TOC'S Five-Step Cycle: An Approach to Instant Results and Cultural Change

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Abstract— *The Theory of Constraints (TOC) offers an interesting alternative to the use of management tools, in especial yours TOC cycle. Although it is an interesting alternative, only a small number of publications focus on the TOC cycle. This article aims to describe the TOC cycle and to present its application in the furniture industry, aiming to show a simplified method of your application. The approach is exploratory and descriptive, with a bibliometric analysis and case study. After finding a restricted number of publications, some of the articles were analyzed and it was possible to propose and demonstrate a simplified method for the application of the TOC. From the application of the five steps of TOC cycle, it was possible to identify and eliminate the bottlenecks. The results obtained were positive, because in less than a year the productive process presented productivity gains and a change in the organizational culture.*

Keywords— Theory of Constraints, Five Steps, Gain, Productivity.

I. INTRODUCTION

Every company is a complex system that needs to apply management tools to provide productivity gains, and thereafter to provide increases in profit, in order to be in balance with production process bottlenecks. Identifying and dealing with the bottlenecks and at the same time promoting a new organizational culture is not a simple equation to be solved. When talking about the management tools used nowadays by organizations, the Theory of Constraints (TOC) offers interesting alternatives to equations, seeing the company not as isolated parts but as an integrated system or a group of elements where any type of connection can be found [1]. It is an integrated management philosophy that changes managers' ways of thinking and represents an important tool to solve problems. Şimşita, Günayb and Vayvay [2] the TOC prescribes methods and tools to control and overcome restrictions (known as strangulation points in bottlenecks) which limit a system's ability to achieve goals [3].

After analysing these tools, the "five steps" methodology was found, which can implement TOC in a process by structured and simplified means. After that, a bibliometric study was realized on the Scopus database, aiming to analyse the occurrence of researches based on TOC's five-step methodology. Searching for the key terms 'theory of constraints' and 'five steps' in the last ten years, 11 scientific works were found, with eight articles being published in periodicals (Figure 1).

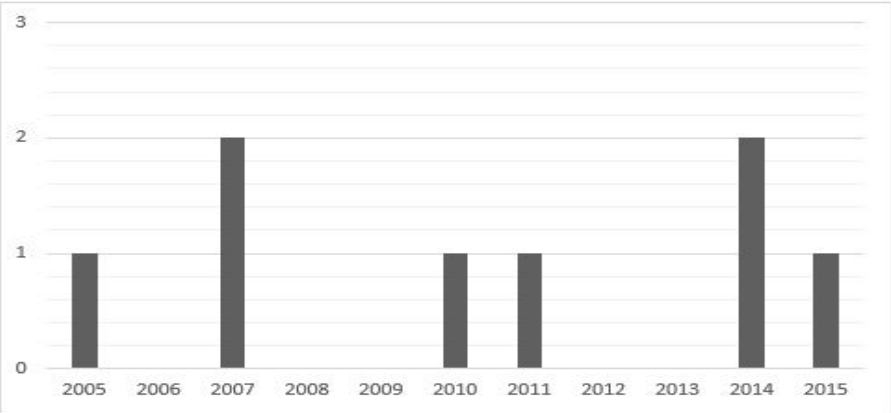

FIGURE 1 – GRAPHIC OF PUBLICATIONS FROM 2005 TO 2015[4]

Considering the small number of publications focused on TOC's five steps – a maximum of two articles per year, with the trend remaining this low – this theme was considered a good one to explore in a theoretical and practical way. According to Silberman et al. [5] despite the advantages provided by TOC, many Brazilian companies still do not use this methodology as a global philosophy of business management. It is believed that this may occur because managers are not compromised to apply the tool or are totally unfamiliar with the theme. In this way, the goal of this article is to describe the five-step methodology and to realize its practical application in a medium-sized company in the furniture industry, aiming to demonstrate a simplified method of applying TOC to identify and eliminate bottlenecks, focused on enhancing productivity.

