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A Methodological Approach to Estimating Production Times in Engineer-to-Order Industry

Uma Abordagem Metodológica para Estimativa de Tempos de Produção na Indústria Engineer-to-Order

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ABSTRACT

The ETO production environment (Engineer to Order) is characterized primarily by customer interaction level since the product design. Another attribute of this is the high level of customization of products, a fact that directly reflects the organization of production. The study aims to analyze the estimation method of production time in an industry with ETO environment. For this was found in the literature, bibliographies and studies that guide the process of estimating production times, observing the practices that most resemble the company's focus of work. Finally, the data collection was carried out, focusing on the comparison between the Predicted Time and Realized production, starting this analysis found the effectiveness of the applied process. Thus, it was found that method adopted in the focus of the work company achieved convincing and favorable results.

Keywords: Production Times. ETO Industry. Method Validation.

RESUMO

O ambiente de produção ETO (Engineer to Order) é caracterizado principalmente pelo nível de interação com o cliente desde a concepção do produto. Outro atributo disso é o alto nível de customização dos produtos, fato que reflete diretamente na organização da produção. O estudo tem como objetivo analisar o método de estimativa do tempo de produção em uma indústria com ambiente ETO. Para isso, foram encontrados na literatura, bibliografias e estudos que orientam o processo de estimativa de tempos de produção, observando as práticas que mais se assemelham ao foco de trabalho da empresa. Por fim, foi realizada a coleta de dados, com foco na comparação entre o Tempo Previsto e a Produção Realizada. Iniciando esta análise, verificou-se a eficácia do processo aplicado. Assim, constatou-se que o método adotado no foco da empresa de trabalho obteve resultados convincentes e favoráveis.

Palavras-Chave: Tempos de Produção. Indústria ETO. Método de Validação.

1 INTRODUCTION

In a production environment with high variability of products surrounded by an even greater range of production processes, it can be said that there is a difficulty in establishing a reliable method of estimating production times. The project is the presentation of this method developed in an industry in the metal-mechanic sector in the north of Porto Alegre, which has the ETO (Engineer to Order) system as a characteristic of its production environment.

In an organization with an ETO production model, the level of process standardization is very low and the products that enter the production system have a high level of variability. In the ETO environment, the stages of design, product engineering and production are carried out on demand, that is, with the customer's guidance (Rocha; Scavarda; Hamacher, 2005; Americo; Costa, 2019). In this environment, the client, in most cases, follows the definitions of the product design being offered, the production process that will be adopted to manufacture it and the deadline for delivery of the completed work.

Because it is an environment with a high rate of product variability, where processes need to adapt to production, it is necessary to find ways to seek patterns to facilitate and organize the different information that changes according to the changes in products entering the factory environment. It is extremely important that an organization seeks alternatives to standardize and organize its processes.

In the studied company, some ways of standardizing the production process are observed. An example is the organization of the layout, which varies according to the characteristics of each productive sector of the company, in this case, the organization divides its production into four productive sectors, they are: Preparation, focus sector that will have its process of estimating production times analyzed, in which it adopts the layout by process, Boilermaking and Final Assembly with positional layout and the Painting sector with mixed layout (by process and positional). Another important issue to standardize the production process is the definition of a production script for each piece and for each set, thus creating a standard flow of information regardless of the type, size, time and process in which the product is entering the manufacturing process own.

Several studies have been developed in recent years. To illustrate this, we highlight the work of Silva et al. (2024), where the authors analyze how improving production efficiency through pull-based systems from Lean manufacturing (such as TPS) aims to optimize production and reduce waste. In this context, the topic of customization versus standardization is also discussed: the research leans towards standardization (Lean, TPS), where the goal is to streamline processes and reduce waste. Even in a customized environment, Lean principles, such as waste reduction and continuous improvement, can be adapted to improve production time accuracy. Thus, tools and methods are studied in broader production system approaches, such as Kaizen, JIT, and VSM, within the same research.

