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APPLICATION OF STATISTICAL CONTROL AND QUALITY TOOLS IN A BRAZILIAN TEXTILE INDUSTRY

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ABSTRACT
The textile industry has been of great importance to the Brazilian economy since the 18th century, serving as a complement to other industries for both large, medium, and small companies. This industry is currently responsible for generating large revenues, in 2023 raising US$ 956 million in exports, registering a turnover of R$ 193.2 billion in 2022 with an investment of R$ 4.6 billion. Therefore, it is necessary to analyze the processes of this industry, so that there is the possibility of generating accurate quantitative data and thus justifying the investment in its sectors. Therefore, this work aims to monitor the production process of a Brazilian company in the textile sector, through statistical process control (SPC) together with quality tools, aiming to present the current scenario of the process that is being used by the company and generating an overview of the manufacturing sectors studied.

Keywords: Statistical process control, quality tools, Quantitative data, Textile industry.

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INTRODUCTION

The textile industry has been very important to the Brazilian economy since the 18th century, serving as a complement to other industries for large, medium, and small companies. From 1960 onwards, a program to stimulate company mergers and modernization, was a crucial point in the recovery of this industry, weakened by the First World War.

Currently, this industry is responsible for generating large revenues; in 2023, it raised US$ 956 million in exports, and recorded a turnover of R$ 193.2 billion in 2022, with an investment of R$ 4.6 billion, with a registered production volume of 2.1 million tons (ABIT, 2024).

Therefore, it is necessary to analyze the processes of this industry, so that there is the possibility of generating accurate quantitative data, which would assist in decision-making for future improvements, together with the presentation of data for studies on the textile sector in the country. Therefore, this study aims to monitor the production process of a Brazilian textile company through statistical process control (SPC) together with quality tools, aiming only to present the current scenario of the process and generating an overview of the manufacturing sectors studied, using the Pareto diagram together with the I-AM control chart. By presenting very detailed processes and a well-aligned production flow, with precision in data collection that is done daily by its employees, it becomes possible to present a study of the production scenario very clearly, showing the points to be studied.

The process chosen for the study was the fabric production line, analyzing the efficiency by-product, more specifically six products of the production line that are the main fabrics sold by this industry, making a comparison with the years 2023 and 2024, and using as analysis the variations of the products between the observed period and after that showing the reasons for these variations and their importance for the production process. Because it is a process that has a great variation and can present a range of data that requires several forms of analysis, the case study was chosen as the methodology, which for Lakatos et al, (2022, p. 306) does not have a priori structural scheme; thus, a scheme of problems, hypotheses, and variables is not organized in advance. It brings together a large amount of detailed information, using different research techniques.

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THEORETICAL FRAMEWORK

STATISTICAL PROCESS CONTROL

Statistical Process Control (SPC) can be understood as a set of tools and methods that assist in monitoring the process in several factors. In this sense, Statistical Process Control is the area of Production Engineering responsible for the use of statistical techniques that enable the reduction of variability in the characteristics of interest and, therefore, the optimization of the loss function (MONTGOMERY, 2004).

I-AM CHART (INDIVIDUAL WITH MOVING RANGE)

The I-AM chart is used to monitor the mean and variation of your process when you have continuous data that are individual observations not in subgroups. Use this control chart to monitor process stability over time so that it is possible to identify and correct instabilities in a process (Support Minitab, 2024) as shown in the Figure.

Figure 1 Example of an I-AM letter.

Support Minitab (2024).

Based on what was presented by the author, the control chart above shows a set of values under statistical control, because when all sample points are randomly arranged

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within the control limits, the process is considered to be "in control" (De Oliveira et al., 2013). According to Montgomery (2016), most of the production is between the lower and upper specification/control limits (LIE and LSE, respectively). When the process is out of control, a greater proportion of the process output is outside these specifications/controls. According to Montgomery (2004), the valid equations for creating control charts of individual values and moving ranges are, respectively, the following:

Eq (1) LC = $\bar{X}$

Eq (2) LIC = $\bar{X} - \left(\frac{3 \times \overline{MR}}{d_2}\right) = \bar{X} - (E_2 \times \overline{MR})$

