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PROCESS APPLICATION OF THE RESTRICTIONS THEORY IN A FURNITURE INDUSTRY: A Case Study in the West Region of Santa Catarina, Brazil

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ABSTRACT

The study aims at the application of the theory of reasoning process of the restrictions in a furniture industry located in the west of the State of Santa Catarina, to identify the constraints of productive machining process. Initially identified the flowchart of the machining process, then the runtime of activities and problems related to production stoppages. It was observed among the 15 steps of the process that the main restriction is the capacity of the machines. Overall, the results show that through the restrictions theory is possible to identify bottlenecks and guide the correction of restrictions.

Keywords: *Restrictions theory. RT. Productive process. Furniture process*

1 INTRODUCTION

The consumer market and technological advances have required companies a continuous and constant process of evolution, in order to stay in front of market scenario, such survival considers the quality assurance of products manufactured or marketed and offer competitive prices to face competition. In this context of competitiveness of the requirements for the survival of businesses respect to the management of its resources and activities developed in order to cope with the changes in the market and ensure the economic and financial profitability of these entities. (KRUGER, et al., 2012).

One of the possibilities of business management, on issues that affect the structure and organizational processes to address the constraints that impede economic and financial performance of companies is the Restrictions Theory (RT). As a tool that can be used in the identification, analysis and solution of problems affecting the development of enterprises and the achievement of its goals (COGAN, 2007).

The Restrictions Theory originated in the late 1970s, being created by Eliyahu Goldratt physical, in order to reduce the production costs and optimize the use of production capacity. In this sense studies and subsequent research indicates that a major goal of the theory of constraints is to identify bottlenecks in the production process (Noreen, SMITH, MACKEY, 1996).

Goldratt and Cox (2002) emphasize the importance of identifying constraints and bottlenecks in the production process, to ensure from the controls on each stage of development of production processes, identify and exploit existing restrictions on companies. The Restrictions Theory becomes a difference for the solution of every problem related to the organization's operating processes, contributing as a tool to support organizational management.

According to Cogan (2007, p. 156) "reasoning processes can be used separately or together, depending on what you want to achieve. In the case of larger scope of problems, they should be used together. We want then to answer three questions: What change? Change for what? How do I change? "In this regard, previous studies such as Alves et al. (2011); Acerda, Rodrigues and Corcini Neto (2011); Kruger et al. (2012);Silberman et al. (2012); show the importance of using the theory of constraints in the business environment as a support tool for the management process, the various business segments.

In this context, the study aims at applying the theory of reasoning process of the restrictions in the machining industry in a furniture industry in order to improve their business competitiveness through the use of one of the techniques used by the management of production, ie, the application of the Restrictions Theory. In this sense, the study aims to answer the following issues: What are the main constraints existing in the machining process of a company in the furniture industry? In order to meet the objective of identifying restrictions in the machining industry in a furniture industry located in the western state of Santa Catarina.

The study is justified by the importance of the furniture industry in the western region of Santa Catarina, both in generating jobs and income, and for regional development. And justifies the importance of studying for companies in this segment, serving as a model for the application of the restrictions theory on companies in this business segment.

The research is organized into five sections, including this introduction, it is contemplated in section 2 the literature review, addressing the application of the restrictions theory and its importance in solving organizational problems. Section 3 discusses the methodology and stages of applied research; Section 4 presents the results of the survey, the survey of the machining process flow diagram, process time and the restrictions identified production. Finally, in section 5 the final considerations about the survey and the results observed.

2 LITERATURE REVIEW

This topic covers the key concepts and the context of the application of restrictions theory facing production costs as well as related studies that contribute to the theme of study.

2.1 Concepts and context of the Restrictions Theory - RT

The Restrictions Theory originated in the late 70's, it was created by the physicist Eliyahu M. Goldratt Israeli, when he developed a software for production planning of a cage factory for birds, this allowed a huge increase in production without increasing costs. (Noreen, SMITH, MACKEY, 1996).

The software developed by Goldratt gave OPT *(Optimized Production Technology)*, namely the optimum production technology. As Tubino (2000), the software in the 80s had penetration in Europe and the United States of America, but in Brazil has not had the same luck. However the issues raised by this software with respect to programming in a production system was structured a set of concepts known as "restrictions theory" that is based on the principle of "bottleneck".

