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ROOT CAUSE ANALYSIS FOR THE IMPROVEMENT OF THE PRODUCTION PROCESS IN A POLYMER COMPANY IN THE CITY OF SERTÃOZINHO

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Abstract: Production management is related to improving the manufacturing process. By mapping the main routines and operational flows, so that bottlenecks can be resolved. The objective of this analysis is to propose an improvement for the production chain by pointing out its variations between production elements, such as production time, maintenance and its frequency and the control of production data. The single case study method was used to highlight information, results and solutions with production management tools, such as production capacity calculations and root cause analysis (acr). This research contributes to the rational use of the company's resources in the production process, transforming it into best practices through the stratification of productive capacity and acr for mapping setbacks and productivity bulletins. This improves the predictability of daily and monthly production costs.
Keywords: production management; polymer industry; production capacity; root cause analysis.

INTRODUCTION

Industry has been constantly evolving since the Industrial Revolution. It began with mechanization and steam engines, and went through the era of mass production. Today, we have reached the age of automation and the *internet*, taking the first steps towards the age of robotics. But the production that will be covered in this work will be the production of polymers in a company in the interior of the state of São Paulo.

The production process consists of a system of creation or transformation (inputs + transformation process + outputs) of a product, the purpose of which is to meet human needs. Ribeiro and Silva (2021) describe that production management is related to process improvement through process mapping in the main operational routines. These authors point out that there are many bottlenecks in the process flow that need to be resolved in order to suggest improvements.

According to Moreira (2011), the industrial segment is generally considered to be a system that transforms raw materials into finished products, with added value for consumers; it is therefore characterized as a production system.

Therefore, the aim of this analysis is to propose an improvement to the production chain, focusing on the specialty of production management at Universo Termoplástico, pointing out the variations in production elements and explaining the importance of these elements (production time, maintenance and its frequency, and data control).

But how can this company's production performance be improved or increased by applying industrial method calculations and then applying the Root Cause Analysis (RCA) method?

The Single Case Study method (YIN, 2015) is used to highlight information, results and solutions using production management tools. By using industrial production calculations, capturing and analyzing data and the results obtained through data collection, it will be possible to analyze production capacity and its variations and, based on this, propose improvements to the deviations found.

The tool's Root *Cause Analysis* (RCA) is applied as a method of identifying and correcting the main factors that caused the problem. In this way, the original defects (root cause) are mapped as a problem rather than looking for immediate solutions to resolve a defect (ANDERSEN; FAGERHAUG, 2002).

THEORETICAL FRAMEWORK

Table 1 shows the concept of productive capacity as found in the literature.

Author	Contributions to the concept of productive capacity
Davis, Aquilano and Chase (2001)	Capacity planning specifies the level of capacity that will satisfy market demands cost-effectively, encompassing activities such as: forecasting sales for each product line and verifying the need for manpower and equipment to meet forecasts over the horizon planning.
Cox and Spencer (2002)	There are five production management functions (Master Production Schedule, Priority Planning, Capacity Planning, Priority Control and Capacity Control), so Capacity Control is the process of measuring production results and comparing them with capacity planning, determining whether the variation exceeds pre-established limits and taking corrective action to meet the planning if the limits have been exceeded targets.
Hayes *et al.* (2008)	There are factors that limit a company's production capacity, such as company policy, the reliability of suppliers and equipment, production rates and human factors. Therefore, these factors contribute to greater variability in the production process, hindering its measurement.
Slack, Chambers and Johnston (2009)	The main objectives of capacity planning and control are the correct decision making of productive performance in organizational capacity policies, such as: (1) the relationship between costs and the balance of capacity and demand, (2) the relationship between revenues and the balance of capacity and demand, (3) the decision to commit working capital to production capacity, (4) the consequences of capacity on the quality of products, (5) the speed of production, (6) the speed of production.
Antunes Junior *et al.* (2012)	Critical to production management is the analysis of capacity productive, which needs to be measured, understood and managed effectively.
Kaydos (2020)	Identifying the constraints and understanding the production system depends on knowing its real capacity, providing reasons to measure the company performance.