In this regard, the process of determining standard operating time in an ETO environment becomes a complex factor, but it can become a competitive advantage in relation to competitors working in the same production environment if executed well. To cover the various parts and assemblies that enter the factory environment of the studied company, the determination of standard operating time is based on the chronoanalysis process, which was applied to characteristics that could change production times, such as thickness, area, weight, number of holes, set size, number of operators involved, among others. The production time estimation model developed at the company will be presented in this project.

The study is focused on solving the proposed research problem with the following question: Is it possible to develop a method for estimating production times in an industry with an ETO environment?

In this sense, the methodology applied in the research will take place through a case study focused on data collection, analysis and identification of the variables that guide the General Objective which is defined as: Analyze the method of estimating production times, adopted in a industry with an ETO environment, in the north of Porto Alegre. In order to explain it, the items described in the Specific Objectives were unfolded, (i) demonstrate how the method of estimating production times is performed in the equipment of the Preparation sector of the target company; (ii) verify the effectiveness of the method and present the results obtained; (iii) propose improvements to the time estimation process at the company in question.

2 PRODUCTION ENVIRONMENT ENGINEER TO ORDER

The main way to differentiate a production environment is according to the way in which customers interact with the final product (Pires, 2004). There are basically four production environments: Make to stock (MTS) - production to stock, Assembly to order (ATO) - assembly to order, Make to order - production to order and Engineer to order (ETO) - design (engineering) and production on request.

The production environment explained in this research is (ETO). In this model of production environment the customer orders the development and possible changes in the product, that is, the products are produced according to the requests and specifications passed by the customer. In this system the products are usually unique, therefore, because they have never been produced and their processes are not mapped, there is often no history of production on these (Stefanelli, 2010).

The industries that work to order, have specific characteristics, in which they have a direct influence on management, which are: (i) long Lead Time, from the moment of the development of the commercial proposal until the final assembly; (ii) risk and costs linked to each contract signed, starting with the development of the proposal; (iii) accounting and finance focused on contracts (Saia, 2009).

The ETO system can cause some interference in the factory and in the progress of programming activities, since the production system of a company focused on ETO products presents a high degree of uncertainty, in view of the high degree of customer interference during the development of the product, while the factory needs to anticipate information on capacity allocation and product specifications to purchase raw material. In addition, the construction site has a number of players that can affect the previously established construction sequence (Da Silva Etges; Viana; Formoso, 2014; Gallo et al., 2021). In this sense, an understanding of the logistical process is essential to assess the alignment between the production of components by the factory and its assembly at the construction site (Silva et al., 2019).

An ETO product is often innovative solutions making it a unique prototype, but because it is a totally new project, the overlapping of the organization's sectors can generate instabilities. An example is the raw material purchase process without the engineering stage having been completed, another factor is that as production evolves, there may be a need for engineering changes, thereby generating new needs for purchase of materials and changes in the production schedule (Saia, 2009).

Another issue that should be highlighted is the stock levels present in this environment. As the variety of products that can be requested by the customer is very large, most organizations decide that they cannot store anything, that is, they wait for the order to enter and only after that trigger the purchase of the necessary inputs for production. Because of this, an industry that relies on the ETO environment cannot rely on strategic stocks, at any level in its production system, so it needs to learn to react and monitor all market variability, so that its sectors can be supplied to meet the demands of these (Correa; Gianesi; Caon, 2001; de Brito Nogueira et al., 2023)

2.1 VARIETY OF PRODUCTS IN THE ENGINEER TO ORDER ENVIRONMENT

Industries with an ETO environment have the characteristic of customizing their products, so that their project is personalized and customer oriented.

The great variety, present in this production environment, generally impacts products that have both the production sequence and their cycle times with a high degree of difference, in which they use the same productive environment (Stefanelli, 2010).

Regarding the volume-variety ratio, it describes the types of processes in manufacturing operations, where each type of process results in a different way of organizing operations activities. Relating to the company that is the focus of this project, the concept that best fits is the Project Processes: in this the manufacturing process deals with very customized projects, where the period of time to make the product is very long (Slack, 2006).