According to Krajewski, Ritzman and Malhotra (2009), the bottleneck is a special type restriction that is related to the lack of capability of a process. As for Tubino (2000, p. 164) "bottleneck point is a production system (engine, transmission, space, men, demand, etc.) which limits the flow of items in the system." It can be said that all companies have at least one restriction in the process, because otherwise this system could produce an infinite amount of product. Even for authors, restriction is considered any factor that somehow limit the performance of

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a system and thus, restrict its outcome. Restrictions may occur either at the beginning or end of the supply chain, it can be the suppliers or customers.

The Restrcitions Theory has to understand the inter-relationship between two resources that are usually present in companies, as follows: the restriction resources and the non-restriction feature. According to Warrior (1999) the restriction feature can be understood as any element that limits the company's performance, as the non-restriction feature can be defined as the element that does not limit the performance of the company.

According to Tubino (2000), one can identify four types of relationships between resource bottlenecks and non-bottleneck. Figure 1 shows the relationships between bottlenecks and non-bottleneck resources. It can be observed in the representation of Figure 1 that in the relationship type 1 production flow flows from a bottleneck resource for a non-bottleneck resource, in this case the non-bottleneck resource is limited to operating at the bottleneck resource that provides the items. In the relationship type 2, the situation is the opposite, because a non-bottleneck resource is responsible for supplying a bottleneck resource, in this situation, if not the bottleneck resource operate 100% of its capacity is only part processed by the bottleneck resource to another will become part stock in the process. Type 3 relationship is representing a mounting situation, where the bottlenecks and non-bottleneck is supply line. In this case, the production flow of the assembly line is limited by the bottleneck resource, because if the non-bottleneck resource accelerate its production is only generating stock for the process.

In type 4 relationship, it is observed in Figure 1, both the bottleneck resource as the non-bottleneck resource are given directly to market demand. Thus, it is understood that the bottlenecks can be both internal and external to the production system, ie the bottleneck resource will work according to its capacity limitation, since the non-bottleneck resources should be triggered only to meet the generated flow by demand.

According to Warrior (1999), the decision-making process of the Restrictions Theory has 5 steps to the manager achieve success in the decision to be made:

1) **Identify the system restrictions:** A means of identifying the restriction ction is measuring the ability of each company's equipment, when the volume of production ction is greater than the capacity of the equipment, there is the restriction ction. According to Krajewski, Ritzman and Malhotra (2009, p. 214), "It is possible to identify where a bottleneck is in a given service or fabrication process in many different ways." Another way to identify and observe the processing time of each product.
2) **Decide how to explore the system restrictions:** in this step we must obtain the best result from the identified restrictions, that is, generating the best result with this restriction. According to Krajewski, Ritzman e Malhotra (2009), we must create programming that maximize the total yield of the existing bottlenecks. The restriction should bring to the company the biggest gain possible and thus should be used in all its time available.
3) **Subordinate any other event to the previous decision:** to Krajewski, Ritzman and Malhotra (2009), the resources that are not restrictions should support the programming of the restriction and not produce more than it can operate.
4) **Elevate the system restrictions:** to Krajewski, Ritzman and Malhotra (2009), if after the planned improvements in steps 1-3 are carried out, the restriction stay, the manager must increase the capacity of restriction.
5) **If, in the previous steps, a restriction breaks, go back to step 1, but don't let the inertia create a system restriction:** after step 4 being completed comes up a new production, thus, one should start the process again at step 1. According to Warrior (1999, p. 22) "Given that a new restriction always arise after step 4, the cycle must be restarted again from the first step ".

Yet, to identify the bottlenecks, it is needed to considerate the times that create the *lead time* that, according to Tubino (2009), are made by wating time, processing, inspection and transport.

1) **Waiting time:** is the time consumed by the batch of products in waiting to be processed effectively. According to Tubino (2009, p.114) "are waits to perform a production schedule, releasing it to manufacturing."
2) **Processing time:** is considered as the only one that adds value to the customer. As Tubino (2009) within the processing time is still found delays by the imbalance between the load and the ability which ends up generating queues or bottlenecks.

3) **Inspection time:** is the time to inspect the item was produced, for one to see if it was really reached the goal set. According to Juran and Gryna (1991) the larger the error rates, the higher the lost time and the greater the rework.
4) **Transport time:** is the time taken to move the item, following its manufacturing roadmap to complete the production. As Krajewski, Ritzman and Malhotra (2009), this time can be reduced if the company choose a suitable layout that fits into their processes and optimize the flow of products in the production process.