TABLE 1 - Literature contributions to the concept of productive capacity in operations management.

Source: based on Davis, Aquilano and Chase (2001), Cox and Spencer (2002), Hayes *et al.* (2008), Slack, Chambers and Johnston (2009), Antunes Junior *et al.* (2012) and Kaydos (2020).

METHODOLOGY

The quantitative methodology applied was the Single Case Study (YIN, 2015) to generate a body of evidence and solutions for production resources in order to improve their manufacturing performance:

1. Data on the production process over the course of a month was collected in three extractions of production capacity balances on the 1st, 15th and 30th to make up this sample.

2. The production management model on productive capacity based on Slack *et al.* (2009) was used and processed in spreadsheets in the 2016 version of Excel@. Three extracts of production capacity balances were generated, consisting of total installed capacity, total nominal capacity, total effective capacity and total realized capacity.

3. Based on the three extracts of production capacity balances, the ACR management tool described in English as RCA (ANDERSEN; FAGERHAUG, 2002) was applied.

CHARACTERIZATION OF THE POLYMER COMPANY FOR THE SINGLE CASE STUDY

The company is located in the city of Sertãozinho, in the state of São Paulo. It has been in business since 2018, has a single parent company and no subsidiaries, and focuses on the production and recovery of polymers used for the production of plastic packaging. Currently, all of its production is directed to a single customer in its supply chain. Its suppliers are located in the following (quantities) cities and (states) - (1) Uberlândia (Minas Gerais), (1) Uberaba (Minas Gerais), (2) Ribeirão Preto (São Paulo) and (1) Curitiba (Paraná). It comprises the production, shipping and receiving departments. Its human resources are outsourced and it has a team of 15 employees, distributed over two shifts, and its maximum production capacity per day is 15 tons.

RESULTS AND DISCUSSION

RESULTS

Initially, the industrial process, with its stages and activities, was surveyed as a way of facilitating the collection of production capacity data in production and operations management.

From a historical perspective, the polymer industry is part of the industrial sector and operates in the plastic packaging segment. As the conventional and regional market did not meet its needs, senior management decided to create a supplier to meet its demands and requirements and thus eliminate this bottleneck. Another important point was the establishment of objectives and targets for its strategic production planning.

Its objectives were defined through the flowchart, suppliers and understanding of the expansion from regional to national:

1. Make specific materials and reduce costs.

2. Having product quality that surpasses that of the conventional market.

Your goals have been aligned with your objectives:

a) Year 2020: produce 150 tons per month of specific materials.

b) Year 2021: produce 200 tons per month.

c) Year 2022: produce 245 tons per month.

d) Year 2023: has a pre-established target of producing 300 tons per month.

ROOT CAUSE ANALYSIS (RCA)

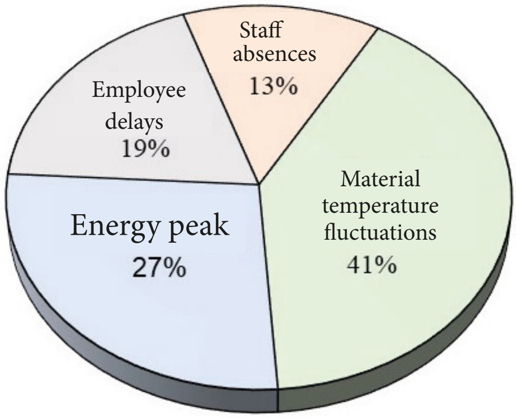
In the industrial production sector, where time is associated with profitability, all companies pay close attention to their time utilization. For this reason, many of them monitor their utilization in the most diverse ways possible; for example: daily, weekly and monthly production, the start and end of production for the day, maintenance schedules and maintenance carried out in a given period, employee absences and delays. With this data, it is possible to have a baseline of the production line's performance, but it can also be applied to sectors to assess their performance individually. But what about unforeseen events? This is no different; in other words, just as these methods are used to mitigate utilization, they are also used for waste and setbacks.

