Processes of Improvement in Operations Management

The Case Study of Corticeira Amorim

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Abstract. This study is carried out at Corticeira Amorim, a world leader in the cork industry. It arises in a context of a competitive environment, such as the existence of substitute products and the increasing expectations from the customer. It was developed in Equipar Industrial Unit of *Corticeira Amorim*, in Coruche, where technical and agglomerated corks are produced. Some of these are customized for the final customer at *Equipar Distribuição*, and this study is focused on these ones. During this work, two main goals were identified: the improvement of the productive process of *Equipar Distribuição* and the creation of a model to support the decision making in the tactical planning of this unit, useful in a context in which demand exceeds the supplier's capacity. In order to achieve the first goal, a literature review on two continuous improvement methodologies, the Theory of Constraints and Lean thinking, was carried out. On the other hand, since the second goal involves multiplicity of criteria, the methodology and respective methods of Multicriteria Decision Analysis were analysed.The improvement of the productive process resulted in the realization of two cycles of the Theory of Constraints. Throughout the first cycle, the packaging process was identified as the constraint. As a result of the improvements implemented the constraint was solved with a 12% increase in productive capacity and a potential additional increase of 15%. In the second cycle the constraint consisted of a cork shortage to process. Therefore, a study was carried out at the supplier of *Equipar Distribuição*, where 5S improvements, Visual Management and Production Levelling were implemented and suggested.The decision process was improved since it was followed a multicriteria methodology where nine stakeholders were involved, who selected, weighted and operationalized five evaluation criteria. This improvement process allows the decision making in accordance with the company interests, in a sustained and justified way.

Keywords: productive process; tactical planning; continuous improvement; Theory of Constraints; Lean Thinking; Multicriteria Decision Analysis.

1. Introduction

The cork, 100% natural material, recyclable and reusable, is present in more than 100 countries. However, Portugal presents itself as the country responsible for bringing cork to the world, being an export leader, with a 65% share (APCOR, 2017).
The cork industry suffered, in the 1990s, enormous pressure from its substitute products. At a time when artificial seals were gaining strength, there was even a chance of losing a market where Portugal is the world leader. However, the strong investment in process improvement, as well as product research and development, has now enabled the majority of the consumers to prefer cork products, returning them to the comfortable position of market leaders.
Corticeira Amorim is the world's largest cork company. It is a sector leader, accounting for around 50% of national exports (Corticeira Amorim, 2017). The success of *Grupo Amorim* is strongly related to the investment made in Research, Development and Innovation, in the improvement of its products and processes. In this context, the present work will be carried out in the cork stoppers Business Unit, the largest one of the company.
This study will be developed on *Equipar Distribuição*, the customization factory of Equipar Industrial Unit. The work herein presented will be focused on the management of the productive capacity of this factory, as well as on the decision support, in its production planning.

2. Literature Review

2.1. Theory of Constraints

The Theory of Constraints (TOC) is a management methodology created in the late 1970s, by Eliyahu Goldratt, through the introduction of a scheduling software, Optimized Production Technology - OPT (Goldratt & Fox, 1986). TOC consists of a management philosophy that has as main characteristic the need to improve the weakest links of a system or organization, in order to increase the efficiency of the whole system (Şimşit et al., 2014). According to Goldratt, TOC can be summarized in a single word: focus (Cox & Schleier, 2010; Pretorius, 2014). The focus should be placed on the constraint and it can be either physical or non-physical constraint (Blackstone, 2001).This methodology evolved from a program for production scheduling, becoming a set of management tools with application in logistics and production, performance measurement, and problem-solving support (Spencer & Cox, 1995).

2.1.1. The Five TOC Focusing Steps

In 1992 Goldratt defined Five Focusing Steps (Goldratt & Cox, 1992) that constitute a methodology of continuous improvement in Operations Management (Pretorius, 2014):

Step 1 – Identify the system's constraint: in this step we proceed to identify the element that determines and, consequently, limits the performance of the system (Pretorius, 2014);
Step 2 - Decide how to exploit the constraint: this step consists of maximizing, with available resources, the efficiency and use of the constraint that limits the system (Pretorius, 2014);
Step 3 - Submit the system to the previous decision: in this step we intend to synchronize all the non-limiting resources with the constraint and with its productive rhythm;
Step 4 - Elevate the system's constraint: This step consists in the addition of physical capacity in the limiting step, which requires investment in new resources, such as equipment and labor (Pretorius, 2014);
Step 5 - Return to step 1: Start a new cycle. This step translates the continuous improvement component of TOC, not allowing inertia to become the constraint of the system.