Eq (3) LSC = $D_4 \times \overline{MR}$

Eq (4) LC = $\overline{MR}$

Eq (5) LIC = $D_3 \times \overline{MR}$

According to the equations presented, LC: Center line: which represents where this process characteristic should be if no sources of variability were present (Montgomery, 2016). X ̅: Sample mean: The sample mean is calculated as the sum of all sample values divided by the sample size. E_2: Correction factor for moving average amplitude: The correction factor is a statistical tool that adjusts values obtained in measurements or calculations, taking into account factors that may affect the accuracy of the results. (MR) ̅: Average amplitude of variation: it is used in control charts for individual values and moving amplitudes (I-MR). It represents the difference between consecutive observations. LIC: Lower control limit: It establishes the lowest limit of acceptable variation in a process. LSC: Upper control limit: It helps to establish the highest limit of acceptable variation in a process. D_4: Factor for upper control limit: This is a statistical factor used to calculate the Upper Control Limit on the Moving Range chart. The value of D4 is determined by a table of control factors for moving average range charts and depends on the sample size. D_3: Factor for lower control limit: This is a statistical factor used to calculate the Lower Control Limit on the Moving Range chart. The value of D3 is determined by a table of control factors for moving average range charts and depends on the sample size. d_2: Moving average range: This is the average of the absolute differences between consecutive observations. It is used to estimate the variation within the process.

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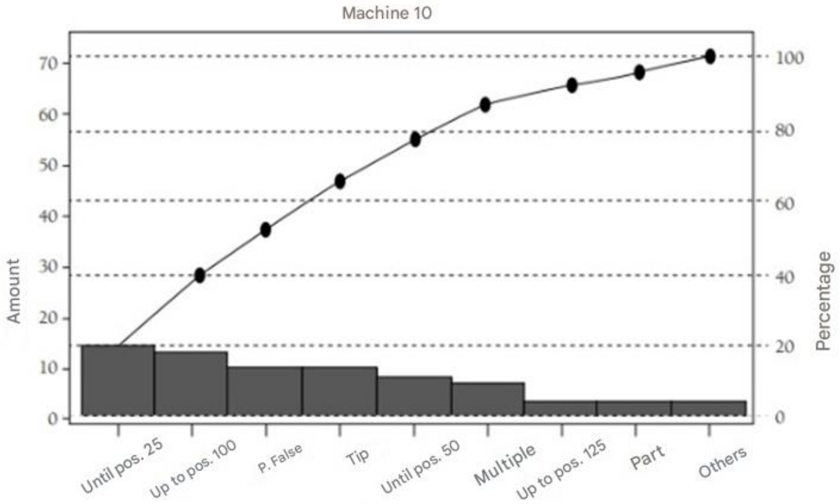
PARETO DIAGRAM

According to Selmer and Stadler (2010), the Pareto Diagram tool “allows the identification and classification of the most important problems that must be corrected first. According to Lobo (2020), it is based on the Pareto principle, also known as the 80/20 rule, which suggests that 80% of the effects come from 20% of the causes. In this sense, the Pareto Diagram aims to show the importance of all conditions to choose the starting point for solving the problem, identify the basic cause of the problem, and monitor success. (MACHADO, 2012, p. 49).

Ferreira and Morgado (2019) say that the Pareto diagram is very useful in industrial management, for analyzing defects in the manufacture of products that usually represent high costs and a significant deterioration in the image of the quality of the products and the company that produces them. Figure 2 depicts a Pareto diagram.

Figure 2 Example of a Pareto Diagram.



Amount	14	13	10	10	8	7	3	3	3
Percentage	19.7	18.3	14.1	14.1	11.3	9.9	4.2	4.2	4.2
Accumulated %	19.7	38.0	52.1	66.2	77.5	87.3	91.5	95.8	100.0

Source: Lobo, Renato N. (2020).

Lozada (2017) states that for the Pareto diagram to be properly prepared and applied, it is recommended that some steps be followed: Step 1 – Data collection: define the problem to be investigated, using a data collection checklist; Step 2 – Data organization: arrange the data in a table in descending order of categories (as shown in Figure 2). Less significant items can be grouped in the "others" category, always being reported at the end, and this category should be less representative than the others (otherwise, it should be evaluated again, extracting the most significant items from it); Step 3 – Calculation of percentages per item: determine the relationship between the quantity of

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an item and the overall total: percentage = quantity of item X 100/overall total; Step 4 – Calculation of accumulated percentages: successively add the percentages, from the first to the last, until the total is 100%; Step 5 – Creating the graph: draw two vertical lines and a horizontal line between them (as shown in Figure 2).