Graph 1, labeled "variations", represents some of the obstacles faced by Universo Termoplásticos. These problems will be addressed at this stage. Complementing what Uberoi. Gupta and Sibal (2004), the aim of RCA is to find out what happened, why it happened and what can be done to prevent the problem from recurring. Unlike addressing only the causes that contributed to the problem occurring or to the worsening of its impacts, RCA aims to discover the original cause of the problem, i.e. its root cause, characterized as that cause which, if it had not occurred, would have caused the problem occurred, the problem would not exist. Only by eliminating it through corrective action will it no longer occur and, consequently, be resolved once and for all.

The benefit of the effective application of an RCA is to significantly reduce the severity and rate of occurrence of undesirable events, but not limited to this, since its benefits cover improvement, in the case of a production line, in the capacity factor, reduction in the incidence of human errors, reduction in operation and maintenance costs, etc. (CHIU, 1990).

Graph 1 shows the variations that were identified in the month of September 2022. This involves five problems that affect production at some point. Graph 1 discusses how the variations in the survey of setbacks are formed.

VARIATIONS



GRAPH 1 - Survey of setbacks in the company.

Source: based on data collected from the company's production capacity (2022).

Of the variations reported, we identified which were due to internal and external factors (Chart 2):

Internal factors	Employee absences and delays: reduce the HHT statistic (Man Hours Worked) of the company.
	Material Temperature Oscillation: this is the company's bottleneck, because this problem causes the product to come out as scrap, making it necessary to reprocess it.
External Factor	Power surges: can cause damage to equipment.

TABLE 2 - Survey of internal and external factors.

Source: based on data collected from the company's production capacity (2022).

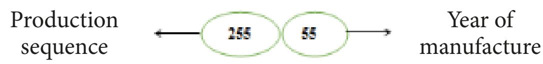
5W2H

The methodology used to deal with the ACR was the 5W2H tool created during the 1950s, and can be applied in various scenarios. After applying it through *brainstorming*, some conclusions were reached. By management decision, it was decided to resolve most of the situations internally and, if there is no improvement, external consultancy services will be outsourced in the coming periods.

DISCUSSION OF THE PROPOSAL'S INTERVENTION (COUNTERMEASURES)

Graph 2 shows the daily, fortnightly and monthly production data for September 2022. In the comparison below, it can be seen that there were differences in the productivity data.

On the 1st of the month, the black and blue multi-technique polymer products were produced, totaling 7,557 kilos, in two work shifts, with a production efficiency of 99%. The products are stored in *big bags* with a capacity of 800 kilos and controlled by batches to facilitate supplier traceability. The batches are identified by five numbers:



These were the batches produced that day:

- Polymer Black: 312/22, 319/22.
- Multitécnica Blue Polymer: 182/22, 277/22, 278/22, 289/22.

On the 15th day of the month, black and white polymer products were produced, totaling 9,841 kilos, in two work shifts, with an increase in productivity compared to the 1st. Its production efficiency was 98% on this day, when the following batches were produced:

- Polymer Black: 324/22, 331/22, 332/22, 335/22, 342/22, 344/22.
- White polymer: 290/22, 294/22, 296/22, 299/22, 303/22, 304/22, 307/22.

Of the three days analyzed, the highest productivity was on the last day - the 30th of the month - with a total of 10,083 kilos. The products were black and white polymers, produced in two shifts, with a production efficiency of 130%. The following batches were produced:

- Black polymer: 382/22.
- White polymer: 310/22, 314/22, 315/22, 316/22, 318/22, 321/22.

