sector makes it more accessible to smaller businesses compared to other industries, which can provide a pathway for them to participate in the global economy.[2] In the past four decades, China has been able to lift 800 million people out of extreme poverty, which was an unprecedented achievement on a massive scale[9]. This success has led many economists and analysts to explore how this knowledge and experience can be leveraged to further economic growth in other developing nations. As part of its transition, China moved 70% of its population from working in agriculture in 1978 to only 18.3% in 2017, with many workers moving into other labor-intensive industries that require soft skills of entry, such as the apparel sector. China currently has the largest market share in apparel exports, estimated at \$161 billion in 2016, with Bangladesh coming in second at \$28 billion. However, in recent years, China's market share has been declining due to the country's shift towards producing more high-tech products. As a result, other developing nations such as Myanmar, Vietnam, and Cambodia have been able to absorb a larger share of the apparel market.[8] In developing countries like Bangladesh, limited land availability relative to the population makes agriculture an inadequate means of economic growth. As a result, the garment industry, which was established in 1978, quickly became the leading industry within a decade. Despite the introduction of mechanization and automation, human resources continue to play a crucial role in enhancing productivity and quality while simultaneously reducing the cost of manufacturing due to the availability of low-cost labor.[10] Efficient resource allocation is crucial for businesses to maintain a competitive edge in the global market. In the garment industry, sewing together different components to create apparel is the most labor-intensive process. This complex and time-consuming process has a significant impact on production performance and product quality. To achieve optimal production, proper planning is necessary. A typical t-shirt sewing line can consist of 25-50 workers and 18-40 sewing machines, with varying levels of worker capacity, making it challenging for floor managers to balance the workload and maximize productivity.[6] The progressive bundle production system is used by most apparel industries and has many problems, including bottlenecks. Time study is a popular work measurement technique to balance the sewing line and solve bottlenecks. [6] Assembly line balancing is a crucial process for minimizing workflow, reducing throughput time, and increasing productivity by efficiently allocating jobs to machines. To achieve this, the Standard Minute Value (SMV) plays a vital role in planning production by estimating the time required to complete a specific task under certain conditions. By utilizing SMV, manufacturers can optimize their assembly lines to ensure that each task is performed with the right amount of time and resources, leading to increased efficiency and reduced costs.[1] A work sample study showed that workers in the sewing section spent 72.7% of their time in productive activities and 23.2% of their time in personal allowances and unavoidable delays. [3]An experimental study was carried out to demonstrate the effectiveness of utilizing SMV and other tools in the apparel industry to enhance production efficiency. The study used a case study approach to investigate ways to improve line efficiency in the production of "T-item" by applying time study and line balancing techniques. The results indicated that by making small changes in work distribution and eliminating unnecessary delays and bottlenecks, the study was able to decrease SMV and increase production per hour. The findings have significant implications for similar apparel industries in Bangladesh seeking to optimize production efficiency through efficient resource management. The study can serve as a valuable knowledge base to identify common challenges and discover effective solutions.[1]

2 DATASET DESCRIPTION

2.1 Dataset

The data is Secondary quantitative data provide provided by Abdullah Al Imra used for the following research papers [4] and [5]. This paper will not continue building upon the previous research instead focus on answering the following four questions from stakeholders and provide a fifth on-based exploitation of the data:

(1) Does the individual team's actual productivity exceed their targeted productivity, and which team is the most/worst productive?
(2) Which of the two garment production processes (i.e. sewing and finishing) is the hardest?
(3) Which of the days is mostly the rest day for the workers, and how does the resting affect their productivity afterwards?
(4) When does the company pay more incentive to its workers? And does both sewing and finishing departments enjoy the same incentives?
(5) What impact do style changes have on general productivity?

The data is mainly dispersed into different attributes that categorize data relevant to factory productivity, the Records are a sample of data collected in span over 6 months in one factory. Data has been collected every day from each of 12 teams from different department sewing and finishing.

2.2 Initial analysis & cleaning

The data were initially represented as a table, and upon initial analysis, multiple null values were found in the "work in progress" (WIP) attribute that were all tied to records called "finishing" in the department attribute. However, based on research into the literature, it was determined that this attribute did not contribute to answering any of the other questions. The data were then formatted with the correct data types, and further investigation into departments found that "finishing" and "finishing " were assumed to be input errors. Cleaning the data resulted in the removal of all trailing and ending white spaces for all data objects in the dataset to eliminate any other errors that could be present. The data were also checked for duplicates that could lead to misrepresentation of the data.