The left vertical axis corresponds to the quantities, ranging from zero to the total. The right vertical axis corresponds to the accumulated percentage, ranging from zero to 100%. The horizontal axis corresponds to the data categories, represented by duly named columns, arranged in ascending order, from left to right.

METHODOLOGY

The following study aimed to analyze, through statistical process control, together with quality tools, the performance of the production process of a textile industry and thus explore possible problems in the current scenario. Data on 6 products were provided, these being the main ones of this company. Based on this, analyses were performed on them, with emphasis on the most critical cases of the current production process, in which the prioritization criterion was defined about the products that presented the worst results among all, when comparing the productivity averages between the years 2023 and 2024 (Figure 3), for each of the products, representing 3 of the total of 6 products. This work is classified as a case study since only the causes where, in principle, there will be no application of the proposed improvements and suggestions will be studied and explored.

STEPS OF THE RESEARCH METHOD

The following methodology used consisted first of collecting data from the sectors that produce certain types of fabrics, then the data were processed and after that, the Excel and Minitab software were used to plot graphs and control charts, which are quality and statistical control tools that aim to monitor and improve the efficiency of the production process.

Data Collection

In the current phase, manufacturing data for the present products of this company were collected, where the periods analyzed were from August 2023 to March 2024, the following observed data present production factors that were used for the analysis. The

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present data were provided through Excel spreadsheets made available by the company's PPC sector, which collects them daily.

Data Preparation

For this analysis, the data of the studied products were separated, after being processed and with the removal of registration errors, discrepant values , and values unnecessary for the study. These were prepared for use in the analysis stage, where the variables that were later used in the study were calculated, namely the average annual productivity of each product, the Kg/m/h, and the setup hours of the machines used in the production of these products.

Data Analysis

Then, Minitab software was used, which uses statistical tools to monitor processes. The option used in the research was the I-AM chart to analyze the behavior of production during the period in which the variable used was Kg/m/h. Next, Excel software was used and the Pareto diagram was plotted to identify the main reasons for production stoppages in a column chart where its variables are the percentage of productivity of each product in the given period observed, the objective of which is to identify the variation in productivity between months.

RESULTS AND DISCUSSIONS

The following company in which the study was conducted is a large-scale textile industry located in Brazil, whose main production focuses are fabrics and yarns, which are its main source of revenue.

First, to have an overview of the process, the average percentage of productivity between the years 2023 and 2024 of the products was observed and with this, it is noted that products 1, 5, and 6 are above average, however, it is noticeable the occurrence of a decline in the productivity of the other products with an emphasis on product 2 which declined 11.21% when comparing the annual averages (Figure3).

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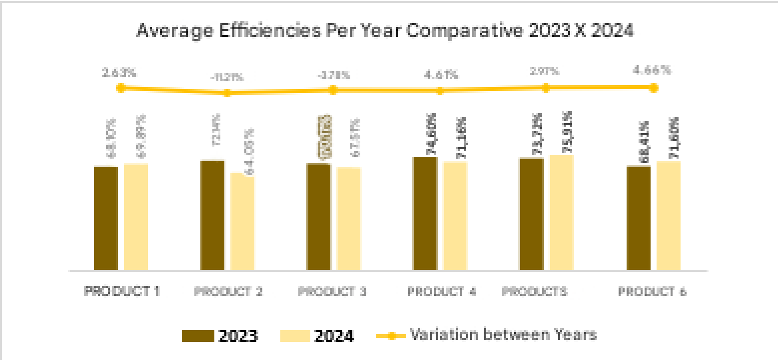
Figure 3 Productivity percentage graph.



Source: Authors (2024).

From this discovery, the focus was to analyze what could be causing such a drop in productivity. To do this, it was decided to observe how the process behaves over time. After that, I-AM control charts were plotted for each of the products in which the observed variable was Kg/Maq./H in the production of fabrics, where the following results were obtained (Figures 4, 5, and 6); the production process of these fabrics, in general, is out of control due to the presence of several special causes, in which it is notable that several points tending to the lower limit can be understood as factors that influence the drop in productivity, in addition to showing a considerably high amplitude indicating a tendency for an increase in variation, where it is understood that the current process finds it difficult to remain stable due to these variations.