2.2. Lean Thinking

After the Second World War, Schoichiro Toyoda and Taiichi Ohno created a production system, so-called Toyota Production System (TPS) (Ohno, 1988). Due to this system, applied initially in the Toyota Motor Company, the concept of Lean arises, with the book "The Machine that Changed the World".
Lean production consists of offering the necessary products to the market in the right time and quantities, based on the absolute elimination of waste (Shah & Ward, 2007).Thus, the Lean concept and its application are described in five key principles (Womack & Jones, 1996):
1. Specify the value for each product according to the customer's perspective;
2. Identify value streams for each product or family of products, eliminating waste;
3. Create value by performing actions that create value flow;
4. Let the customer pull the value ("pull srategy") by offering him just what he wants, when he wants (Just in Time - JIT);
5. Pursue perfection by continually removing wastes along the entire value chain.

2.2.1. Lean Tools

The following are the Lean tools that will be useful in this study:
1. Value Stream Mapping (VSM);
2. Root Cause Analysis (RCA);
3. 5S;
4. SMED;
5. Visual Management;
6. Standardization.

2.3. Multicirteria Decision Analysis (MCDA)

The MCDA allows dealing with problems characterized by the presence of multiple and complex criteria that influence decision making. MCDA methods allow all stakeholders to better understand the problem, as it becomes clearer after formalizing criteria and alternatives (Lahdelma, 2000). The MCDA is useful for mainly four types of decision problems: choice, sorting, ranking, and description and should follow this standard methodology:

1- Representation of the problem;
2- Formulation of the problem;
3- Evaluation model;
4- Final recommendation.

2.3.1. Multicriteria Decision Support Methods

The existing literature on MCDA comprises several methods and different ways of describing them. However, according to the book by Figueira et al. (2005), it is possible to find two main categories of MCDA methods, inserted in a context of Multi-Attribute Decision Making (MADM):

Multi-attribute Utility and Value Theories
These methods assign each alternative a number representative of its value through additive or multiplicative models, for example.

Outranking Methods
Outranking methods are characterized by a comparison of alternatives with the objective of determining the preference of each alternative in relation to the others, for each of the criteria.

Considering the problem under study, the model to be applied will fit with the Multi-attribute Value Theory (MAVT) method, because it is intended to associate a real number with each alternative, in order to construct an order of preference between the alternatives, based on an additive value aggregation model.

3. CASE STUDY

This work was developed in *Equipar*, a factory located in Coruche. It belongs to *Corticeira Amorim*, the world leader in selling cork stoppers. The industrial unit is composed by 4 big sections: Grinding unit, TT unit, AGLO unit and EQD. The study was focused on the customization unit (EQD). This, can be understood as the main customer of AGLO unit (which produces agglomerated cork stoppers), since almost all of its production needs customization before the shipment to the final customer. *Equipar Distribuição* is composed by 3 processes that give the final customization to the cork stoppers: Branding, Treatment and Packaging. The **Branding** process consists of placing the mark on the stoppers, as specified by the customer in the order. **Treatment** is a process where a film with lubricating and sealing characteristics is applied to the stopper to facilitate bottling, sealing and extracting. Finally, the **Packaging** is the last step before shipping the product and aims to ensure the product's integrity and most convenient handling for the customer.

The productivity of Equipar Distribuição is below the established internal objectives. In this way, it is extremely important to improve its production flow, by increasing the productive capacities of the processes that limit it and, consequently, turning the whole system more efficient.

On the other hand, the productivity of the EQD is extremely influenced by the availability of cork stoppers manufactured in AGLO unit, which sometimes is lower than needed. Besides that, *Corticeira Amorim* needs to monetize the cork, a finite raw material that has seen its price rise in recent years, so it should be strategically used, whenever possible, in the production of the most profitable products.

Therefore, two major challenges arise to *Equipar Distribuição*, described below and that were analysed throughout the study:

- Improvement of Equipar Distribuição processes.
- Development of a decision support tool which allows taking planning decisions, whenever there is a context in which market demand exceeds *Equipar Distribuição* supply capacity.

4. METHODOLOGY

The methodology of steps followed to develop the work is presented below (see figure 1).