Another factor, takes into account that at the time of the definitions in the product design, if poorly defined or with some uncertainty, the consequence of this can be changes during the production process itself. In this process the work has well-defined start and finish activities and depending on the physical structure of the product, the resources that will perform this task must be organized in a special way for each case. Operations with a high variety of products that generate low volume, will have more demanding consumers with regard to processes, than operations that provide serial products and standards (Slack, 2006).

2.2 ALTERNATIVES FOR MANAGING THE IMPACT OF VARIETY OF PRODUCTS ON PRODUCTION

Operations look for alternatives that make the cost of producing a high variety viable by standardizing their products, services and processes (Amaral et al., 2018). The standardization of an operation helps to reduce the complexity of the products. Some alternatives can be verified to manage the impact caused by the variety of products in the production (Slack, 2006).

Basically, the physical arrangement of a productive area defines the location of the transformation resources within the available physical space. The adequate disposition of these resources directly influences the flow of materials and people and affects the overall efficiency of production. The definition and adjustment of the type of physical arrangement starts from the type of process and this is the characteristic of volume-variety (Slack, 2006).

The layout is one of the main decisions that will determine the efficiency of the organization in the long run, if it is effective it can become a competitive advantage in relation to competitors, for this the layout needs to be designed in a way that meets the company's competitive requirements. They argue that in any situation the definition and organization of the layout should seek to define the following requirements: (i) greater use of space, equipment and people; (ii) better flow of information, materials or people; (iii) better employee morale and safer working conditions; (iv) better interaction with consumers and customers; (v) flexibility (whatever the current layout will need to be modified) (Slack, 2006).

The project's focus company divides its production into four macro productive sectors: Preparation, Boilermaking, Painting and Final Assembly, the order is in accordance with the sequence of the production flow. The sectors organize their production using basically two types of physical arrangement, so these were considered for the realization of the project.

The Painting sector uses two types of physical arrangement: physical arrangement by process and physical positional arrangement. In the area where the line painting process is carried out, where the pieces move to the painting area, it adopts the physical arrangement by process. For large sets, where it uses a stationary painting booth, the physical arrangement adopted is the positional one. Another alternative, present in the project's focus company, to manage the impact caused by the variety of products is the Production Roadmap. This tool assists in guiding the flow and sequencing of production, it distributes the operations inherent in the process, for the manufacture of a certain item, in the various work centers arranged in the factory environment.

The production roadmap for a product describes the necessary sequence of operations to produce a particular part or component. The roadmap sheet highlights the entry for each operation that must be performed on the item being produced. Another important factor present in the production script is the raw material needed for product transformation (Slack, 2006).

The production script is the path that the material takes along its production process, in them are present the necessary operations to carry out the task, its sequencing and other very relevant factor and the presence of the task execution time. Therefore, the production script is a document generated for each component and each set specifying which operations must be carried out, in which order and which resources will be responsible for them, this document accompanies the raw material until the final product ready for dispatch. All of this information creates a workflow, organizing and ordering the entire “mix” of products that enter the factory, from this it becomes a tool to manage the impact of the variety of products on the factory environment (Slack, 2006).

2.3 ESTIMATED PRODUCTION TIMES IN AN ENGINEER TO ORDER ENVIRONMENT

Due to the high diversity of products in an ETO environment, it is difficult to have extremely precise standard times for operations. When receiving the order under order, the script should be detailed, including the expected operating times to carry out its work. Depending on the product and even its production volume, the estimation of production times can be performed through the analysis of similar products previously produced, in this process, you must have your production times accomplished, filed in a database, with this, the comparison stage becomes more secure and organized (Stefanelli, 2010).

The study of times and movements can be used to determine the standard operating time in a time estimation process. Through it it is possible to determine the time that a qualified and properly trained person uses to perform a certain task, working and normal conditions. The most common process used to measure an operator's work is timing. The operation to be studied is divided into elements and each of these elements is timed. A representative value is calculated for each element and the addition of the elementary times provides the total time for the execution of the operation. The speed used by the operator during the timing is evaluated by the observer and the selected time can be adjusted so that a qualified operator, working at a normal pace, can easily perform the work in the specified time. This set time is called the normal time. Tolerances for personal needs, fatigue and waiting are added to the normal time, thus resulting in the standard time for operation (Stefanelli, 2010).