To gain insight into the distribution of the data, histograms were plotted for all columns to check the frequency and probability of when specific data points appear. The attribute "actual productivity" was found to be the only one with a normal distribution, while "date" and "time" were relatively uniformly distributed. The rest had skewed distributions, suggesting the presence of a significant number of outliers. Further correlation analysis with a Pearson comparison matrix yielded little insight into the dispersion of the data. However, further exploration showed a correlation between the attributes that initially seemed to be outliers and occurred within a specific time frame.

Using a z-score on all records in the data set to gain insight into the outliers from the 3rd standard deviation of 97.5%, we found that most of the data was not normally distributed. Removing all outliers after this standard would not be prudent, as it would negatively affect the realism of the answer to the question. Instead, each of the attributes was evaluated individually with regard to the specific question's potential, utilizing other methods such as IQR to handle outliers. This gave rise to the hypothesis that these specific attributes were correlated over time and thus cannot be excluded as outliers.

To further confirm the significance of a large part of the outliers to the analysis, we used the Pearson coefficient formula, flagging all values outside the first quartile of standard deviation as outliers. This essentially flipped the correlation analysis onto all none common values, allowing us to see any linear correlation that couldn't be observed before.

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

The below matrix shows some pretty strong correlations in the outliers data set further confirming the hypothesis and providing the analysis with fitht and final question regarding the data set.

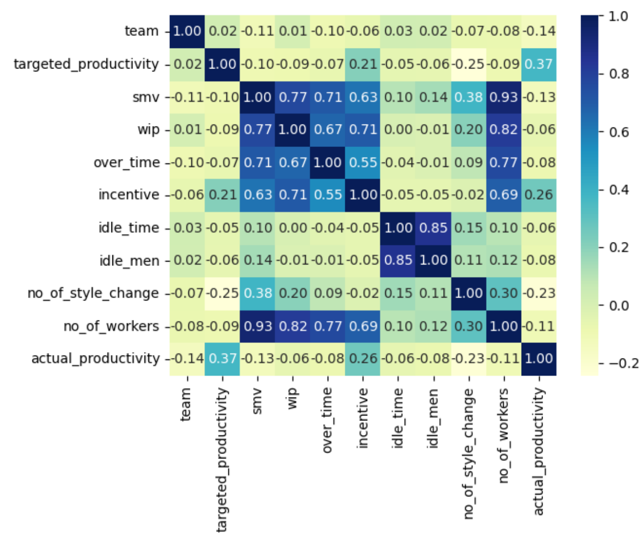

Figure 1: Correlation matrix

Upon further inspection of the data, it was noticed that some generic terms, such as "Quarter," were used to subdivide the work month into what is commonly referred to as a "work week." This creates confusion and undermines the purpose of the term "quarter," which typically refers to a business year divided into four quarters. While the data set includes a fifth quarter, analyzing it would provide limited value to the questions at hand. Additionally, misspelled words such as "fineshing" and "sweing" were observed, along with a few apparent input errors.

Furthermore, incentives are paid out in BDT, which is the currency of Bangladesh. This leads us to assume that this is a garment factory in Bangladesh, which could explain some of the outliers, such as national holidays. However, the origin of the data is not provided, and it is beyond the scope of this analysis to investigate further.

3 DATA ANALYSIS

3.1 Question 1

Does the individual team's actual productivity exceed their targeted productivity, and which team is the most/worst productive?

. The graph provides a comprehensive view of the productivity indicator for the entire time frame of the dataset. However, it's important to note that productivity can be impacted by external factors, such as the release of new styles and seasonal fluctuations, which can affect different teams in varying ways. As such, when analyzing productivity, it's crucial to take into account these contextual factors and evaluate individual teams' performance accordingly.