Figure 4 Product Kg/Machine/H Control Chart 2.

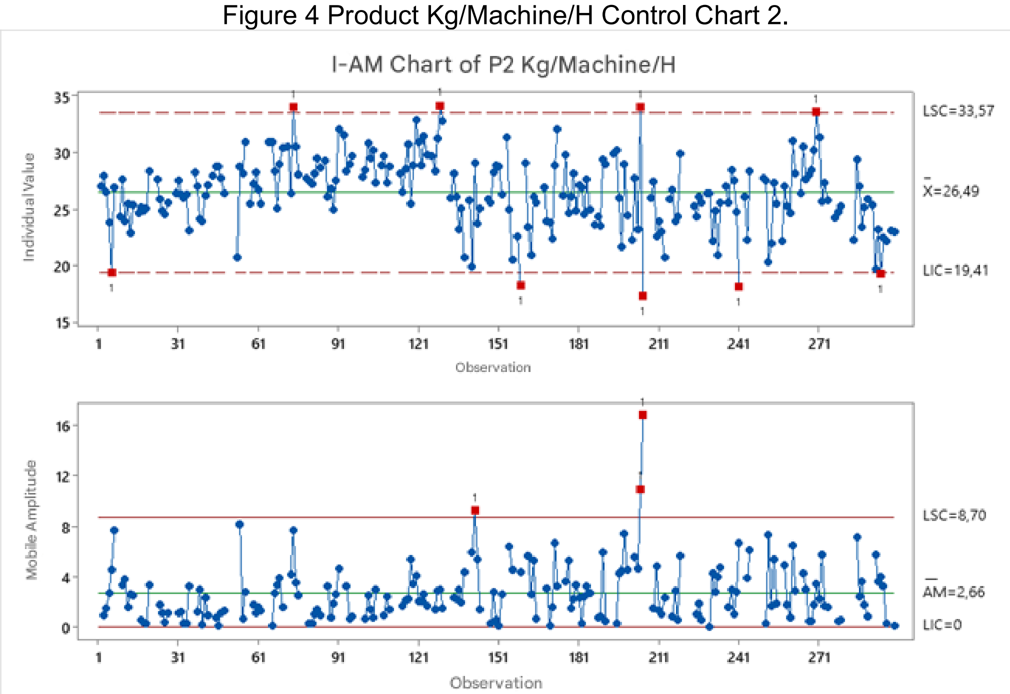


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Figure 5 Control Chart of Kg/Machine/H of Product 3.

