

Analysis of the Production Capacity of a Packaging Machine in the Plastic Components Sector in a Company of the Manaus Industrial Complex

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Abstract— *The industrial scenario demonstrates a production dispute not only with other companies competing in the market, but competition within the organization in order to demonstrate excellence in the production process. Establishing a correct manufacturing goal will aid in production planning, determine concise objectives with actual plant capability, and ensure that outliers are identified in advance for the correct solution and application of efforts to improve the process. These steps will ensure the correct evaluation of the plant before other business units, as well as stipulation measures that are adopted so as not to impair the real perception of the process and to consider the indicators without any margins of disagreement. The production to be studied comes from the work of packaging plastic components performed by a machine divided into two stages of operation, first manual and manufactured and then automated packaging. The production data is improved by shifts of eight hours through those used and subsequently entered into the company's database. In these, statistical tools will be used, helping to better compose the data, where a qualified sample is sought for the study, which through the OEE - Overall Equipment Effectiveness indicator provided in this set, will measure the efficiency through the indices of availability, quality and productivity and whether the disposition of values and their representativeness within what has been established is practicable. The grouping of generated data demonstrates a condition expected by the production team, but that only through numerical results can be explained, a target based on the nominal capacity of the machine does not represent the current state of the process and becomes infeasible to achieve the normal conditions of production. Consider a value below what was previously stipulated, non-demonstration to be an erroneous strategy because of the history of the demonstration process and also because the calculations demonstrated are in accordance with the reality and production volumes achieved. Understanding a real productive capacity and working on concise numbers will allow accurate decision making.*

I. INTRODUCTION

Production targets established by companies do not represent the actual production capacity of machines. The determined values are based on the machine's nominal

value, the design capacity. As explained by [1], design capacity does not take into account losses during the process. Also, according to the authors, production capacity is the maximum amount of output of a good or service in a given period of time.

Planning the production capacity is an advantage for companies, as with the correct value set to achieve the results, it is possible to prepare for the demand, in addition to structuring project expenses and manufacturing inputs. The degrees and levels of capacity may vary depending on authors and different companies; however, the meaning of the content remains the same [1].

Statistical calculation, based on the global production indicator called OEE – Overall Equipment Efficiency, was used to study the equipment's production capacity. The OEE is an indicator that shows how efficient a factory is based on the assets installed in it [2].

As stated by [3], the overall efficiency of an equipment is established by the TPM as an indicator that continuously assesses the machine's production capacity to deliver what was theoretically calculated in the manufacturing design. The authors explain that the OEE can identify values and measure losses during the manufacturing process, which is divided into three (3) factors: availability, productivity and quality.

The OEE indicator uses simple methodological models and non-complex tools to stratify problems. With this, it seeks to achieve, in the short term, and gradually, improvements which should eventually become continuous and long-lasting. This reachability through indicators, which are fragmented for better understanding, also allows for an in-depth study in order to increase results [3].

As developed in the study by [4], it is essential to analyze alternative indicators to Overall Equipment Effectiveness (OEE). To complement and structure industrial management that is up to date with market demands, the form of application of OEE can be adapted to suit the context in which it will be used.

With the data and numbers related to the company's production in hand, it is possible to organize and conduct a statistical study. Statistics, as a science, comprises the studies based on the collection of data, understanding and analysis of this information to present the results of a group in an explanatory manner, to understand a general picture and observe the whole scenario.

Statistical studies support production capacity studies through the OEE. Statistics avoid presenting biased information, being able to study the whole from a set of data. Data is understood as a set of values, numerical or not. Through its models, statistics allow knowing determining factors for various events [5].

This article aims to study the production history of a company of the Manaus Industrial Complex (MIC), by comparing it with its current productivity, using mathematical principles to analyze the current production

capacity of a packaging machine in the plastic components sector.

II. MATERIAL AND METHODS

The company under study, part of the Manaus Industrial Complex (MIC) and consolidated worldwide, makes plastic components for packaging, distributed in the domestic and foreign markets. Increase in efficiency is an improvement pillar for the structure of this company. The sector to be studied is the production of final packaging for shipment to customers, whose process is divided into two parts: manual and automatic.

It is necessary to define goals that are tangible and achievable, according to the statistical reality and based on the study of the Overall Equipment Effectiveness (OEE) production indicator. Thus, these goals can be compared with the goals currently established, and it is possible to verify if they were achieved and are consistent with the values shown in this study.

A general data spreadsheet (Microsoft Excel® 2019, Redmond, WA, USA) extracted from production reports will be presented, and statistics will be used as a tool to obtain a correct average to represent the real status of the machine. Subsequently, these values will be compared with OEE values to analyze machine numbers and actual production by shifts.