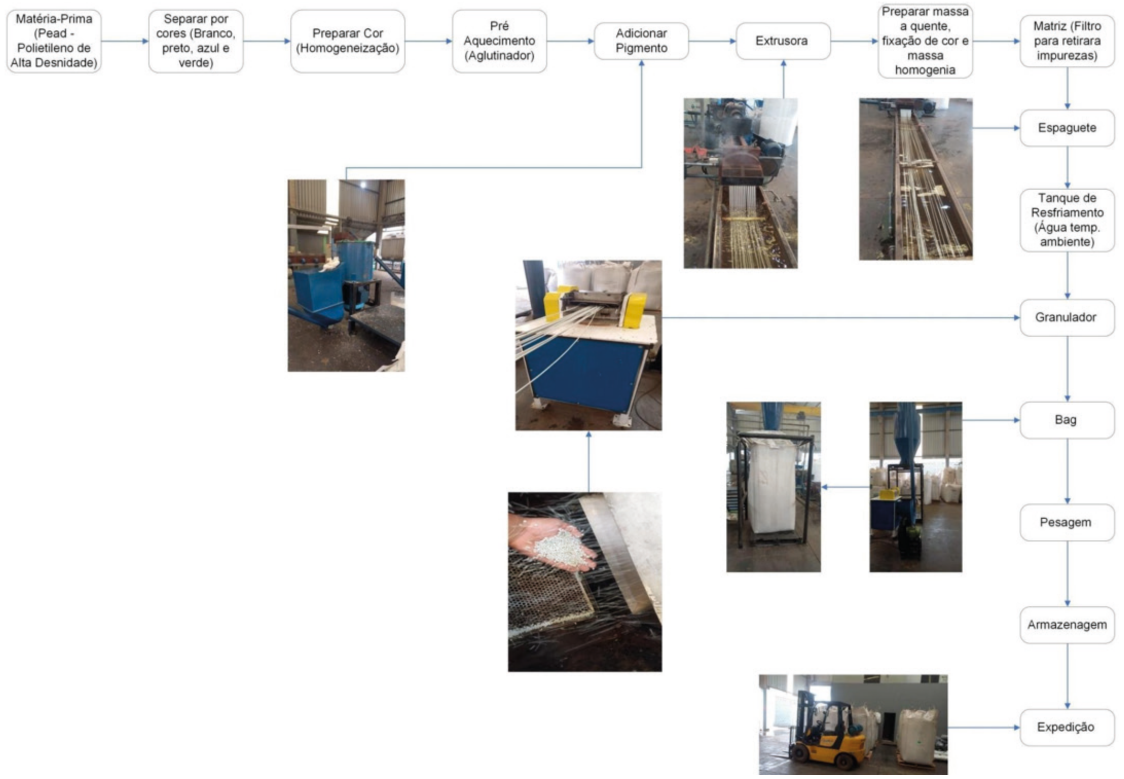


FIGURE 1 - Flowchart of the polymer industry's industrial process by stages and activities.

Source: based on company data (2022).

Increased yield on the polymer production line						
What? (***What***)	Who? (***Who***)	When? (***When***)	Where? (***Where***)	How? ***(How)***	Why? (***Why***)	How much? (***How much***)
Energy Variations	Industrial Management	2024	Industry	Capacitor Bank	Standardize the flow of energy	R$ 1.500.000,00
Material Temperature Oscillations	Industrial Control	2023	Industry	Temperature control (set limits acceptable)	Reduce the number of oscillations	R$ 0 Internally
Employee Absences/ Lateness	Human Resources / Management	2023	Company-wide	Creation of bonuses for employees who do not missing	Reduce the number of absences and delays	R$ 0 Internally
Employee Absences/ Lateness	Human Resources / Management	Dec/2022	Company-wide	Application of punitive measures for non justified	Reduce the number of absences and delays	R$ 0 Internally

TABLE 3 - Application of the 5W2H tool.

Source: based on data collected from the company's production capacity (2022).