II. MATERIALS AND METHODS

The research was exploratory and descriptive. Vergara [6] comments that the exploratory research can be realized in areas where only a little accumulated scientific knowledge exists. This work is a research that aims to discover theoretical concepts regarding the five steps of the TOC and the resulting gains and productivity, a subject matter that has not yet been fully explored. Combined with the theoretical research, a bibliometric analysis of the Scopus database was carried out using the keywords 'theory of constraints' and 'five steps'. The research period was from 2005 until August 2015 and the research considered the Scopus database using these keywords. It aimed to learn the distribution of scientific articles published during the period as well as to qualitatively analyse the concepts related to this research. It was also descriptive, because it was realized to try to describe the characteristics that made the TOC five steps a real concept in a familiar company. For this case study, the steps described in the next chapter were followed.

According to Reid [7] the five steps of focalization were carried out to ensure that management would direct its attention to what was really important for the system's good performance, that is, what made the system's constraint performance better. When talking about the cycle, the five steps are represented in Figure 2, showing that after each developed step, another one is unlocked, until the fifth step is reached, when the process can be repeated for the same constraint or starting from a new one, beginning a new cycle, as represented by the doted arrow.

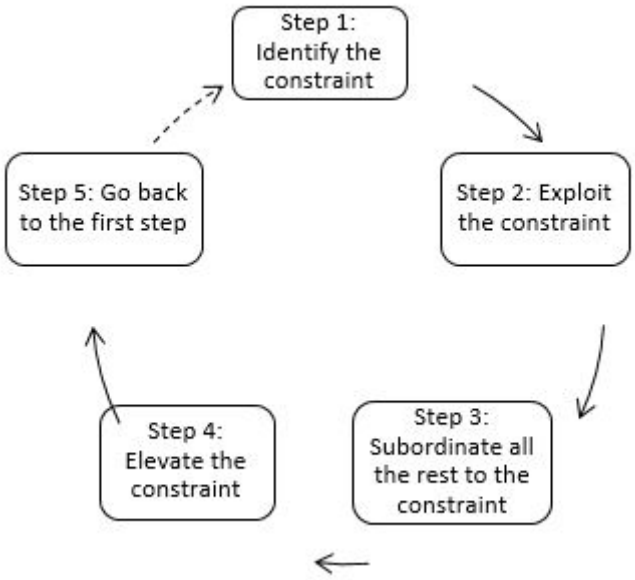

FIGURE 2 – TOC FIVE-STEP CYCLE

The five steps of TOC flow representations are joined by arrows indicating the next step of the cycle. The last arrow can represent the two possible next steps of the process: one is when the bottleneck has not been eliminated in only one round, and the other is when the bottleneck has been eliminated and Step 1 considers a new constraint.

Step 1: Identify the constraint. The identification of the constraint phase of the system must start from process information, focusing on lateness or where most working hours are usually needed, which means that the constraint identification begins from previous knowledge of the process. According to Souza [8], in order to verify whether there is a real bottleneck, the total load must be calculated, generated by the requests that should have been dealt with during the programmed horizon imposed for each type of resource. According to Goldratt [9] in the calculation of machine load, all the requests that should be dealt with inside the horizon must be taken into account. Other complementary variables of the calculation are the existing stock and the set-up times or the machine preparation time. After the calculation, a comparison of the results of the machine

load for each resource must be done, with all the available time determined for the same period. In the case that the machine load presents a higher value than the availability of the resource, this will be treated as a bottleneck.

Step 2: Exploit the constraint. The exploration is likely to reveal the 'hidden capacity' that will allow the transfer rate to increase without additional costs [10]. As Reid [7] mentioned, this step aims to maximize the existing operational set-up efficiency from the constraint resource inside the system. In other words, the management must focus on eliminating all the waste or unproductive time in activities where the constraint occurs, increasing the capacity of the production system.

Step 3: Subordinate all the rest to the constraint. The subordinate step consists in the process of making a non-constraint to produce only what the system constraint allows. According to Pretorius [11], the third step deals only with the management rules for non-constraints, which are often related tothe 'Road Runner ethic' or behaviour. This means that the non-constraint's level of application is determined by constraints on the capacity and usage.