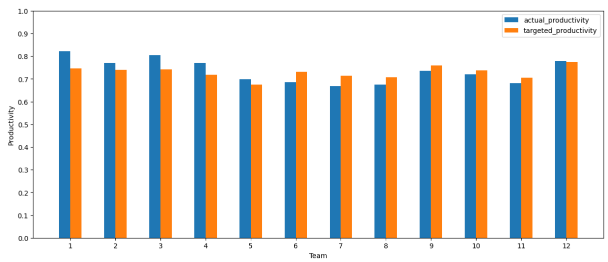

Figure 2: Difference between targeted and actual productive above the mean

. The table shows the difference between targeted and actual productivity, ranked in descending order. Team 1 has the highest productivity, exceeding their target by 9.96%, while Team 7 has the lowest productivity, falling short of their target by the largest margin. However, it is important to note that productivity alone may not be the only factor to consider when ranking teams. Without further data, it is difficult to accurately determine the underlying factors that contribute to overall productivity. In this particular sample, the rankings based on productivity still hold, but more information would be needed to draw definitive conclusions about team performance.

Team	Targeted	Actual	Difference
1	0.75	0.82	9.96 %
3	0.74	0.80	8.32 %
4	0.72	0.77	7.30 %
2	0.74	0.77	4.18 %
5	0.67	0.70	3.61 %
12	0.77	0.78	0.62 %
10	0.74	0.72	-2.54 %
11	0.70	0.68	-3.12 %
9	0.76	0.73	-3.13 %
8	0.71	0.67	-4.82 %
6	0.73	0.69	-6.29 %
7	0.71	0.67	-6.48 %

3.2 Question 2

Which of the two garment production processes (i.e. sewing and finishing) is the hardest?

. One comparison indicator that would be valuable in this situation would be Work in progress; however, this a measure only used by the sewing department and, therefore, not relevant in this scenario. The following hypothesized that a high amount of overtime and the lowest amount of time exceeding the target productivity goal would be the department that is most difficult to work in. To calculate the overtime, we first need to divide the overtime by the number of workers for each record in the data set. By aggregating the result through a mean calculation, we got the following results:

Table 1: Percentage increase from the work day with the lowest productivity

Day	Finishing	Sewing	Difference
overtime	176.64	124.72	141,62%
standard deviation	91.78	38.09	240,95%

The analysis shows that the finishing department has a higher average overtime than the sewing department, with a larger deviation from the mean. The graph also shows that finishing has more peaks where the average overtime can reach up to 5 times the norm, while sewing is more uniformly distributed throughout the sample time.

When it comes to meeting target productivity expectations, the finishing department exceeds their target by an average of 104.2% of the time, while sewing reaches 100.34%. This could indicate that it is more difficult to reach targets in the sewing department or that the target may be more ambitious.

However, when observing both departments over the given time span, the sewing department seems to have a more consistent line around the target productivity. In contrast, finishing seems to have a more volatile pattern, with more significant variations in productivity. This could be due to the nature of the work in each department or differences in the management approach.

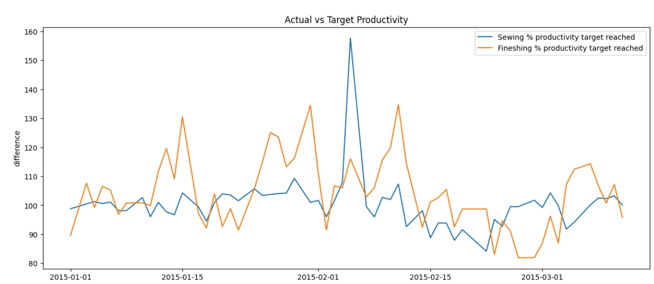

Figure 3: Percent of the time productivity target is reached

While the data does suggest that finishing may be the most challenging department to work in due to higher overtime hours and less consistency in meeting productivity targets, further analysis and information would be needed to make a definitive conclusion. It's also important to consider other factors such as the nature of the work in each department, the experience and skill level of workers, and potential differences in management or working conditions.

3.3 Question 3

Which of the days is mostly the rest day for the workers and how does the resting affect their productivity afterward?

. Since there has been no data gathered on Friday, the assumption is made that this is the day of rest.