The study of times serves to determine the standard costs of the products, this information is very important for the elaboration of the budget of sale of the product having a safe commercial proposal with respect to the cost of labor involved in the product being offered to the client. The person performing the time estimation must know the requirements necessary to carry out a reliable study such as, understand and know the production process, know how to handle and use time tables and graphs well. The measure delivered in an estimate of production times usually takes place in hour / man or hour / machine, so the cost department multiplies this data by its unit costs (Stefanelli, 2010).

This further reinforces that the longer the time spent to perform the estimate, the more accurate the result of the analysis will be, however the person responsible for the analysis must determine an optimal time for the study to take into account the final application of his work, that is, , an estimate for high volume production must be extremely accurate, while an estimate for determining a manufacturing device production time, for example, can be roughly performed.

There are two methods of estimating production times: (i) estimation by comparison; and (ii) detailed estimate. The comparison estimation method uses similar products as a basis on which its production time is already known, in which case it is up to the person responsible for the analysis to carry out weightings on similar characteristics, thereby resulting in an increase or decrease in time and, consequently, in the cost of the product. . In an industry with an ETO production environment, the products supplied by it usually have a high range of components, so in most cases an estimate is required, some of the components that make up the new product have already been produced in the past and has its production costs stored in a database. This results in an agile and reliable estimate, considering that only a small part of the product will need a more elaborate estimate (Stefanelli, 2010).

In the company that is the focus of this project, the project is to use the method of estimation by comparison in the sectors that are responsible for the aggregation of parts to form a component set of a final product, these sectors are the Boiler and Final Assembly. The detailed estimation method seeks to more accurately verify the production costs of a given product, but because it is a process with a high degree of criticality, it needs some information such as: drawings, material list, adopted process, batch of manufacturing, etc. This process can result, for example, in the delivery of the total amount of hour / man required to manufacture a given product in a given sector.

As in an industry with an ETO production environment, the data collection process, due to the high variety of products, is very complex. In order to carry out a process to estimate production times, the sequence of activities and product characteristics can make it easier to carry out the analysis. These sequences can be described as: (i) carrying out the collection of processing times for some products; (ii) definition of the variables of these products that interfere with processing times (such as thickness, weight, length, for example); (iii) elaboration of a mathematical formula that lists the product variables whose processing times have not been collected; and (iv) checking the variation between processing times calculated by the defined formula and measured in the process in order to verify the formula's margin of error (Stefanelli, 2010).

3 METHODOLOGICAL CHOICES

The present research was carried out through an exploratory case study, in the company TMSA - Tecnologia em Movimentação. SA. Case study is a method in which it allows the researcher to retain characteristics of organizational and administrative processes. Unlike other research methods, the case study is not intended to demonstrate specific characteristics on a subject, but rather, a global view of the problem and to show the factors that influence or are influenced by it (Gil, 2018).

The data collection process took place through spontaneous observation, in which the researcher, remaining unaware of the community, group or situation he intends to study, observes the facts that occur there. It is suitable for exploratory studies, as it favors the approach of the researcher as the researched phenomenon (Gil, 2018).

As this is a case study, all data collected during the process are analyzed and interpreted in parallel with its collection. In this way, the analysis starts from the first observation record, with that the information ends up being processed and compared in real time, thus becoming a useful tool for the researcher (Gil, 2018).

The case study was applied at TMSA - Tecnologia em Movimentação. SA. Located in the north of Porto Alegre, capital of the state of Rio Grande do Sul, the company founded in 1966 has approximately 600 employees. The organization is an industry in the metal-mechanical sector, characterized by being one of the main suppliers in MERCOSUR of equipment for port terminals and handling of solid bulk in high capacities and long distances.