For the company to achieve excellence in the production process, must have control of all the steps involved in its production process and know exactly how long it takes to perform each activity, and the time lost between the stages of production. According Tubino (2000) *lead times* are usually measured through observation and the use of timers, to know for sure how long you spend on each part of the production process, always observing the reason the lead time is being generated and can therefore decrease these values. As Slack et al. (2010) when it comes to reducing lead times are not required very drastic changes but relatively simple that cause for organizing incredible benefits.

Besides knowing the *lead times,* we need to identify the process capability, to identify the constraints. As Moreira (2009, p. 137) the concept capacity can be understood as [...] "the maximum amount of products and services that can be produced in a production unit, at a given time." As for Slack et al. (2010), production capacity is the maximum value added to an activity over a given period of time, the process can be carried out under normal production conditions.

The main problem of measuring capacity of production is not the uncertainty of data, but the complexity of this process. When a production is highly standardized measuring their ability can easily be measured, because the process is repeated, but if the output has a broader range of products, the process will automatically variable and more complex, and involve more resources and time, so it will be more difficult to measure production capacity and identify the problems of the production process.

As Cogan (2007), the key to understanding the undesirable effects is in fact understand that they do not represent the real problem, that is, in fact, undesirable effects are problems or visible symptoms of the real problem, so it is up to the challenge of identify them or map the web of inter-relationship of cause and effect that unites the undesirable effects to the problem that needs to be resolved or improved to minimize the impacts they cause the production process. According to Table 1, the capacity can be measured in several ways, depending on the product.

It is observed in Table 1 that there are several ways to measure the capacity of production, and depending on the product can be measured by the amount and in some cases the quality of the production.Capacity can also be measured through the manufacturing time, and can measure both in hours, days or months depending on the business need. For Cogan (2007), the resources must be observed, especially when operating with full capacity (critical resources) so that the other will be sized according to the same, allowing the production efficiency is limited by the efficiency bottleneck and thus facilitating the identification of possible solutions or improvements to the production process.

2.2 Studies related to studied thematic

We identified some related studies the subject studied, as Alves et al. (2011); Kruger et al. (2012); Acerda, Rodrigues and Corcini Neto (2011) Silberman et al. (2012); the use of the restrictions theory in the business environment, demonstrate its importance as a support tool for the management process, the various business segments independent of the size of organizations

Alves research et al. (2011) aims to present a mapping of the production process of a jeans factory with potential for increased productivity, through the investigation of the main problems of the production process using the tools of the Theory of Constraints. The survey results show that the main constraint was the overflow errors in the sewing industry, which were caused by a particular group of seamstresses. The findings of the study allowed from the use of the RT tools guide the resolution of the constraints of jeans production process. The authors also guide managers in the search for adjustments proposals to remedy the highlighted constraints and achieve better profitability results for the business through productivity, which includes everything from training and guiding employees to correct failings identified, to adjustments in parts termination processes.

The Acerda, Rodrigues and Corcini Neto study (2011) presents a survey of research, scientific and academic papers on the problem of understanding, learning and action in relation to organizational problems which use the RT. The study in this regard shows the restrictions process of the theory of thinking as a conductor element of organizational discussion, for this, the paper argues in the review of the relevant literature to the point where demand clarify the heart of the application and correction of the central problems related to the effects unwanted. In general, the research discusses the limitations and RT capabilities, to contribute in broadening the perspectives for the conduct of the debate and learning in organizations, especially in the use of RT in the management and resolution of organizational problems.

The search Kruger et al. (2012) aimed to the application of the theory of reasoning process of the restrictions on a company' branch, to identify alternatives to existing problems, from the purchase of raw materials to processing to mate, by applying the tree of the current reality of the theory of constraints. The results of the study by the RT indicated the need for investments in human and physical improvements resources, as well as the implementation of internal controls and cost management, as well as the development and ARA analysis the authors identified the entry points the cause and effect link are responsible for the reduction in the company profitability; as the ratio of responsible competition with the drop in sales, but point out that quality problems also contribute to the reduction in sales and profitability, as well as the price reduction did not generate better results. The results of the general study contribute to discussions on the importance of using TOC in solving problems related to production bottlenecks, in this case demonstrating its applicability to a company in the agribusiness sector.