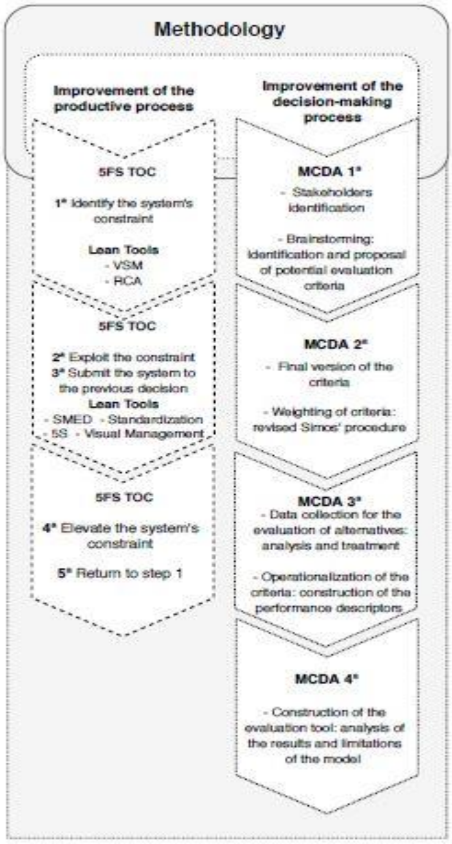

Figure 1 - Methodology applied in this study

For the first challenge, improvement of the productive process, the five steps of the Theory of Constraints are followed (1 - Identify the system's constraint, 2 - Exploit the constraint, 3 - Submit the system to the previous decision, 4 – Elevate the system's constraint, 5 - Return to step 1). The operation of these steps is supported by using Lean tools (VSM, RCA, SMED, 5S, Standardization and Visual Management).

On the other hand, the improvement of the decision-making process follows a Multicriteria Decision Support Methodology divided into four steps: 1 - Stakeholders identification and identification / proposal of potential evaluation criteria; 2 - Final version of the evaluation criteria and weighting them, by using the revised Simos' procedure; 3 - Analysis and treatment of data for the evaluation of alternatives and operationalization of the criteria, through performance descriptors; 4 - Construction of the decision support tool, analysis of results and limitations of the model.

5. Improvement Of The Productive Process

5.1. First TOC Cycle: Identification Of The Constraint

To identify the system's constraint, in a first stage, the theoretical production capacities of each of the sectors were calculated. Next, real production data were used, through the construction of a Value Stream Mapping. Subsequently, in order to show the system constraint, it was made an analysis of the industrial reality, where the variation of Work in Process of *Equipar Distribuição* was studied, as well as the allocation of work on non-working days. Finally, comparing the data obtained, the limiting step of the EQD was identified.

In order to calculate the theoretical production capacities of each stage, time measurements were made on the shop-floor. The theoretical rhythm of each machine was measured, and then, the programmed stoppages were taken into account, such as lunch and setups, for instance. Afterwards, it was decided, together with the heads of the factory, to apply an operational efficiency rate of 85% at each stage, in order to account for losses related to performance and quality in the processes, like is shown in table 1.

Table 1 - Capacity of the processes

	Branding	Treatment	Packaging
Installed Capacity (Thousands/day)	6855,305	5339,0794	5722,56
Installed Capacity (Thousands/hour)	285,64	222,46	238,44
Disponibility (%)	93%	86%	56%
Capacity with programmed stoppages (Thousands/day)	6369,32	4582,71	3191,52
Capacity with programmed stoppages (Thousands/hour)	265,39	190,95	132,98
Efficiency Rate (Performance | Quality)	85%	85%	85%
Effective capacity (Thousands/day)	5413,92	3895,30	2712,79
Effective capacity (Thousands/hour)	225,58	162,30	113,03

From the analysis of table 1 it is possible to infer that Branding is, evidently, the stage where there is greater capacity, both installed and effective. On the other hand, the packaging process is the one with the lowest effective capacity. Thus, an increase in the level of production at this stage may trigger an increase in the overall productivity of the EQD. It should be noted that the effective capacity of the Packaging is 2712.79 thousands / day (equivalent to 113 thousands / hour), for an internal production objective of 2800 thousands / day (117 thousands / hour), which allows us to conclude, with this first analysis, that the Packaging is the stage that restricts the productivity of the EQD.