TMSA has a very diversified participation in several market segments such as: Port Terminals; Mining; Energy; Coal; Fertilizers; Sugar; Agribusiness. Due to its high supply line, combined with the high level of customization of its projects and products, TMSA fits its production environment as the ETO (Engineer to Order). Through this production method it provides customized solutions, oriented and according to the requirements of its customers.

The first stage of the work was the realization of the present project, using a bibliographic search based on articles, books and websites in which the relevant subjects of the work guide. This bibliographic search based on the keywords: Production times; ETO Industry; Method Validation.

The second stage of the work will be the identification and analysis of the method of estimating production times adopted in the Preparation sector of the focus company. The sector has ten workstations, each with specific characteristics for determining operating times. The characteristics and necessary information will be investigated in the work.

The third stage involves the validation of the method using the timing process, in the main Workstations in the Preparation sector. The timed time at the Workstation can be compared with the standard forecasted time available in the database spreadsheet. At this stage of the work, based on the analysis described above, the method of estimating production times can be validated.

As a form of evidence, graphs and tables comparing Estimated Time (database) and Realized Time (timed) will be used. For this, with regard to the display of data, the matrices are arrangements made up of columns and rows that quickly enable the comparison between the data (Gil, 2018).

4 RESULTS AND DISCUSSION

The Preparation sector of the company that focuses on the work, has the function of manufacturing parts for the other productive sectors of the company. This organizes your production using the process layout.

Each process, with similar characteristics, is divided into ten Workstations. Their assignments can be seen below, in Table 1.

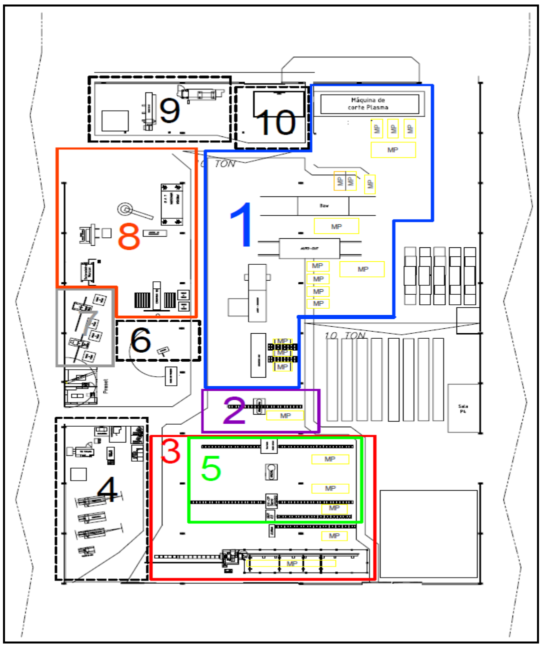
Table 1 – Assignments per Workstation of the Preparation sector

Stations	Stations attributions
P1	Thermal and mechanical cutting of the plates.
P2	Cutting and stamping of profiles from punching.
P3	Cut, mechanical and punctured, profiled.
P4	Turning, milling, drilling and threading of light parts and equipment.
P5	Drilling, countersinking and cutting of plates and profiles.
P6	Bending and bending operation of sheets, profiles and tubes.
P7	Stamping operation by eccentric presses.
P8	Bending and shaping of plates by turning machines.
P9	Turning operation of heavy equipment and parts.
P10	Machining operation (milling and threading) by machining center.

Source: research data

For better understanding, the sector's Workstations have been numbered, according to the floor plan layout shown in figure 1. It is worth noting that Workstations 4, 6, 9 and 10 appear dotted in the layout because they are in the process of development the timing and consequently the determination of their productive times, not being objects of the data collection.

Figure 1 – TMSA Preparation Sector Plant



Source: TMSA – Tecnologia em Movimentação SA.

The data collection process took place at Workstations 1, 2, 3, 5, 6, 7 and 8, which were sampled for verification the quantity of approximately ten Production Orders, with items (pieces) and various lots. The intention of using a random sample related to the quantities of parts and batches of the Production Order is to seek the high production variability existing in the sector, which reinforces the presence of the ETO production environment in the organization.