Silberman et al. (2012) analyzed the application of the Theory of Constraints in papers presented in the electronic proceedings of three scientific events in accounting (Brazilian Congress of Costs, Meeting of ANPAD and USP Congress of Controlling and Accounting) from the period 1994 to 2010. The results show that 50% of the studied organizations were private, 18.2% were public, 4.5% were non-profit entities and 27.3% of cases do not report the type studied entity; regarding size, 18% were micro-enterprises, 9% were large companies and in 73% of cases it was not possible to identify the size of the studied entity; about the economic sector of operation, 50% belonged to the industrial sector, 32% were in the service sector and 18% was part of the public administration. With regard to the type of application of TOC, observed that the throughput accounting was used in 50% of case studies, followed by the thought process by 27%, the combined drum-lung-string method with the accounting gains with 14% and the drum-lung-string method with 9%. The authors emphasize that the improvement of the decision-making process and increasing the profitability of companies as the main considerations of the analyzed studies and indicate that the RT is indicated as a tool that contributes to the improvement of the results of organizations.

3 METHODOLOGY

Methodologically the research is characterized as an exploratory study, carried out through a case study applied in a furniture branch company located in the western region of the state of Santa Catarina, in Chapecó, especially considering the line of machining this company to identify restrictions on the production process.

The company studied produces standard custom high-end furniture. Your mix is composed of chairs, armchairs, dining rooms and furniture for living room, among others. The product differentiation occurs in the assembly industry, machining being composed of a continuous flow that involves 15 steps. Daily 50 are machined parts after machining, the parts are packed in a stock lung, feeding the assembly, which is triggered only by order.

To collect data, we used the observation of the production process of the machining line, considering the steps and the flow of the machining process of the furniture company in question. Subsequently elaborated a spreadsheet that was sent to two people, one of the first and the other the second round. It was up to these people the responsibility to fill in the requested data to monitor the steps of the machining process. Those selected are responsible for stopping the treadmill when there is some need or problem related to the processes of this production step. Thus considering that they are responsible for the "stops" identify the reason and the time the activity was interrupted or "stop". The observed time period and measuring the production capacity took place between the months of October and November 2013.

There was the flowchart of the machining process, the machining time step of processing and subsequently through the collection of the problems observed in the production process we identified the main restrictions that hinder the optimization of the production process.

4 RESEARCH RESULT ANALYSIS

This topic is initially addresses the machining process mapped in the studied company, later identified to process steps and the time of the activities, and the restrictions observed in the development of the activities of the production process.

For better organization, the machining industry is divided into three sectors, as shown in Figure 2. Initially the piece is inserted in sector 1 of the process in the trowlling machine (1), at this stage, the first cuts in wood (raw are made material) after the piece is sent to the planer machine (2) reframes timber taking all the excess. Thus, the piece is sent to the machine plane (3), which gauge the work piece, or the work piece leaves the extent necessary. After this stage there is the quantity of the pieces are in compliance with requirements (4), because, in the planer machine some parts may be discarded or destroyed by poor quality parts are in lower amounts (5), the process must return for the trowlling machine (6), if the parts are in perfect amount (7) goes to the trimming machine (8), where the wood then wins his first form and design, after it is sent to the band saw machine (9) curves where cuts are made. After this step the part is sent to the sector 2 for the copying machine (10), which copies are drawn (drawing) of the parts, then is sent to the machine level (11) which performs the cuts in degrees (1 ° , 180 °, 360 °) after it is sent to the trowlling machine (12) further performs the necessary cuts in the wood. The work piece is sent to the lathe machine (13) that is responsible for turning the pieces after the piece goes through the router (14) where the necessary fittings are made.

After these steps, the piece goes to the sector 3, last machining industry. He begins his process in the belt sander (15) is finishing the piece, after it is sent to the sander 2:10 (16) which is also responsible for the finishing touches, the play follows for drilling (17) makes the necessary holes in parts, then is sent to the sander broadband (18) which is also responsible for other finishes, as shown in Figure 2.

After working out the flow chart of production and machining industry and describe the steps that make it up, started the measurement of *lead times.* To perform the measurement selected is the chair (1090), which is one of the parts produced by the company studied. Table 1 shows the setups (B), the production capacity (column C) and the actual output (D), taking as a parameter an hour of production. It also presents the percentage of capacity utilization (E) - actual production / capacity, and you can still see the motives of setups (F) occurring during the production process occurred during the period under review.