Step 4: Increase the constraint. Pretorius [11] affirms that when improvement of the system through exploration and subordination is not possible, the next step is to increase the constraint capacity. This step aims to find alternative ways to increase the constraint capacity. Once the capacity of the constraint is increased, constraint new constraint may happen in another activity of the production system or the constraint could continue in the same place, but with its capacity increased [11].

Step 5: Go back to the first step. From the TOC's cycle, depending on the decisions made during the process, a new constraint is created. In this way, the fifth and last step aims to go back to the first one if the constraint has been solved or to go to the identification of a new constraint caused by the elimination of the bottleneck. Reid [7] states that when a decision is made to keep the constraint in its current location, management actions taken in later steps will lead to a new location of constraint in the system. Therefore, it is necessary to return to the first step and identify a new system constraint.

III. THEORETICAL FRAMEWORK

3.1 Theory of Constraints (TOC)

According to Naor et al. [12], the origin of TOC dates from 1970, when Goldratt [9] was motivated to assist his neighbour, who worked in a cage factory, by developing an effective programme to increase the industry output. The programme, later called Optimized Production Technology (OPT), was quickly adopted by big US corporations. Despite the huge adoption a few years after its creation, many failures were identified. To improve the OPT,Goldratt [13] created the TOC, which spread worldwide after publication in 1984 of the book *The Goal*. The book sold more than 5 million copies, was translated into 21 languages, and became a mandatory read on many management courses around the world [12]. From the book*The Goal*, which claims that the only purpose of a company is to make a profit now and in the future, the authors define six variables as organizational measures to reach that goal. Three of them are operational: income, inventory, and organizational expenses. The other three are financial: liquid profit, return on investment (ROI), and cash flow. All these metrics are combined through relationships [14]. According to Ifandoudas and Chapman [15], the benefits achievable with the adoption of TOC are reported as a reduction in delivery time, cycle time, reduced inventory, and improved productivity and quality of production.

The tools that compose the TOC thinking process allow diagnosis of the problem, the development of new solutions, and the building of action plans Kim et al. [16] allowing the manager to pay attention to more serious questions [17]. TOC is a theory that clearly identifies a gain orientation, together with three dimensions: mind maps, metrics, and methodology [18]. It can also be defined as a management philosophy that provides a focus on continuous improvement, resulting in advances in organizational performance [19, 20]. This philosophy starts from the principle that each organization has constraints that stop it from achieving its goals; in this way, a company is as strong as its biggest constraint. Therefore, there is always an aspect in every system which determines its result. A constraint can be a physical resource, management politics, or behaviour factors [21].

There are good cases of TOC application in many different sectors, such as production, logistics, supply chain, distribution, project management, accounting, research and development, sales and marketing, and others [22, 2]. Its first application was in production planning and programming to maximize profits and effectiveness related to market demand by identifying and exploring the constraint resources [23], using the Drum–Puffer–Rope (DPR)methodology [24, 25] and defining five steps for the TOC process.

The DPR methodology is a basic TOC principle, where all the bottleneck's resources impose the production rhythm, because they are the chain's weakest link [5]. The method focuses on seeking a production flow balance, directed by the restrictions

and resource capacity. According to Naor et al. [12], the 'drum' represents the production rate. It gives the synchronization rhythm to the system's activities flow. The 'rope' is a communication mechanism that transfers information to the system based on 'puffer' consumption, which is the information flow or materials. In this way, the whole mechanism must work in harmony.

3.2 Five steps

The TOC principle emphasizes the importance of identifying and eliminating bottlenecks (constraints) in the manufacturing process, not only to increase productivity, but also as a tool to measure and control the materials flow [26]. The five steps comprise a methodology that aims to break up the system constraints and to achieve a high level of performance management [27]. According to the TOC, every system oriented towardsa defined goal needs to have at least one limitation on achieving this goal; otherwise the system's profitability would be endless. In this direction, TOC proposes that every organization should follow the five steps [13, 28, and 9] as a way to identify constraint factors that stop the company achieving its goals, with the aim of breaking them, and repeating these steps as part of a continuous process improvement [29].