One of the essential metrics that Value Stream Mapping gives in order to identify the constraint, is the actual cycle time. This, effectively represents the seconds required for each process to produce a thousand of corks. Its calculation has as inputs the total quantity processed in each step for a given number of hours actually worked, obtaining the hourly production, as it is shown below:

$$Actual\ Cycle\ Time = \frac{3600}{Hourly\ Production}\ (sec./thousands)$$

After collecting the results, the conclusion was that the Treatment and Packaging processes have the worst actual cycle times, of 31,47 seconds / thousands of stoppers and 32,29 seconds / thousands of stoppers, respectively.

By studying the industrial reality, it was observed that, from the analysis of the values recorded in eight months (january – setpember 2017), it is verified that the intermediate inventory area Treatment – Packaging, has on average more 420 thousand stoppers than the intermediate inventory area Branding - Treatment. By using the previously calculated actual cycle time (32,29 seconds / thousands of stoppers), it is concluded that, on average, the packaging has a further 3,8 hours of stock to be processed than the treatment.

From the allocation of work on non-working days analysis, it can be observed that of the total amount processed on Saturday, 53% was carried out in the Packaging (25 955 thousands), while 47% corresponded to the Treatment process (22 942 thousands). In addition, in 71% of the analyzed days (22/31), the Packaging processed more quantity than the Treatment, which indicates that although both steps worked, the resources were allocated in greater number or during more time in the Packaging process, because it was the most needed one.

By gathering all the results obtained in this section it was confirmed that the Packaging process is, effectively, the constraint that limits the EQD flow.

5.2. TOC First Cicle: Exploit The Constraint – Improvement Proposals

After observing and studying the wastes in the packaging process, the causes presented below were pointed out as the main focus of concern:

- **Cycle times between packaged bags**

After analyzing the values obtained from the measurements made to calculate the capacities of the sectors, it was possible to conclude that there is a discrepancy in the cycle time to pack cork stoppers type sparkling compared to wine type corks, since for the first one it is higher. In addition, there is still a difference in the average cycle time of line 1 compared to line 2, the latter being slower.

- **Wasted caused by order exchanges / containers**

The Packaging suffers constant stops during the production time. These occur both for the exchange of containers that supply the counting machine, and for order exchange, whenever there is a need to change reference regardless of the type of stopper or customer. Table 2 shows the average stopping times that cause the main unproductivities.

Table 2 - Packaging setups

	Line 1	Line 2
Average time to change containers (minutes)	1,57	
Average order exchange time (minutes)	8,98	13,95
Frequency of order exchanges (number of containers)	3,86	3,27

- **Failures of 5S and Visual Management in the identification of containers**

Most EQD containers do not have any type of support for the product identification labels, which are often bonded with adhesive tape, as shown in figure 2, which creates unnecessary dirt and waste. Another fault present in the identification of the containers is the lack of visual management in the labels, since all of them have the same color and shape, varying only the information written by the operators.

Figure 2 - 5S and Visual Management failures

5.2.1. Improvement Of Cycle Times: Changing Of Counting Machines

In order to improve the cycle time between packaged bags and, consequently, the Packaging stage, a study was made for the counting machines, precedent of the packaging ones. With this study, it was possible to conclude that, the MCE-48 counting machine (located at line nº2) has a cycle time of approximately 50% compared to that of the MCE-24 machine (located at line nº1). After this study it was decided, together with the head of Equipar Distribuição and Industrial Director, that the counting machines should be changed, since the MCE-24 was in line 1, together with the most productive packaging machine, maybe being a constraint on the flow of the latter and, consequently, of the whole line.

This change resulted in a decrease in cycle time by 3 seconds per bag and an increase in cadence by 13,3 units per second. Thus, it can be concluded that the effective production capacity of the packaging stage previously calculated, increased from 113 thousands / hour to approximately 126 thousands / hour, representing an increase of 12%, since the MCE-24 machine was restricting the flow of the most productive line.

5.2.2. Improvement proposal for Setup time: Standard working method

In order to present improvement proposals to reduce setup times, a detailed study was carried out on the packaging line 1, observing and timing the tasks constituting the two types of setups (type 1: order exchange and type 2: container exchange). This study was developed based on the SMED 4 step methodology, adequate to this type of problems. During the first 2 steps of this study it was observed that all the setup tasks are internal tasks, which means that are done with the line stopped. It was also concluded that there are activities that are not standardized, as they are not always performed by the same operator.