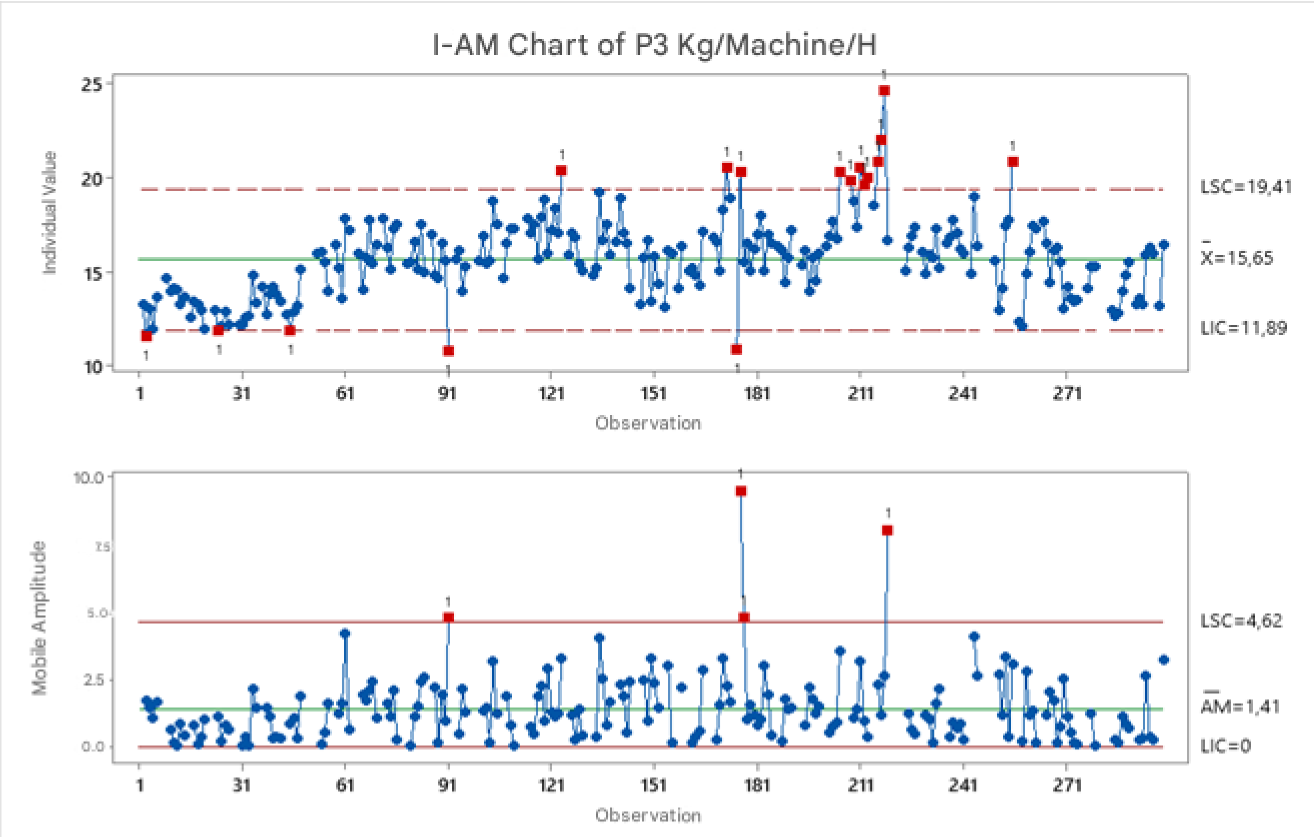

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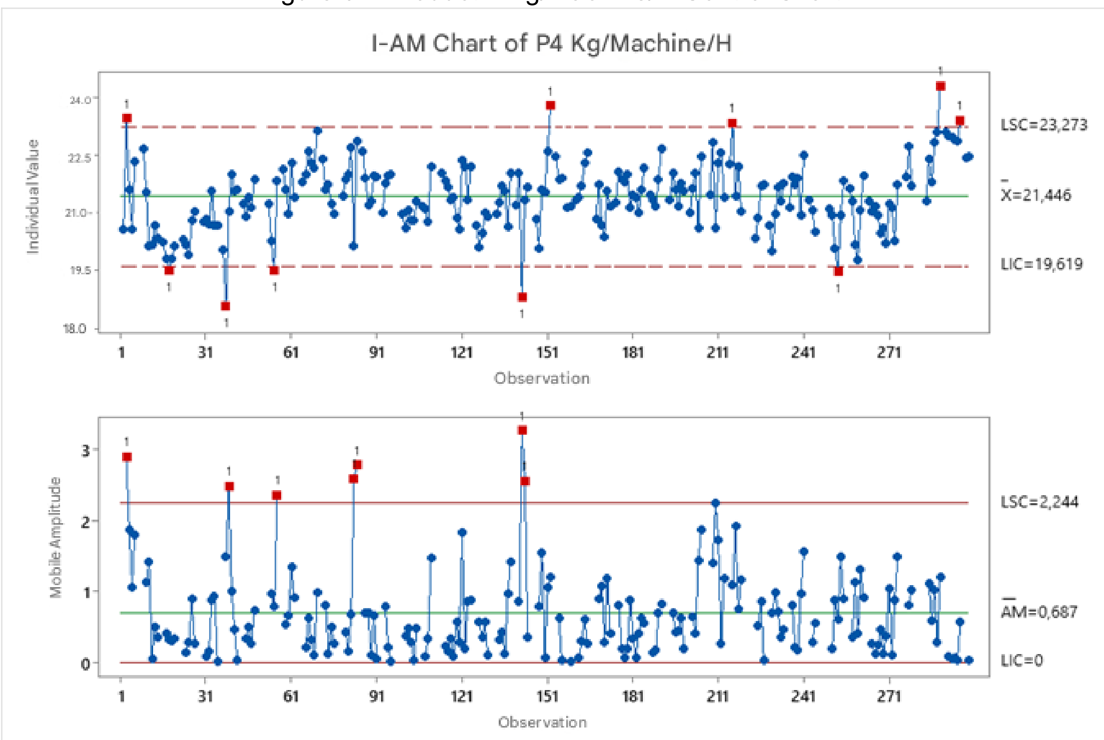
Figure 6 – Product 4 Kg/Machine/H Control Chart.