The OEE metrics are shown through productivity, quality and availability equations. Multiplying the three factors results in the OEE value [6]:

Productivity equals good production divided by theoretical production:

$$P = GP \div \text{THEORP};$$

$$\text{THEORP} = OT * \text{PPM};$$

OT is the operation time and PPM stands for pieces per minute.

The calculation only considers the time the machine is running, discarding any machine downtimes, scheduled or not. The pieces per minute value is the machine standard, informed by the manufacturer and defined by process engineering.

Quality is calculated by dividing Good Production (GP) by Total Machine Output (TP).

$$Q = GP \div TP;$$

The calculation of availability takes into account all production times that are managed in production. Operation time (OT), Planned Operation Time (POT), which is calculated by discarding all scheduled machine downtimes.

Machine losses that directly affect availability are those that are unforeseen and require corrective maintenance actions [7]. Scheduled downtimes are those that involve planning and are previously scheduled so as

not to impact the production schedule, such as preventive maintenance, cleaning, machine lubrication, shutdowns due to high inventory.

The equation is defined as:

$$A = OT \div POT;$$

Thus, the OEE formula is:

$$OEE = P * Q * A$$

Due to the high number of shifts to be analyzed, statistical calculations with standard deviation can be used. This study will make it possible to use a model with reduced range, closer to the mean curve of the data set, centralizing the information for analysis. This enables the analysis to disregard cases that are exceptions, out of the ordinary, and unusual to the standard process, which do not contribute to the case study [8].

Standard deviation is a calculation made from the mean to observe how values vary in the dataset. It indicates what the average error will be, also understood as the deviation made when trying to replace each observation with the average [9].

Standard deviation helps to understand the dispersion of values in the dataset. By transforming its value into a unit, the number of factors that are grouped in a given region of the complete set can be visualized [10].

To have a more accurate measurement of the total data set, it is necessary to separate the sample into classes and limit the range to values closer to the mean. Class distribution makes it possible to study a sample and verify the reliability of the data, allowing to analyze representativeness according to the object of study [11].

As described by [10], when the raw data is defragmented and distributed into classes, some information is lost due to no longer being able to observe the individual characteristics of each value; however, compared to the gain in concise information and real representation, it is considered that this loss can be dismissed.

In a distribution into classes, data are divided into value ranges or intervals. A class is a line of frequency distribution, in which the difference between the lowest and highest observed value of variable X is called total amplitude ($AT = x_{\max} - x_{\min}$); the lowest value of the class is called the lower limit; and the highest value of the class is called upper limit [11].

III. RESULTS AND DISCUSSIONS

Table 1 shows a total of 1046 work shifts, in which each individual has a production value, with a standard time interval of eight work hours. Furthermore, there can be more than one productive shift per day. The Shifts/Day reference helps to check the number of shifts needed to reach the production average.

Table 1. Production values per shift

Years	Shifts	Days	Shifts /Day	Average production / shift (output)	Average production/day (output)
2018	345	149	2.3	32,106	69,018
2019	421	284	1.5	30,183	72,710
2020	280	106	2.6	32,436	82,129
Total	1,046	539	1.9	31,420	73,638

It was possible to verify that the values are historically below 40,000 units produced, which is the number set as the production target of the packaging machine. In 2020, to get to an average output per day that reached the goal, in this case, 80,000, as it involves two production shifts, it was necessary to work 23% more, with an average of 2.6 shifts per day.

Table 2, using standard deviation to limit the amplitude, obtained higher averages than the previous table. This is because this analysis excludes outliers, reducing the sample to 60% of the population.

Table 2. Production considering the standard deviation.

Year	Standard deviation	Production average in the standard deviation range ($\pm 1\sigma$)
2018	10,235	34,170
2019	8,475	30,823
2020	7,959	33,262
Total	9,017	32,434

Comparing the values shown in Tables 1 and 2, there is an increase in average output when using the standard deviation to limit the sample values. With the increase in average, it can be inferred that limiting the sample increases the production average, as it reduces the number of elements outside the production proportionality.

Table 3 presents the number of shifts and divides them into classes to check the region with the highest number of elements, in order to calculate the average that represents the production.

Table 3. Distribution of shifts into classes

Number of shifts				
Class/Year	2018	2019	2020	Period total

$x < 30K$	115	186	89	390
$30 \geq x < 35$	66	102	77	245
$35 \geq x < 40$	76	84	70	230
$x \geq 40k$	88	49	44	181
Total n. of shifts	345	421	280	1046

As can be seen, 46% of the shifts have values greater than 30k and less than or equal to 40k. The 40k machines target is reached in only 17% of the shifts, which represents 181 shifts out of 1046. In addition, 37% of the shifts have output of less than 30k.