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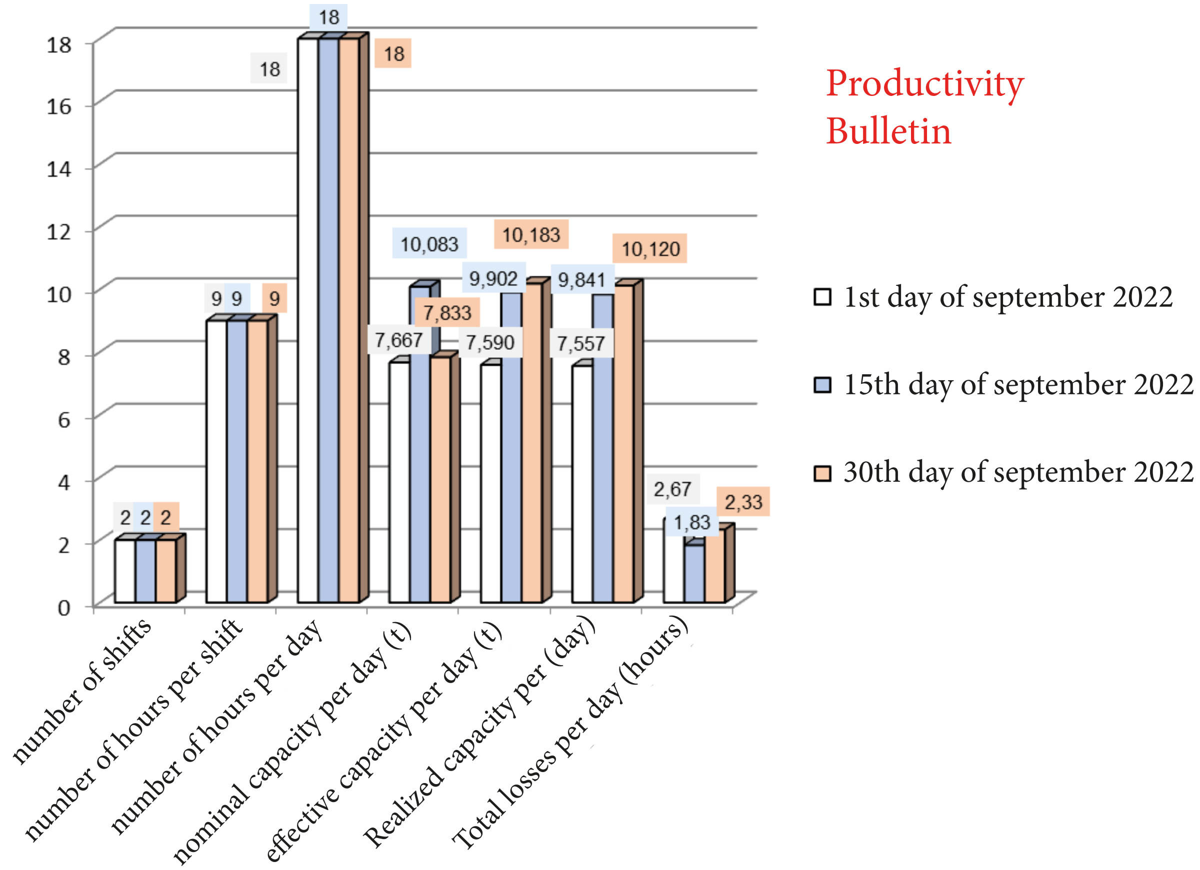
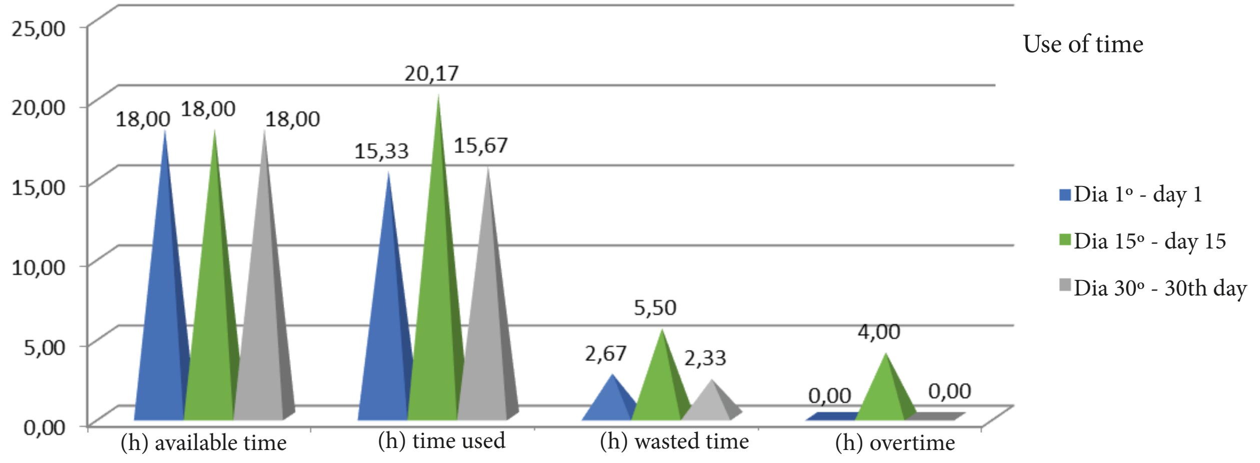