1. Identify the system constraints;
2. To exploit the system constraints to their maximum;
3. To subordinate everything else to the system constraints;
4. To raise the system constraints;
5. To go back to the first step.

In the next part, the results found from the exploration and descriptions of the realized research are presented.

IV. RESULTS AND DISCUSSION

From the exploration of research using bibliometric analysis, the results listed in Table I were obtained.

TABLE 1
LIST OF ARTICLES, AUTHORS, AND PUBLICATION DATE (2005 – AUGUST 2015).

Article title	Authors	Publication Year
Theory of constraints – application in land transportation systems [3]	AleksandarZivaljevic	2015
Introducing in-between decision points to TOC's five focusing steps [11]	Pieter Pretorius	2014
Applying the Theory of Constraints in the South African coal supply chain [30]	Ken Mathu	2014
Theory of constraints – lessons for academicians and practicing managers from "the goal – II" [31]	Ajay Kumar Gupta; Arvind Bhardwaj; Arun Kanda	2011
The TOC-based algorithm for solving multiple constraint resources [32]	KumarAmitava Ray; Bijan R. Sarkar; Subir KumarSanyal	2010
Applying the TOC five-step focusing process in the service sector: A banking subsystem [7]	Richard A. Reid	2007
Applying Theory of Constraints on ongoing improvement in manufacturing system dealing with animal feed [33]	Sumitra K Mukhopadhyay; Joy Prakash Panda	2007
From Management by Constraints (MBC) to Management by Criticalities (MBC II) [34]	Dan Trietsch	2005

Table 1 presents the articles found from the bibliometric analysis realized using the Scopus database covering the period from 2005 until August 2015. From these titles, an exploratory research was made in the completed texts, where it was possible to access five of them. Table 2 synthesizes the main aspects of these five works, highlighting the major results of the five steps described and using tools.

TABLE 2
SYNTHESIS OF THE MAIN INFORMATION FROM THE FIVE ARTICLES IN THE REALIZED BIBLIOMETRIC ANALYSIS.

Author (year)	Objective	Method	Main Results
AleksandarZivaljevic (2015) [3]	To exploit the usage of TOC in the approach to traffic jams as a main restriction to improve the usage of a land transport system.	Exploratory research to develop a provisional theory through the generation of new ideas and assumptions, making an image database for the advancement of investigations.	The research concludes that the biggest restriction is broken at the third step of TOC's five steps and that improvement in certain segments of land transport could be reached using the theory.
Pieter Pretorius (2014) [11]	To ensure a large application of the five steps to also include non-physical constraints, which cannot be approached when using linear programming.	Conceptual research through a search for concepts to define a diagram that helps the execution of the TOC's five steps when a non-physical constraint occurs.	A focus diagram of the TOC's five steps, detailing the decision point, especially for non-physical constraint cases.
Ken Mathu (2014) [30]	To establish processes to minimize or relieve the constraint found at a coal mining supply chain in South Africa with the aim of improving its operational effectiveness, efficiency, and profitability.	Qualitative research.	The main process restrictions were found and the steps required to minimize the constraints were indicated.
KumarAmitava Ray; Bijan R. Sarkar; Subir KumarSanyal (2010)[32]	To analyse the heuristic model integration, comprising the Analytic Hierarchy Process (AHP) and TOC in a decision model.	The methodology incorporates an analysis to provide the decision maker with additional information about the model strength, so he or she can make the best decision.	Elaboration and revision of an algorithm. Many advantages are indicated: 1) It is suitable to deal with production analysis. This includes quantitative factors. 2) It eliminates strict mathematical expressions. 3) It is simple and direct. 4) It generates the ideal solution in any case.
Richard A. Reid (2007) [7]	To present a detailed descriptive analysis of sequential TOC application with a focus on the process improvement of five steps for service process, that was limited all the service system.	The five-step approach is presented with each step being described and evaluated in relation to its role in effective constraint management. An example of a bank sub-system provides additional insights.	An illustrative tutorial that details the TOC application in the effective management of a service process.