Complete data collection of production times, as shown in Table 1 began the evaluation of setups that each hour of production has. In the evaluation it was possible to observe that *the lead time* of the machining industry is high on average takes 30 days of production parts 100 of the seat 1090, with the parts that after passing this process is stored for use when ordering the same being preassembled and continue the process until the end of its production. These parts are produced only when the existing stock is the security level.

It is understood that the overall setup time is low, and as long as the machines stood still during observation was that occur at intervals over 15 min. in the morning and 15 min. in the afternoon, and is an internal rule of the company, however, it is observed that in a production step machines have less capacity, thus reducing the pace of production and the number of parts produced. It was observed that the machines that make the finishes at the end of the production process is slower, because these machines carry out the final finish which must have concentration of the employee and the parts observation for the identification of defects.

At the beginning of production in the trowelling machines and the process is fast, so often the employees help other sectors, therefore, when possible can be speed up the process, however, some machines are not this then the process itself is time-consuming, as the copy machine. This machine requires a comparable single-employee services as supervisor reports, because it is a new investment company, where once to produce the current amount needed of five staff services, and now needs only one. Still, with the evaluation of setups, one can see that the pieces are on hold from the band saw machine, because the machines that start the process have increased production capacity, then, as the trimming machine is capable of producing 13 units per hour, the band saw machine is capable of producing only five units. With this assessment, it is also possible to identify existing restrictions in the machining process, and which is mentioned machine to machine in one hour of production.

4.1 Identification of the restrictions from the machining process

Based on the table with the processing time data, the existing restrictions in the machining production process have been identified. It was observed that the main restriction of each machine is in production capacity, therefore, at the beginning of the process machines have greater capacity and at the end of the production is performed in which the finish of parts, the machine has a lower production capacity, and, that the analysis was based on the production of the chair in 1090 in one hour time.

It is understood that the lumber trimmer, trowelling and planer machines have on average the same production capacity, however, when the part arrives at the band saw machine is stopped for a while, because this machine have on average half the size the previous ones, and thus cannot follow the production at the same pace. The next process machine, copier also has the average production capacity as the band saw machine, so at this stage no stops pieces, however, the process that the copier machine performs is time consuming and it is necessary to monitor employee's concentration the process that the machine performs.

It is observed that the process of restriction is on machines with less production capacity are: band saw, copier, router, tire sander, belt sander, sander 2.10, drilling and squeezer, most of which is at the end of process, where the finish of the pieces is performed. The process beginning of machines have increased production capacity, and hence arriving at a time to produce 200% more than the machines that make the part finish. It is understood that these restrictions can be eliminated with actions for process optimization.

Thus, the overall results of the study corroborate the studies of Alves et al. (2011); Kruger et al. (2012); Acerda, Rodrigues and Corcini Neto (2011) Silberman et al. (2012); highlighting the importance of using the restrictions theory as a support tool in the process, in this case also when applied to the furniture industry to identify bottlenecks and fix problems perceived by restrictions in the production process.

5 FINAL CONSIDERATIONS

The study developed aimed at the application of the theory of reasoning process of the restrictions in the machining industry in a furniture industry in order to improve their business competitiveness through the use of one of the techniques used by the management of production from the restrictions theory. In this sense, it was possible to identify the main constraints existing in the machining process of a company in the furniture branches located in the western state of Santa Catarina.

Justifies the importance of the results for companies in the furniture industry and other industries, serving as a model for the application of the restrictions theory in the business environment especially geared to the production process. And emphasizes the relevance of the findings for the study subject company, given its applicability and address the identified problems.

It was observed from the research and elaborate flowchart that the company has the well-structured production sector, but at times the production process faces some restrictions, which can compromise the production process and its profitability, this effect was observed mainly the ratio between the capacity of the machines used in the process.

The analysis shows that the main restrictions of the process are the machines with lower production capacity are: band saw, copier, router, tire sander, belt sander, sander 2.10, drilling and squeezer, most of which is in end of the process, which is carried out part of the finished parts. The beginning process of machines have increased production capacity, and hence arriving at a time to produce 200% more than the machines that make the part finish. It is understood that these restrictions can be eliminated with actions to optimize processes and better productive results.