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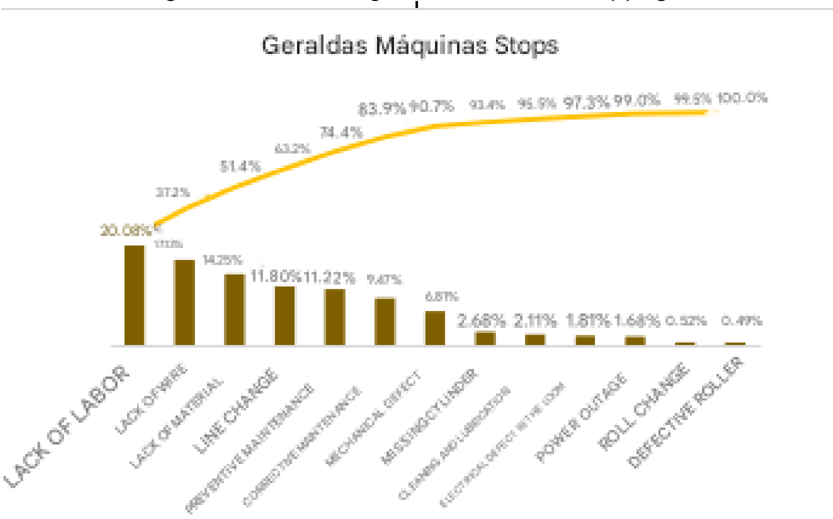
The Pareto diagram was then plotted (Figure 7), and it was noted that the main reason for the factory's machinery to stop was due to a lack of labor, leading the factory to operate below normal capacity. When analyzing the occurrences of stoppages, it is also noted that the lack of material and yarn has a significantly high value, accounting for 14.25% and 17.13% of the total stoppages, respectively. These stoppages are caused by the lack of supply of intermediate materials. These materials are produced in processes before the observed one but have a total impact on it since the observed process depends on the others. If there is a lack, the machinery will be stopped until the material arrives for use. The sum of the two percentages due to lack of yarn and material results in 31.38% of the total, in addition to the stoppage due to lack of direct labor for fabric production, which represents 20.03%, which, when added to the previous ones, results in a total of 51.41% of the general occurrences.

To better understand this fact, the authors contacted the company's PPC department and were informed that the factory was facing a labor shortage in the sectors in general, so the production of materials would be lower than normal. This leads us to understand that the lack of labor in these sectors is directly affecting production, since less will be produced, which will result in a lack of intermediate material for the production of fabrics, causing the machines to stop production completely until the material arrives for use, which is extremely harmful, since production will be stopped due to this shortage, which may be one of the main contributors to the abnormal variation in the process and also to the drop in productivity.

Figure 7 Pareto diagram of machine stoppages.



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CONCLUSION

The present study aimed to analyze the production process of a textile company, using quality tools, with a focus on statistical process control (SPC). From this, with the use of SPC, it is clear that the organization has problems with the lack of labor and intermediate materials, due to the lack of labor; which is extremely detrimental since the factory has to stop its activities due to the lack of materials due to the lack of labor, resulting in losses due to lost time. Due to the confidentiality that we must maintain at the company's request, some limitations to the research are noted, since the data provided by the organization are general and not by type of product and therefore it is not possible to identify the root causes of certain problems. In the meantime, it is suggested that the company seek ways to overcome and monitor this problem, where employee surveys can be carried out by sector, for which minimum employee limits can be defined, which facilitates decision-making when requesting the hiring of labor from the company's recruiters, resulting in a preventive measure against the problem faced. From this measure, the factory will no longer experience this deficit, since before this shortage occurs, managers will already be aware, which can prevent operation with limited capacity in this regard, which will make the factory work more efficiently.

Therefore, with the use of the CEP being of great relevance for this research, we recommend the use of this tool for a better understanding of other problems that may eventually arise. Another important point for problem-solving is the use of the problem analysis method (MASP) which aims to find the roots of the problem, attacking directly at the source of the problem.

Therefore, this article seeks to show the advantages that quality tools, especially CEP, can bring to an organization, considering that industries are increasingly seeking excellence in their processes, thus the study serves as a basis for other research that seeks ways to use these quality tools.

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