Figure 4: Day vs actual productivity

By aggregating all data into six different workdays and calculating the mean and median of all values, the median in the following chart is represented by the line going through the box that represents the interquartile range of the middle 50% of the scores. The outer lines represent the remainder 50%, and black diamonds represent outliers outside 1.5 times the interquartile range. Further research into why productivity regularly dips into the outlier range is required cause the occurrence of values does not seem to be input failure but rather shows an event that transpires with regular frequency. Both median and mean, however, show an increase in productivity after the rest day, as shown in the table below.

Table 2: Percentage increase from the work day with the lowest productivity

Day	Median%	Mean%
Monday	5.96	1.78
Saturday	6.59	4.05
Sunday	0.00	0.83
Thursday	0.00	0.00
Tuesday	0.02	2.78
Wednesday	4.34	1.08

Friday, the day of rest, calculating the mean results in a 4% increase over the least productive day whilst the median results 6.59% over the same day.

3.4 Question 4

When does the company pay more incentives to its workers? And do both sewing and finishing departments enjoy the same incentives?

. Observing that both departments pay out incentives to employees, it has be noted that "sewing" calculates incentives on a daily basis whilst finishing only one record of calculating incentives on 09-03-2015 since the data set is limited to roughly the first three months in 2015. No additional information is provided; we cannot conclude whether this is on an annual, semi-annual, or quarterly basis. For this analysis, we will assume that finishing incentives are calculated on the exact range of dates provided in the data set. Once again, using the Pearson coefficient formula.

We compare all attributes filtered by "sewing department" in the correlation matrix below. As data is complete, and allow us to see the linear correlation.

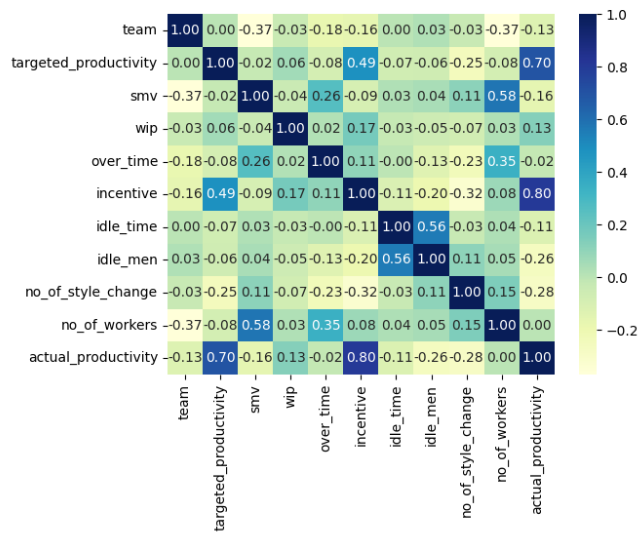

Figure 5: Correlation Matrix

From the correlation matrix, we can determine that the strongest correction with "incentive" is "actual_productivity" yielding a coefficient of 0.8; however, through this analysis, it was observed that "target_productivity" also had a coefficient of 0.49 which warranted further exploration into both attributes.

. Aggregating all data by the mean for the individual teams and arranging the incentives as the green bar and the plotted lines as actual and target productivity further shows a similar correlation as in the above matrix.

. For clarity, "Sewing" and "Finishing" are displayed in separate graphs.