In order to transform the greater number of internal activities into external ones, and with this, eliminate the waste inherent to setups, a standard work method was proposed and documented in a Standard Work template. In this new working method, it was suggested the introduction of an operator, designated as logistics operator, responsible for all logistical activities, until then carried out with the line stopped. This operator is essential in the advance preparation of all the necessary resources, to proceed to the order exchange. Following this method, type 2 setup (container exchange) is now considered an external activity, not interfering with the line operation. In type 1 setup, all activities are also transformed into external activities, with the exception of the "Clean the counting machine" activity, with an average duration of 1,93 minutes. This continues to be performed by the operator of choice, with the machine stopped, to ensure a proper line operation. The organizational model of this work would require the stopping of line 2. However, after an analysis of the production and stopping times, it was concluded that it is possible to increase the production time by approximately 39% and consequently , achieve an increase in effective production capacity in the sector of 15% compared to the previous improvement, by changing the counting machines, from an effective capacity of 126,61 thousands / hour to 146,09 thousands / hour.

5.2.3. 5S AND VISUAL MANAGEMENT IMPROVEMENT PROPOSALS IN CONTAINER IDENTIFICATION

In order to solve the 5S and Visual Management identified failures, some improvement proposals were suggested.

A new support was suggested to identify the containers (shown in figure 3).This support is made of stainless steel and instead of being bolted to the container, it has a shape that allows it to fit on either side, ensuring flexibility. Thus, after the Treatment process, the containers can continue to be disposed sideways, however, it is possible to place the support so that the operators can easily see and identify the product.

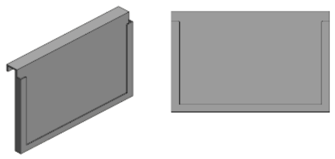

Figure 3 - Suggested support to the container tags

New tags were also suggested. These contain all the necessary information to identify the product and have a field to be placed in the future that will be generated by the Manufacturing Execution System, currently being implemented in the Group. However, the biggest advantage of these new labels is that they follow a color coding depending on the required stabilization period, for a given type of cork stopper or applied treatment. Thus, three types of labels were suggested, as it is shown in figure 4.

Figure 4 - Suggestion of new labels with color coding

5.3. TOC SECOND CYCLE: IDENTIFICATION OF THE CONSTRAINT

After the work developed in the Packaging stage, the productivity of Equipar Distribuição remained under the objectives, but at this time, having as main cause the shortage of AGLO cork stoppers. Thus, at the moment, the constraint was at EQD supplier and, therefore, outside the system studied until that moment. Because of that, it was carried out a study in the AGLO unit in order to suggest/implement improvements that could enhance the service level.

Note that, AGLO unit also packs part of its producted stoppers for other customization units of the Group. The weekly quantity to pack in this unit is decided by the Central Logistics department and has, logically, direct impact on the availability of cork stoppers for EQD. However, another of the main causes for the shortage of the intended quantity of stopeers is related to the fulfillment of the production plan, since this is done based on EQD's production plan. Thus, to confirm the identification of the constraint, it was made an analysis about the degree of compliance with the plan, for nine weeks (March and April 2018), as can be seen in figure 5.

From the analysis of the graph of figure 5, it can be concluded that, in addition to a decreasing trend, the degree of compliance with the production plan presents fairly low values, with an average of approximately 49%.

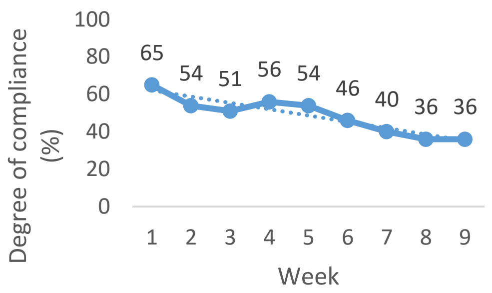

Figure 5 - Degree of compliance with the production plan (AGLO)

5.3.1. TOC SECOND CYCLE: EXPLOIT THE CONSTRAINT – IMPROVEMENT PROPOSALS

Having has main objective, the presentation and implementation of improvements, the main sources of waste identified, that contribute to the non-compliance of AGLO production plan, are presented below:

- **5S and Visual Management failures in the production orders board**

After monitoring the process, it was verified that the plan introduced in the shop-floor by the production manager, at the end of the week, for the planning of the Washing stage (a process developed at AGLO unit), presents many inefficiencies (see figure 6).