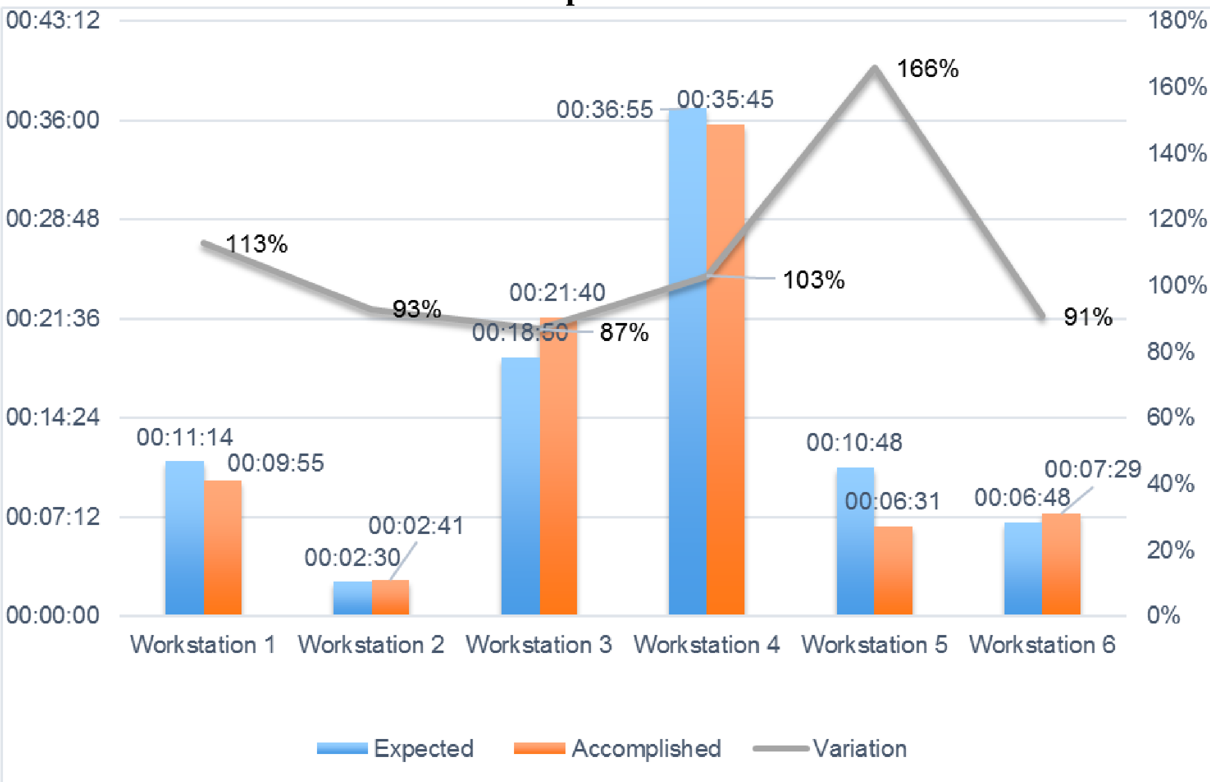
In each workstation, the most common process was used to assess the time taken for the task. To determine the expected operating time, the Manufacturing Timesheet was adopted, available in the company's system directory. This tool uses the main characteristics of the Workstations as a basis for preparing the times, which directly influence the operating time. After the survey of the Realized Time data - defined by timing - and Estimated Time - calculated by the Manufacturing Timesheet available in the company's database - these will be presented and analyzed through the comparative tables and graphs.

In order to highlight the data collection process, comparative tables and graphs were created for the analysis. These bring the Estimated Time, generated by the Manufacturing

Timesheet. Another data evidenced is the Realized Time, generated by the timing process. Each Workstation analyzed generated a table and a graph describing the comparison between the times.

After having the data analysis process completed, as a means of verification, it was created and is presented below, in Figure 2. This establishes the consolidation of all times (Expected and Accomplished) raised and analyzed in the study.

Figure 2 – Time Consolidation Chart - Workstations Preparation.