From Table 2, it was possible to identify the satisfactory results that the research focusing on the TOC's five steps showed, making the idea of a practical and effective application strong for this methodology. Also for to realize that theoretical researches are still broadly discussed, aiming to improve the TOC cycle usage in diverse industrial sectors

In relation to the case study realized, it was observed that the main productive process flow involves the following sectors of: cutting, edge banding, drilling, painting, and packaging.

Knowing the process, the TOC application started with the previous analysis of each sector to identify the first constraint. In this way, for each constraint found, the five-step methodology with an execution chronogram of the bottleneck elimination work were followed, always in search of the goal, according to Reid [7] After the fifth step ,return to step 1 and eliminating the next bottleneck by repeating the steps until the current bottleneck was elminated. After the identification of the first bottleneck and execution of TOC, three other bottlenecks were identified in different sectors (Figure 3).

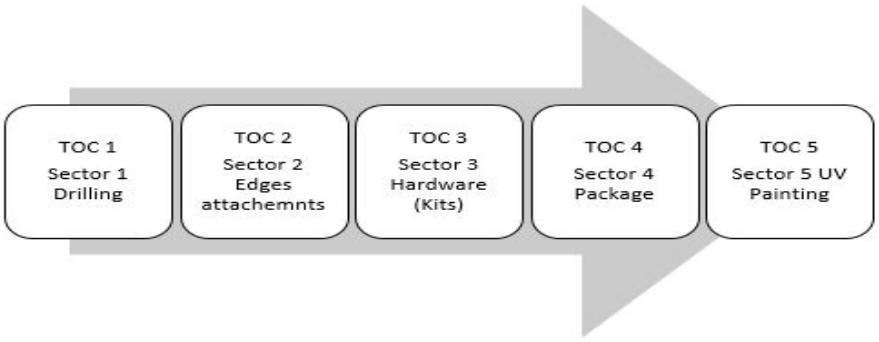

FIGURE 3 – CONSTRAINTS FLOW

In TOC 1, the application of the first tool was realized from the initial identification of the bottleneck. This bottleneck was a problem known by all personnel working in the factory, and in this way, the analysis started from this manufacturing limitation. According to Vergara [6] analysis of the first step is based on information about the process that is already known, usually concerning failures. In Figure 4 shows a flowchart of the five steps of TOC 1, with the first step being at the top of the flow.

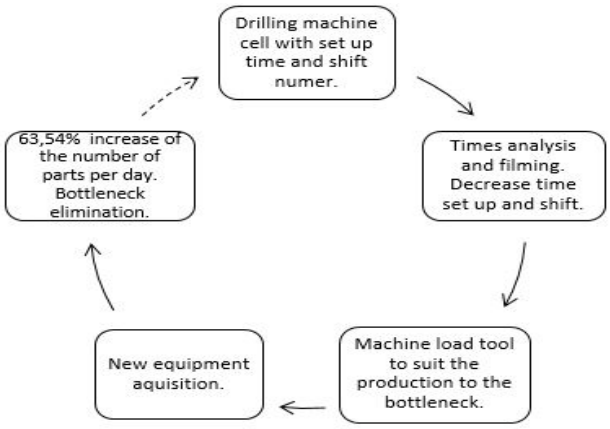

FIGURE 4 – FIVE STEPS OF TOC 1

The elimination of the bottleneck in the tool sector, led to a significant increase in the daily production, which ultimately initiated a new constraint in the cell that predates the drilling machine in the process. As a solution, the production was maximized through the lifting of the restriction, transforming the machine into two equal parts. This premise confirms the finding of Goldratt [9] that when perfection of the system is reached, the alternative is to raise the restrictive factor. Thus, Figure 5 shows the five-step flowchart of TOC 2, with the first step being at the top of the flow.