As can be seen in figure 6, the boarder consists of 16 production orders, one for each article. However, on average, it is necessary to weekly produce 37 articles and therefore, that space is not enough to allocate all articles. So, the need to place more than one article in each production order is quite often present. In addition, there is no visual management, what makes the board more difficult to understand. In this way, the production board is very confusing and difficult for the operators to read, making it slow to understand which items are behind schedule.

Figure 6 - Production orders board of the Washing stage

- **Lack of visual information regarding the destination of each container**

After the Washing process, the containers go through the Eletronic Choice process and are then placed in the final inventory before packaging or customization in EQD. On the shop floor, both the production orders board as well as the containers do not have the information regarding the destination of each container after the Eletronic Choice process. Therefore, the EQD provider (operator who transports the containers from AGLO to EQD unit) often has to request for information and ask if he can carry certain containers, as these may be required to pack in AGLO unit.

- **Failures of planning production levelling between units**

The planning of Equipar Distribuição is carried out weekly, based on its portfolio of orders. This is adjusted by the Central Logistics department of Amorim & Irmãos, taking into account its production capacity against the portfolio of orders. Every Thursdays, the responsible for *Equipar Distribuição* plans the following week, based on the adjustments made by the central logistics department, as well as the internal available capacity. However, this process does not take into account AGLO's production capacity or its availability of stoppers for EQD. Thus, sometimes, the weekly planning of Equipar Distribuição contains an exaggerated amount of Sparkling / Wine stoppers or the distribution by type of cork stopper is not equitative throughout the week. Therefore, the need for readjustment in the production planning is frequent.

5.3.2 Improvements in the materials and information flow: 5S and Visual Management

In order to minimize the wastes identified in the first two points of the previous section, a new boarder of production orders for the Washing process was suggested and implemented, as shown in figure 7. This, with the same dimensions as the previous one, has capacity for 37 articles, so that it is now possible to clearly observe the production orders for each article. In each line is allocated an article, as well as all the necessary information for its production and traceability.

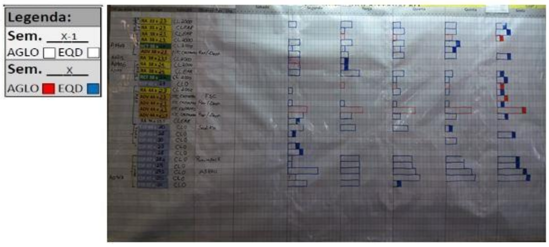

Figure 7 - New order production board for the Washing process

This visual method enables to take decisions in a quicker way and to have an overview of all the articles, avoiding forgetting and mistakes by operators. In order to facilitate the reading of the board, identification labels were also created, which respect the color coding already existant in the unit.

Additionality, it was created a flow of information from the logistics manager of Equipar IU to the operators of the AGLO unit and EQD provider. Therefore, the Logistics manager sends the weekly planning to the production manager, informing him about the destination of each container after the washing process. This information is transmitted to the operators through a color coding created for the production orders board (figure 7). After that, for all the containers that will be packed at AGLO unit (lower percentage), a black label identifying them is attached (figure 8), while the others are destined to EQD.

Figure 8 - Containers' identificative labels

5.3.3 Levelling of the Production Plan between EQD / AGLO units

An analysis of the productive capacities of the AGLO unit was carried out, with the support of the Industrial Director of Equipar IU and the responsible of AGLO unit. The analyisis was done for the Extrusion and Molding processes, because it is here that are formed the cork bodies which will define the type of cork stopper to be produced.

The results of this study showed that there is a total productive capacity of 15,616 million corks per week. Nevertheless, it was decided to establish a maximum limit of 90% of the capacity for EQD orders, taking into account the stoppers that are not destined to EQD, although this amount is weekly decided by the central logistics. In this way, it was concluded that in its weekly orders, *Equipar Distribuição* can hold a maximum of approximately 5 million Sparkling and 9 million Wine Stoppers (4,397 without Advantec and 8,933 Advantec). Based on this analysis, it was suggested a change to the EQD production planning template, with the introduction of a table that, according to the orders included in the plan, returns the daily and weekly amount per type of cork stopper (figure 9).