Overall, the study results show that using the restrictions theory is possible to identify bottlenecks in the production process, as well as guiding the restrictions corrected through improvement actions aiming to optimize the industrial production process.

For future research, we suggest other analyzes related to production processes, aiming at the implementation and use of restrictions theory in other business models as well, it is understood that can be carried out research showing implementations and comparative analysis of the processes before and after application of the restrictions theory in production processes.

REFERENCES

ACERDA, D. P.; RODRIGUES, L. H.; CORCINI NETO, S. L. H. Processo de pensamento da Teoria das Restrições: uma abordagem para compreensão, aprendizagem e ação sobre problemas complexos. *Perspectivas em Gestão & Conhecimento*, v. 1, n. 2, art. 3, p. 59-76, 2011.

ALVES, A. P.; SILVA, T. G.; ALMEIDA, R. S.; COGAN, S. Utilizando os passos da Teoria das Restrições para a melhoria contínua da produção: um estudo aplicado a uma fábrica de jeans. *Revista do Mestrado em Administração e Desenvolvimento Empresarial*, v. 15, n. 1, art. 77, p. 93-114, 2011.

COGAN, Samuel. *Contabilidade gerencial:* uma abordagem da teoria das restrições. São Paulo: Saraiva, 2007.

GOLDRATT, Eliyahu. M.; COX, Jeff. *A meta - um processo de melhoria contínua.* 2 ed. São Paulo: Nobel, 2002.

GUERREIRO, Reinaldo. *A meta da empresa: seu alcance sem mistérios.* São Paulo: Atlas, 1999.

JURAN, J. M.; GRYNA, Frank, M. *Controle da Qualidade Handbook.* São Paulo: Makron, McGraw-Hill, 1991.

KRAJEWSKI, Lee; RITZMAN, Larry; MALHOTRA, Manoj. *Administração de produção e operações.* 8. ed. São Paulo: Pearson Prentice Hall, 2009.

KRUGER, Silvana Dalmutt; OENNING, Vilmar; CAREZIA, Francieli Diane Merlin; MAZZIONI, Sady; GUBIANI, Clésia Ana. *A aplicação do processo de raciocínio da teoria das restrições.* In: Encontro Nacional de Engenharia de Produção, 32., Bento Gonçalves, 2012. Anais... Bento Gonçalves: ABEPRO, 2012.

MOREIRA, Daniel Augusto. *Administração da produção e operações.* 2. ed. São Paulo: Cengage Learning, 2009.

NOREEN, Eric W. , SMITH, Debra, MACKEY, James T. *A teoria das restrições e suas implicações na contabilidade gerencial: um relatório independente.* São Paulo: Educator, 1996.

RITZMAN, Larry; KRAJEWSKI, Lee. *Administração da produção e operações.* São Paulo: Pearson Prentice Hall, 2004.

SILBERMAN, I. M.; AYRES, R. M.; SILVA, P. R.; COGAN, S. Teoria das Restrições (TOC): uma análise de estudos de caso disponíveis em anais de congressos. *Revista de Contabilidade do Mestrado em Ciências Contábeis da UERJ*, v. 17, n. 2, p. 28-44, 2012.