Analyzing the high number of shifts that do not reach 30k of units made, it should be considered that the factory operation system has two shifts with reduced time every week, for general cleaning (5S program). Thus, production below 30k does not always represent machine failure; it may also be due to planned downtime. This shorter production time cannot impact the assessment indicators. Based on this information, one can choose to study the class that presents production values between 30k and 40k of units made, as the statistical values of this area are in closer agreement with the reality of machine output (Table 4).

Table 4. Average of units made in classes $30 \leq x < 40$ between 2018 and 2020.

Year	Average of units made between 30k and 40k
2018	35311
2019	34737
2019	35040
Total average	35003

It can be seen that the production averages using the separation by class have less variation than the other averages and sets of values. This represents a more uniform process, excluding shifts that were outside the normal process pattern.

The OEE will be calculated according to the averages of the shifts per year, and before the collection of the interval that was analyzed: shifts that produced more than 30k and less than 40k.

The values obtained from the total shifts in 2019 were 75.6% productivity, 99.8% quality and 85.2% availability. In 2020, 73.5% productivity, 99.9% quality and 89% availability. The analysis found an evolution in availability, which is a result of improvements and

machine failures that were fixed; in contrast, there was a decrease in productivity.

This can be explained by the increase in production time, process failures and micro-stops have become more frequent, directly impacting the productivity indicator.

Micro-stops (less than 10 minutes) are not included in lost time that affects availability. These micro-stops affect the productivity indicator. This is the beginning of the comparison of the OEE and the good production volume. Considering the range with output of more than 30k and less than 40k, we have:

- Operation time = 359 minutes
- Planned Production Time = 385 minutes
- Good production = 35040 products
- Total production (shavers) = 35076 products
- Theoretical production (shavers) = 47372

products

Considering these averages in a 480-minute shift:

Production loss (Planned Production - Good Production) is 12332 products; the machine downtime (Planned Production Time - Operation Time) is 26 minutes. These 12332 shavers represent, in terms of time, 132 parts per minute produced by the machine; dividing these numbers 12332/132, the result is 93 minutes.

During the shift, the work process has 93 minutes of micro-stops; this represents the losses and downtime inherent to the process, and which do not directly affect availability, but rather productivity.

Considering the target of producing 40,000 products, and the Theoretical Production Average, the machine will have a loss of 7372 shavers, which represents 55 minutes.

Calculations proved that the nominal target does not represent the actual machine operation process, as the number of shifts that reached the target is 17%, which does not represent even half of the total shifts. The total average is that of 2020 compared to the nominal target, with a difference of almost 8 thousand, that is, 1/3 of the achieved value. It would take 33% more productivity to reach the goal; analyzing the machine history, this number cannot be reached.

The average between 30k and 40k represents the process better, due to the characteristics of the machines and the statistic calculation as well. As stated by [9], the choice of intervals is arbitrary and the researcher's familiarity with the data is what will suggest how many and which classes (intervals) should be used. However, it

should be noted that a low number of classes can mean loss of information, and with a high number of classes, the objective of summarizing data is impaired.

Based on the OEE, and simulating a production shift, 55 minutes is the maximum time of micro-stops to meet the real production volume target equal to 40000. This value assumes that quality and availability will be 100%, which represents 79% of productivity and, consequently, of the overall equipment effectiveness.

The time for loading the raw material into the machine, calculated based on the averages, and taking into account good working conditions, will be at least 28 minutes, as in a shift that has good output numbers, the plastic packages are refilled four times. If the machine is in good working order, it will take 30 minutes to adjust it. Just the time for reloading and adjusting the raw materials already reaches the maximum downtime minutes to reach the established target.

According to [4], it is of paramount importance to concatenate the numerical values with the interpretation of OEE data. These values must be considered by management in order to understand the real production scenario.

The analysis of the volume production history and the packaging production process was shown. The calculation, reducing the number of shifts to the total average, considering shifts that produced more than 30k and less than 40k, results in a new average: 35k.

IV. CONCLUSION

Considering the overall process, the number of 35,000 was proven to be the actual and current capacity of the packaging machine. To gain efficiency and, consequently, increase productivity, it is necessary to tackle problems and improve the engineering of the packaging machine, enabling it to work with lower loss values. Stipulating 40,000 as a production target is not consistent with the real numbers, as it is reached few times, which causes frustration and poor representation of productivity.

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