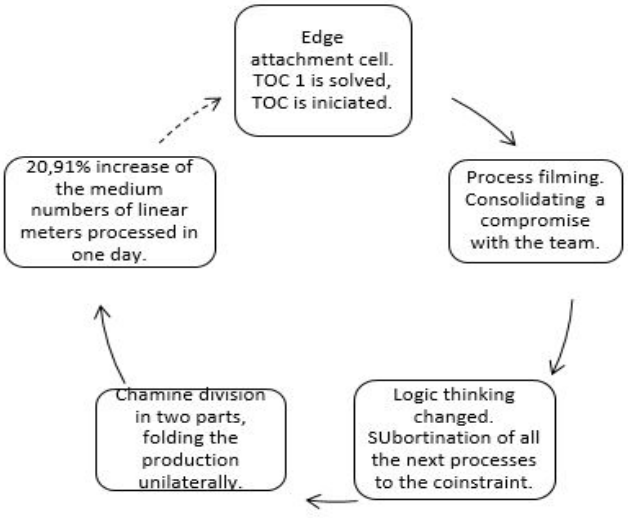

FIGURE 5 – FIVE STEPS OF TOC 2

With the increase of daily production in these two manufacturing sectors, the fittings sector becomes incapable of supplying the production demand with a reduced shift and becomes a new process bottleneck. According to Silberman et al. [5], depending on the decisions regarding the process, a new constraint is generated. From this bottleneck, TOC 3 is initiated and its five steps are represented in the flowchart shown in Figure 6.

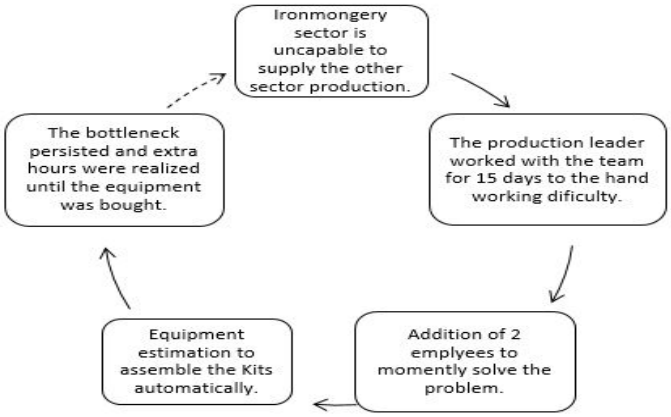

FIGURE 6 – FIVE STEPS OF TOC 3

In the last productive flow step, the fourth constraint was found, initiated by the increase in production in most of the other sectors. This constraint was about the inability to supply the final processing of the product. TOC 4 arises from that event, and its five steps are represented in the flowchart in Figure 7.

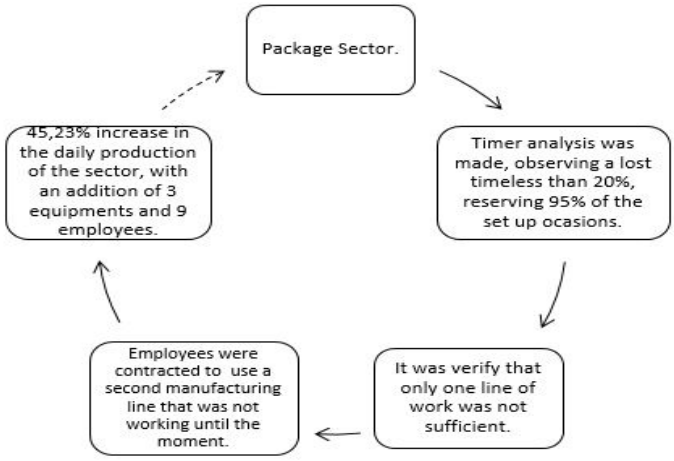

FIGURE 7 – FIVE STEPS OF TOC 4

With the elimination of the bottleneck by TOC 4, the daily appearance of new bottlenecks is inevitable, because the natural cycle of the TOC is to find and eliminate them through the five steps. Tyan et al. [36] suggest that the principles of TOC are effective tools for continuous improvement of a process. From the satisfactory results, the continued use of this tool is already shaping a new culture at the factory, allowing gains in productivity and profit, as can be seen in Figure 8.