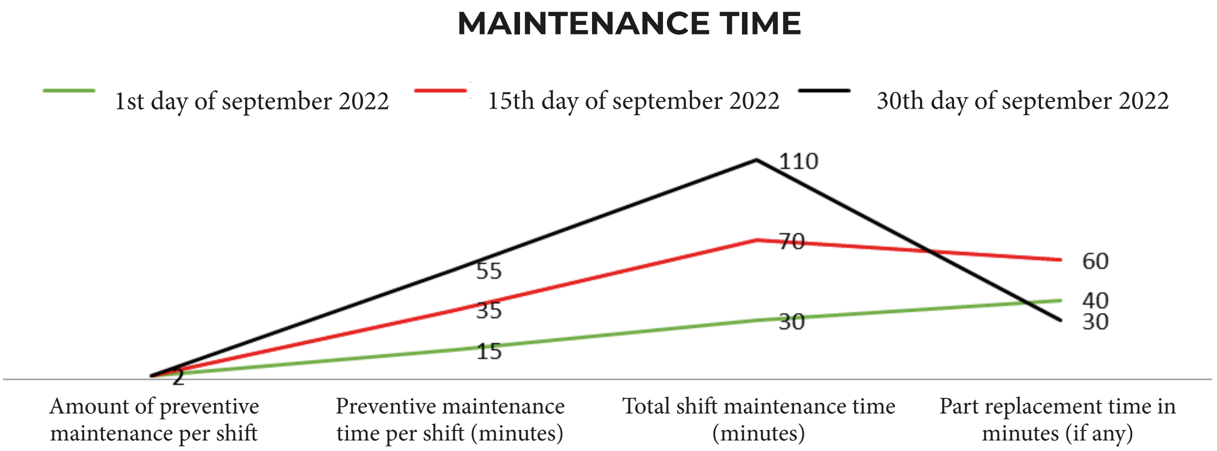
CHART 2 - The company's productivity record.

Source: based on data collected from the company's production capacity (2022).



GRAPH 2 - Use of company time.

Source: based on data collected from the company's production capacity (2022).



GRAPH 3 - Maintenance times at the Polymer Company.

Source: based on data collected from the company's production capacity (2022).

However, even though production and efficiency were higher than on the other two days, it was necessary to extend working hours by another four hours, as shown in Graph 3 of the company's time utilization analysis.

The data was interpreted as follows: available time represents the sum of shift hours, used time represents shift hours minus hours spent on maintenance and wasted time represents the number of hours spent on maintenance and overtime. This information is shown in Graph 4.

The company did not have a specific control or system for the maintenance area. As this limitation was identified, parts of this data were estimated to ensure a more attractive comparison. As previously reported, day 30 was the day with the highest maintenance costs, but with the shortest time to change parts.

FINAL CONSIDERATIONS

The aim of this research was achieved by stratifying the balances installed capacity, nominal capacity, effective capacity and realized capacity. In this way, it was possible to identify, through indicators, that the variation in setbacks is influenced by human resources and the need for new training for operational positions related to the jobs in the polymer production process. On the other hand, an external factor influenced production downtimes. This factor is linked to the outage and capacity of the external energy network that supplies the industry, which is an uncontrollable cost that impacts on this production process.

The contribution of this research highlights that the rational use of a company's resources in its production process can be transformed into best practices through the stratification of balances, which make up a company's productive capacity. After this process, it is essential to include analysis of the mapping of which aspects form your setbacks, productivity reports and maintenance times, in order to generate better predictability in production costs and improve the observation of time and its control in daily and monthly production.

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