Source: research data

When analyzing the chart, a reliability pattern in the Estimated Time stands out in most of the Workstations, however Workstations 3 and 7, still have small divergences when considering their times, which was reported as an opportunity for improvement in the method.

4.1 PROPOSED IMPROVEMENTS FOR THE METHOD OF ESTIMATING PRODUCTION TIMES

Among the improvements applied to adapt the method to the ETO production environment, present in the sector, the update in the way of measuring the setup time at Work Station 1, responsible for the thermal cutting process, stands out. Previously, early in the development of the method, each piece sent to Workstation 1, counted a setup time of 14 minutes, this time generated by the timing process. This factor started to distort the Estimated Time in relation to the Realized Time of setup.

Based on this problem, a process was developed to improve the accuracy in the Estimated Time of setup. Basically, the update had as a formula the direct weighting of the part area with the raw material area (plate), used for the thermal cutting process. As it is a relatively new method in the organization, it is still undergoing expansion and development. From the progress of data collection for the project, it was possible to see a series of opportunities for improvements to the proposed production time estimation method.

To this end, the following opportunities stand out: (i) to define a method to estimate the time for moving parts in Workstations P2, P3 and P7; (ii) to create a factor of aggregation of productive time for activities that involve more than one operator at Work Station 8, with this the guarantee of the hourly / man data in the resources of this station will become more reliable; (iii) to develop a method of Estimation by Comparison for the sectors of Boilermaking and Final Assembly; (iv) to develop the Detailed Estimation method for the Painting sector; (v) to use the production hours to measure the Estimated Time of operation.

5 FINAL CONSIDERATIONS

This study addressed the method of estimating production times adopted in an industry with the ETO production environment. A process of extreme complexity, due to the high rate of customization of products combined with the high variability of production existing in this production system.

The method was analyzed in the Preparation sector of the target company, from there the detailed estimation process was evidenced in the data collection. In it, it was possible to observe that characteristics that directly influence the time of operation, such as thickness, dimensions, area, amount of drilling, height, etc., are the basis for the development of the result of the Predicted Times in all analyzed Workstations of the sector, where each of them uses characteristics inherent to their processes to determine the most suitable standard operating time.

From the data analysis, the effectiveness of the method was verified. It is worth mentioning that some Workstations need to have their method of estimating production times more refined, as highlighted in figure 21, which brings the consolidation of the Estimated Time in relation to the Time Realized in all Workstations.

The study also brought opportunities for improvement in the method, topic directly addressed in the specific objectives of this paper. This fact proved to be extremely important for the development, expansion and maintenance of the process. From it, the critical points are highlighted and defined as a priority for future actions.

The limitation of this work was to deal with the great variability of production existing in the TMSA factory environment. Due to this, sometimes idle resources in Workstations, made data collection impossible. On the other hand, depending on the production mix present in the manufacturing environment, the large number of parts hindered the timing process in bottleneck resources. In this sense, the great challenge of the work was to find ideal gaps for the safe performance of data collection.

For future work, it is suggested that the sectors that remained as an opportunity for improvement to create the method of estimating production times, Boilermaking, Painting and Final Assembly, be analyzed and validated. With this, all the productive sectors of the company that is the focus of the study will have their methods defined and validated.

Another suggestion is, from the determination of the Estimated Times for the other sectors, to monitor a product, checking its production times in all the productive sectors of the organization.

It can be concluded that the study met the proposed research problem. Yes, it is possible to develop a method of estimating production times in an industry with an ETO environment. For this, it is important to develop factors that allow working with the great variability of products and the unpredictability of production existing in this environment. The clear knowledge of the various products, the adjustment of an appropriate and specific physical layout for each process involved, the understanding of the physical characteristics of the products that directly influence their production times, combined with a reliable chronoanalysis process, thus bringing confidence for determination from a detailed estimate, you can determine an extremely reliable production times estimate.

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1) concepção e planejamento.	X				
2) análise e interpretação dos dados.	X	X	X		X
3) elaboração do rascunho ou na revisão crítica do conteúdo.	X	X	X		X
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