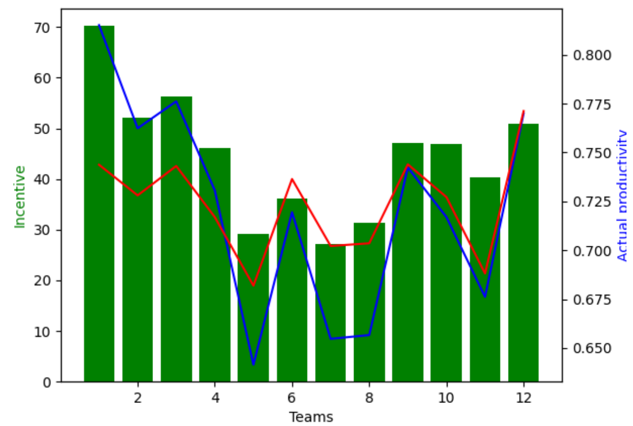

Figure 6: Sewing Department

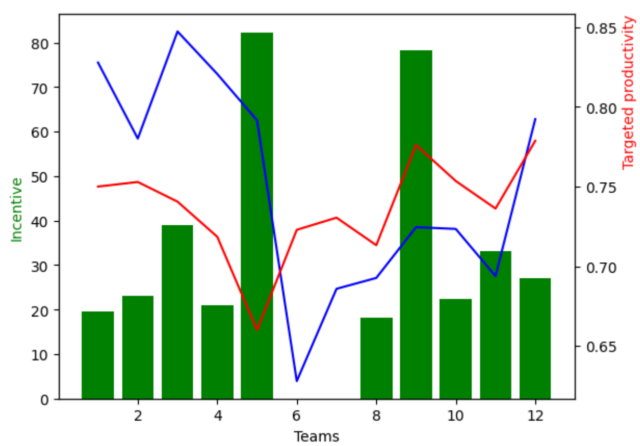

Figure 7: Finishing Department

The bars follow the general trend line on actual productivity, and we can assume with high probability that "actual productivity" is a vital attribute when calculating the incentives; however, there seem to be other factors also contributing otherwise where there would not be a discrepancy on those teams who produce at a similar level. It is plausible that Incentives are calculated by aggregating a combination of "actual_productivity", "target_productivity", and other indicators of performance. Initial research into the apparel and garment Industry showed "SMW" a commonly used indicator of productivity and could be hypothesized to be potentially a good determinant of incentives; however, this is outside the scope of this analysis.

A further difficulty arises when establishing the total amount of incentives paid for each department as "finishing" we once again make the assumption that incentives are calculated based on performance for the whole time span of the sample. Thus simply dividing the mean of incentives by the number of workers will result in only it being calculated for the specific day that workers' result is calculated; the problem arises because the work teams vary in size throughout the time span. The solution instead is calculating the mean of all incentives and then dividing that by the mean of workers throughout the period. Thus yielding the most relevant result for the given data set, the "sewing" department is more straightforward as data is recorded on each individual day. The results are seen in the table below.

Table 3: Average per day

	Workers	Incentive	Incentive per worker
Finishing	10.25	29.64	2.89
Sewing	52.44	44.48	0.85

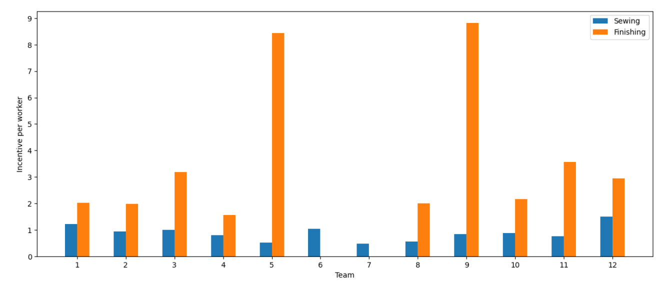

Figure 8: Incentives aggregated team in each specific Department

Furthermore, we can also see the per-day average per worker aggregated by the teams, showing a significant difference in the amount paid to each team. Based on assumptions we made on this specific data set, we can conclude that Finishing enjoys a higher amount of incentives.

3.5 Question 5

What impact do style changes have on general productivity?

. The Initial analysis provided insight into to effect of outliers on other data, as so much of the data was skewed. Specifically, the number of record of style changes that would be replaced using the aforementioned tech. This raised the hypothesis that these specific attributes in time span were correlated and thus can not be excluded as outliers.

Initial observations with histograms found specific attributes with more skewed data to warrant further analysis. By calculating the percentage of the max value for each of the observed attributes, we can see a correlation at a specific time in the production process. The graph makes certain attributes visualize more clearly over time; this shows cases of specific attributes that lie dormant and tell a significant change occurred.