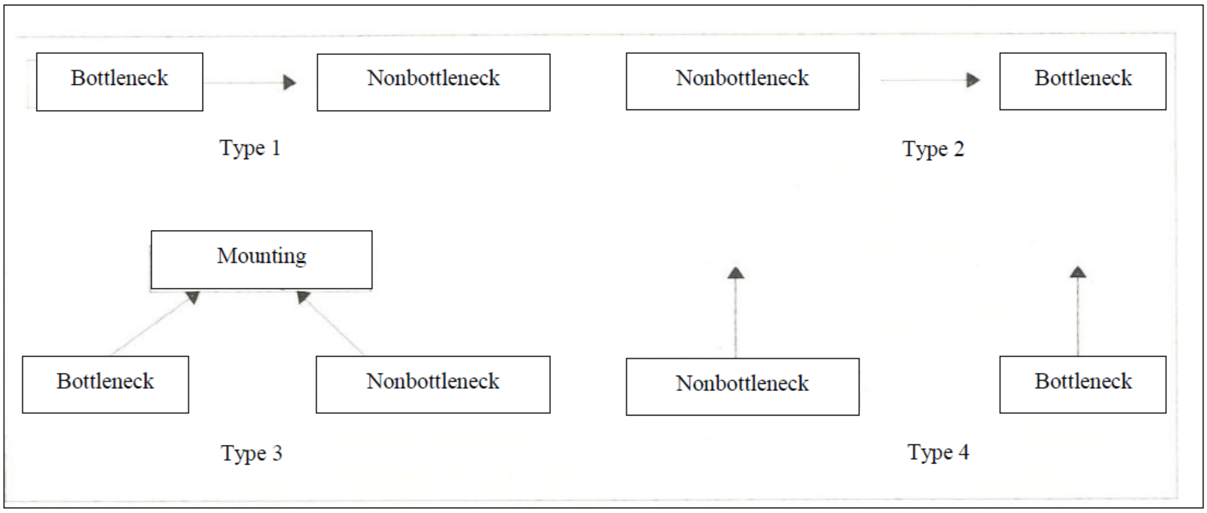
SILVA, Liane M. e; PINTO, Marcel de Gois. *Reflexões relativas aos métodos de medição e avaliação da produtividade de fator simples (STP) e de fator total (TFP) sob a ótica da teoria das restrições (TOC) utilizando simulação computacional.* ENEGEP, 2007.

SLACK, Nigel; CHAMBERS, Stuart; HARLAND, Christine; HARRISON, Alan; JOHNSTON, Robert. *Administração da Produção.* São Paulo: Atlas, 2010.

TUBINO, Dalvio Ferrari. *Manual de planejamento e controle de produção.* São Paulo: Atlas, 2000.

_______, Dalvio Ferrari. *Planejamento e controle da produção.* 2. ed. São Paulo: Atlas, 2009.

Figure 1: Types of relationships between bottlenecks and non-bottlenecks



Source: Tubino (2000, p. 165)

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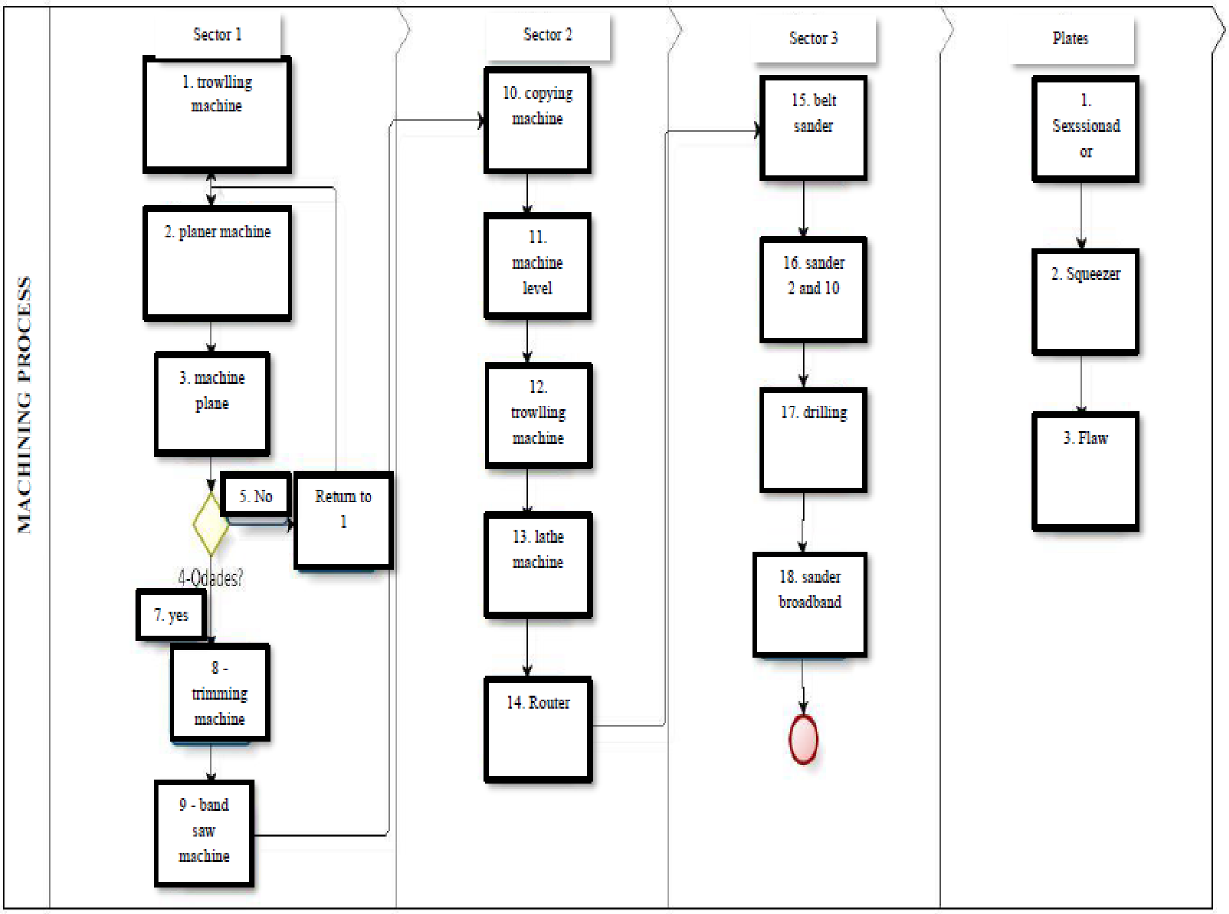
Board 1: Input capacity measures and products for different operations.