	2ª	3ª	4ª	5ª	6ª	Total
Espumosos	1538	1166	908	782	937,6	5331
Vinho s/ advantec	445	730	1075	1025	378	3653
Advantec	227	400	275	456	975	2333
0+1 / 0+2 / TTGR	70	0	0	0	0	70
TOTAL	2280	2296	2258	2263	2291	11387

Figure 9 - Production levelling between units

With the introduction of this table, whenever planning the EQD, it is possible to have the perception of the quantities that AGLO will need to produce daily and weekly. Thus, whenever the maximum weekly quantities defined are exceeded, their respective Excel cell in the planning file automatically turns red, warning that the production plan can not be realized because the desired stoppers will not be available to EQD, unless there is stock from the previous week.

6. Improvement Of The Decision Making Process

6.1 Stakeholders identification and Proposal of potential evaluation criteria

The stakeholders involved in the construction of the decision making support tool were identified and invited to participate, with the objective of creating a multidisciplinary working team that allowed to obtain several inputs translating the sensibility and experience of all the stakeholders in the process. In this way, the selected actors represent an added value for the construction of the model, since the problem of decision is in the interest of all, and these, because they have different responsibilities within the organization, have different points of view regarding the problem. In this way, 9 stakeholders from various departments were selected.

After the presentation of the problem and the identification and selection of stakeholders, the formulation of the model started with the preliminary identification of possible evaluation criteria. The proposal for the first set of criteria resulted from a brainstorming conducted at Equipar IU, where 8 potential criteria were identified:

g1): Consolidated gross profit margin of the customer at Amorim & Irmãos (€);

g2): Gross margin of the customer in Equipar Distribuição (€);

g3): Strategic client / "premium";

g4): Customer with logistic specifications;

g5): Date of order entry into the system - First In First Out (FIFO);

g6): Deviation from the annual sales budget provided by the customer;

g7): Number of orders to postpone;

g8): Compliance with the level of service pre-established by *Equipar Distribuição*.

6.2 Decision Conference – Final version of the Evaluation Criteria and Criteria Weighting

Decision conferences are made up by an impartial facilitator, in this case, the author of this study, and the other stakeholders, who know and have an interest in the problem.

The eight potential evaluation criteria that resulted from the brainstorming process were sent in a survey format for each of the stakeholders. Subsequently, all the stakeholders answered to the surveys, in order to choose the final version of the evaluation criteria. The results of the survey are presented in figure 10.

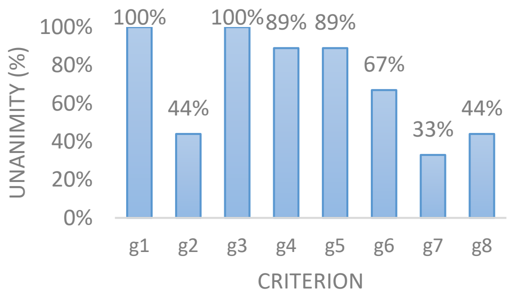

Figure 10 - Unanimity of the potential evaluation criteria

By the graph analysis it is possible to infer that the majority agreed the ones that should be present in the evaluation model are: g1, g3, g4, g5 and g6, even though the last one with only 67% of unanimity. After the discussion and sharing of opinions between the stakeholders, the agreed final version of the evaluation criteria is presented in figure 11. Note that, the criterion g5 has changed, even though the 89% unanimity in the survey. That change happened because of an identified gap. This criterion would benefit the customer who had their order introduced into the internal system of the company first. However it does not have any kind of correlation with the date that the customer wants to receive the order. So it was agreed by the stakeholders that this criterion should be changed for “Production date planned for the order”.

Figure 11 - Final version of the evaluation criteria

For weighting the criteria it was used the Revised Simos’ Procedure (Figueira & Roy, 2002). This method allows the decision makers to easily express their opinion and weight the criteria by ranking cards (corresponding to criterions) from the last to the most relevant. Afterwards they are asked to put blanck cards between each subsequent criteria which represents the difference of importance between consecutive criteria. Lastly, the decisors are asked about how many times is the criterion on the top more important than the one on the bottom (ratio Z). The results of the weighting are shown in figures 12 and 13.

From the analysis of figure 13, it is shown that the criterion g5 was considered the least important, with a normalized weight of 2,86%, in opposition with criterion g1 (the most important) with 34,38% weight. Note that the ratio Z defined by the stakeholders was 12.