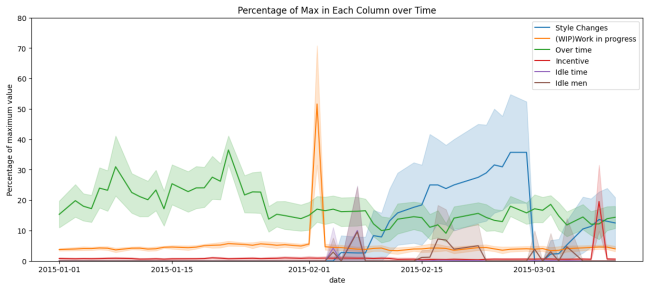

Figure 9: Percentage of max on each attribute over period of time

The next graph shows the target and actual productivity over the span of the sample. The lines represent the mean of the and the light colour zone the standard deviation

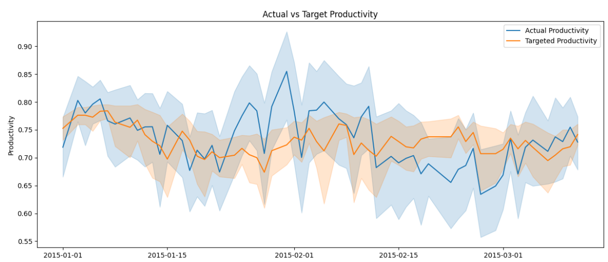

Figure 10: Actual vs Target productivity

When observing both graphs, we can see a pattern emerging over time of time where both targeted and actual productive seem to further shed a spotlight on those details; our analysis broke the following down into the follow table:

Table 4: Productivity while style changes are occurring

Style changes	targeted	actual	percent difference
0	0.74	0.75	101.64%
1	0.66	0.62	92.93%
2	0.69	0.66	96.23%

The data displayed in the table we that see that whilst style changes are occurring that not only the productivity targets lower but workers are not able reach those targets.

Though correlation does not imply causation, there seems to be evidence that in factories changing styles have an impact on overall productivity; this also coincides with the finding of the initial research that there is an overhead that occurs when changing styles with educating personnel and streamlining new work processes. However, given the limited sample, more data is needed before advising any changes.

4 DISCUSSION

The data analysis presented raises several interesting questions and provides insights into the garment production industry.

The first question addressed is whether the individual team's actual productivity exceeds their targeted productivity and which team is the most/worst productive. The analysis revealed that Team 1 had the best performance, exceeding their targeted productivity by 9.96%, while Team 7 was the worst performing team, falling short of their target by 6.48%. However, it was noted that productivity alone might not be enough to rank teams accurately, and further data is needed to gauge the underlying factors that affect overall productivity.

The second question addressed whether the sewing or finishing department was the hardest to work in. The analysis showed that the finishing department had an average of 141.6% more overtime hours than sewing, indicating that it is harder to predict the amount of work needed in the department. Further, the analysis found that finishing exceeds their target productivity by 104.2% of the time on average, while sewing reaches 100.34%. It was concluded that finishing might be the most challenging department because of its inconsistent target productivity and more ambitious targets.

The third question addressed which day is mostly the rest day for workers and how resting affects their productivity afterward. The analysis found that Friday is assumed to be the rest day since there was no data gathered on that day. Productivity on Monday, after the rest day, increased by 5.96% in median and 1.78% in mean productivity. It was noted that the occurrence of productivity outliers regularly dips but requires further research to understand the event's frequency.

The fourth question addressed when the company pays more incentives to its workers and whether both sewing and finishing departments enjoy the same incentives. The analysis found that sewing calculates incentives on a daily basis while finishing only has one record of calculating incentives. The incentives are likely based on aggregating a combination of actual and target productivity and possibly other indicators of performance. It was concluded that the finishing department enjoys a higher amount of incentives compared to sewing.

The fifth question addressed the impact of style changes on the sewing department's productivity and idle time. The analysis found that when style changes occurred, both targeted and actual productivity decreased, and workers were unable to reach their productivity targets. This is likely due to the overhead that occurs when changing styles, such as educating personnel and streamlining new work processes.

Overall, this data analysis provides valuable insights into the garment production industry and raises several interesting questions that require further research.

5 CONCLUSION

In conclusion, while the data had flaws, it can provide valuable insights into the workings of garment production. However, a more extended observation period on the factories preceding it would be necessary to normalize a more significant part of the data and draw more conclusive results. Additionally, exploring the seasonal cycle in garments and apparel over multiple iterations could provide added value and prevent the observed extremes from being misinterpreted as outliers when using standard statistical methods.

Attempting to calculate workarounds on the dataset without sufficient domain knowledge or clarification from the dataset owner could lead to erroneous conclusions. It is crucial to approach the data with caution and acknowledge its limitations while also utilizing proper statistical methods to draw accurate insights

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