Operation	Measure of input capacity	Measure the volume of production capacity
Air conditioning manufactures	Time of available machines	Number of units per week
Hospital	Beds available	Number of patients treated per week
Theater	Number of seats	Number of customers entertained a week
University	Number of students	Graduate students per year
Sale of retail store	Sales area	Number of items sold per day
Airline	Number of seats available	Number of passengers per week
Power company	Size of the generator	Generated electricity megawatts
Brewery	Volume of fermentation tanks	Liters per week

Source: Slack et al. (2010, p. 261)

Figure 2: Machining flowchart



Source: Elaborated by the authors with research data

Table 1: Processing time

Part name: Chair 1090

Machine (A)	Time	Setups (B)	Production capacity (C)	Real production (D)	% of the capacity utilization (E)	Setups Reason (F)
Destopar	1 hour 1 hour 1 hour	17 min. 23 min. 30 min.	9 9 9	6 5 4	67% 56% 45%	Aid to other machines. Break of 15 min. and conversation with colleague. Break of 15 min. bathroom
Unbend	08:00 09:00 10:00	4 min. 20 min. 3 min.	13 13 13	12 7 13	93% 54% 100%	Machine maintenance. Break. Observation of parts in other machines.
Plane	11:00 15:30 09:00	5 min. 18 min. 15 min.	13 13 13	12 9 10	93% 63% 77%	Bathroom. Conversation with *PCP*. Break.
Trimming	11:00 15:30 08:00	2 min. 17 min. 5 min.	13 13 13	13 9 12	100% 70% 93%	Guidance on measurement. Break. Bathroom.
Saw Blade	10:00 14:30 08:00	10 min. 4 min. 0 min.	5 5 5	4 5 5	80% 100% 100%	Organization of parts in production. Production Order Information.
Copier	08:00 14:00 11:00	8 min. 3 min. 10 min.	4 4 4	3 4 3	75% 100% 75%	Organization of parts in production. Bathroom. Organization of parts in production.
Tenoning	08:00 16:00 11:00	5 min. 10 min. 5 min.	13 13 13	12 10 12	93% 77% 93%	Bathroom. Talk with production manager. Parts organization.
Router	17:00 10:00	10 min. 0 min.	5 5	4 5	80% 100%	Machine maintenance.
Tire sander	08:00 11:00	8 min. 3 min.	7 7	6 7	86% 100%	Parts organization. Production Order Information.
Belt sander	08:00 11:00	8 min. 12min.	5 5	4 4	80% 80%	Talk with production manager. Organization of parts and going to the bathroom.
Sander 2,10	09:00 14:00	20 min. 5 min.	7 7	5 6	72% 86%	Break. Bathroom.
Drilling	09:00 14:00	23 min. 0	6 6	4 6	67% 100%	Aid in another machine.
Belt sander	10:00 15:30	0 20 min.	6 6	6 4	100% 67%	Break, bathroom.
Squeezer	10:00 16:30	12 min. 0 min.	4 4	3 4	75% 100%	Conversation with another employee about the part.

Source: Elaborated by the authors with research data