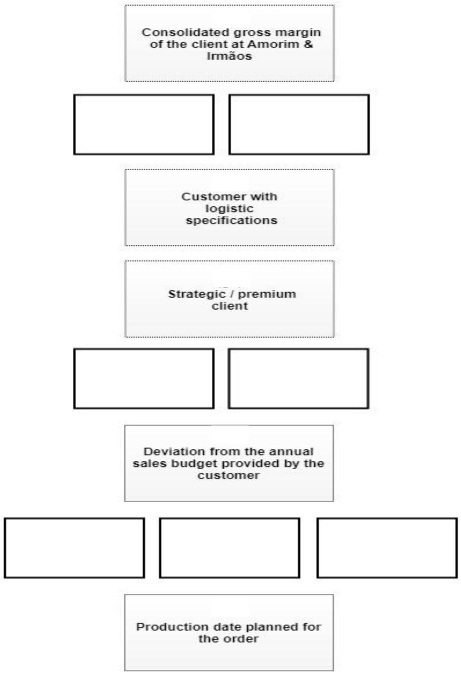

Figure 12- Weighting of the criteria (ranking)

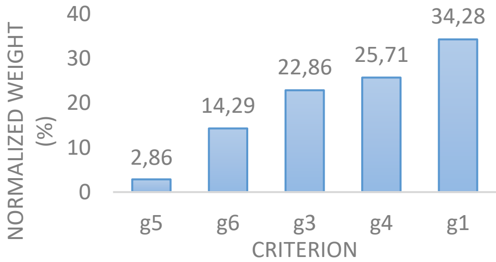

Figure 13 - Normalized weights

6.3 Operationalization of the criteria and construction of the model

To operationalizate the criteria and construct the model, it was necessary the collection and processing of information, in order to construct databases. Besides that, performance descriptors were defined for each criterion, for operationalization. A performance descriptor consists of an ordered set of performance levels, which aims to measure the degree of satisfaction that each criterion presents, objectively describing the impacts on the options of each criterion. In the context of this work, it was decided together with the decision makers to introduce two levels of reference performance in all descriptors: "Very high priority", which is assigned a score of 1 and "No Priority" whose score is 0. In addition to these, each descriptor may have additional levels, which correspond to other plausible performances of the criteria.

Having the databases for the operationalization of the criteria created, as well as the respective descriptors and levels of performance, the decision aiding model is successfully developed.

7. Final conclusions

The first improvement cycle started with the identification of the system constraint. In this stage, it was concluded that the Packaging process was the constraint, which was later explored. The cycle time of the packaging lines was acted upon by switching the counting machines from line 1 to line 2, and vice versa, which allowed an effective capacity increase of 12% (from 113,03 to 126,61 thousands / hour). In addition, a SMED analysis was performed, with the purpose of reducing setup times. A new standardized working method has been proposed for packaging line number 1 with the introduction of a logistics operator, which resulted in a potential effective capacity increase of 15% to 146,09 thousands / hour. Finally, proposals for improvement of 5S and Visual Management were suggested for the identification of containers, which directly affect the Packaging process.

A second cycle of TOC was carried out at AGLO unit, with the aim of improving its service level and the availability of cork stoppers for EQD. The existence of this restriction was identified by the scarcity of stoppers to process in *Equipar Distribuição*, which was proven with the low degree of compliance of AGLO production plan (approximately 49%). In this cycle, the restriction was explored through improvements in the flow of information and materials, using 5S and Visual Management, with the introduction of a new board for the production orders in the Washing process and also new identification labels for the articles and containers. Finally, an amendment was proposed to the Excel file where production planning of *Equipar Distribuição* is carried out, with the objective of levelling the planning of the two units (EQD and AGLO) and, consequently, increase the service level.

In order to improve the decision-making process in *Equipar Distribuição's* planning, whenever demand exceeds market supply capacity, a multicriteria decision support methodology (MCDA) was followed. A review of the literature on Multicriteria Decision Analysis, methodology and main multicriteria methods was done. In this way, it was decided to divide the methodology into four main stages: in the first stage, were identified the stakeholders that would have an impact on the development and approval of the model and the identification of potential evaluation criteria. From this stage, resulted in the identification of nine stakeholders and eight potential criteria. The final version of the evaluation criteria was then defined and weighted in a decision-making conference. In this phase, the eight criterion initially identified were filtered, from which the five final criterion were obtained and weighted. The third step consisted of the operationalization of the criteria, through the collection and processing of information for the construction of databases and the definition of descriptors, as well as the respective levels of performance. Finally, having the model created and operationalized in an Excel tool, the decisors are able to make decisions in a sustained and justified way.

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