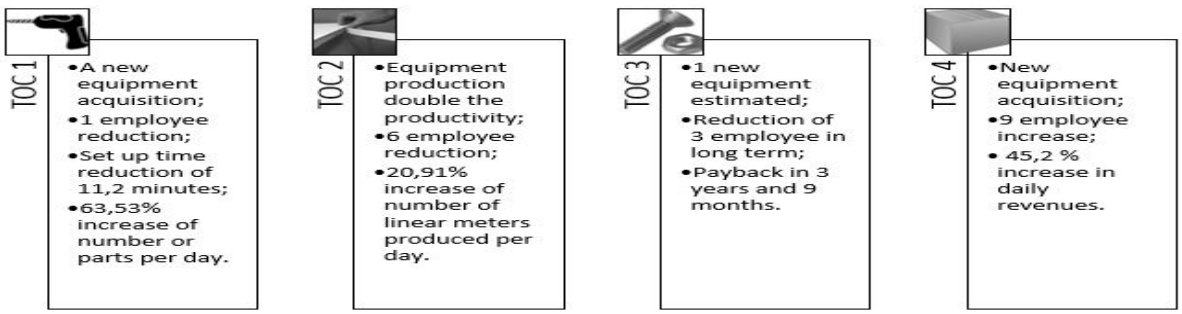

FIGURE 8 – RESULTS FOUND WITH THE USE OF THE TOC CYCLE

Figure 8 represents the gains acquired in each realized TOC cycle in the process. From these numbers it is possible to perceive the improvement achieved in each step either by reducing the number of employees or by increasing productivity, strengthening the affirmation of Naor et al. [12] that the TOC is an example of an operations management approach used successfully in practice.

Sharma [35] considers that of the production operations of a company will always be relevant, as it facilitates a clear understanding and problem analysis. Visualizing the results in terms of operational aspects, income increases and decreases in inventory and operational expenses, which improves the company's financial variables, increasing its liquid profit, ROI, and cash flow. These six variables are the so-called organizational measures described in the book *The Goal*, and they have a direct connection with the organizational goal of making money. These relations between operational and financial aspects shows that the main gain that every company seeks – profit – becomes more achievable after the application of the TOC's five steps to the process, turning the operational gains into financial ones.

Another important aspect is the change in cultural organization or the alteration of the mind maps developed in the employees involved during the execution of each cycle. It was observed that the execution of the TOC cycle promoted better employee performance and a greater contribution of the employees to the improvement of the process as a whole. The change of this mental model adopted by the employees came from the TOC's measures and methodology, naturally adopted during its application, proving the results of Gupta and Boyd [18], shows the TOC's relationship with mental models, measures, and methodologies. With the use of the TOC cycle, there are changes in the way each employee behaves and sees his or her work, leading to changes in his or her way of acting in relation to work and the organization.

This change in mental models caused by the measures and changes in methodology adopted in the TOC cycles can be considered the most important, because this aspect ensures the continuity of the TOC process and in consequence the company's evolution and increase in benefits achieved, as stated by Goldratt [13] who reported operating earnings by using the TOC.

V. CONCLUSION

From the point of view of theoretical studies, the TOC showed to be more effective when the five-step methodology is applied, because of its understandable simplicity and practical application in numerous industrial sectors.

From the theoretical researches realized, it was possible to verify the existence of just a few articles that used the TOC five steps as the main strategy for theapplication of tools. In this way, it was possible to propose and demonstrate a simplified method for the application of the TOC. In this application of this method, the results achieved by the application of the five steps were very positive, because it was observed that in less than one year the production already showed results very close to the expected results, besides ensuring a culture change in the factory that changed the employees' way of thinking and acting regarding their jobs.

The mind maps underwent significant alterations following the measures and changes of the methodologies of the daily work of every employee. The relations between these three dimensions demonstrate the strong connection when things change. After the operational results, work measures, and methodologies, modification of the mind maps through which the organization and its productive methods were visualized could be observed, bringing gains in all aspects.

Finally, through the case study it could be observed that TOC is a trustable and flexible theory that brings gains and objectivity to solving problems such as bottleneck elimination with profit gains, besides significantly changing the industry's daily work, bringing a more effective dynamic to achieve the goal of the company.

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