Implementation of lean methodologies in the production planning of process industries
The case study of Company X

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Abstract

The consumer demand and competitive pressure in current markets have increased its complexity over the past few years. This trend has also been observed in food processing industries and has led companies to be more aware of their both material and information flows and focused on their optimization to ensure the high service level demanded by customers.

Company X is nowadays one of the largest tomato paste and fruit purées producer worldwide. They have become more aware of the production planning (PP) impacts on achieving results, ensuring competitiveness to sustain their business. Currently, Company X's PP system presents some structural problems that may compromise the company's medium term results. In this context, the lean methodology has been presented and widely applied as a strategy that allows organizations to leverage their performance in multiple industry sectors, through the value creation and waste reduction in operations.

After conducting a state-of-the-art review in both tools and methodologies associated to the lean thinking concept, a methodology was developed, focused on the design and implementation of a PP system, based on a pull supply strategy, which intends to overcome the Company X challenges.

After the implementation period of the proposed improvement activities, the service level for the plastic line increased 9.0%, the OEE increased 8.8% and the forecast accuracy planning indicator increased 38.8%. There were also gains in reducing the inventory management complexity and increasing the visibility of information flow along the supply chain.

Keywords: Lean methodology, production planning, process industry, pull system, filling line.

1. Introduction

The growing demand for diversified products adapted to consumer needs and requirements has been one of the main challenges for the management of organizations (Guo et al., 2015). Combined with a highly competitive market, it is fundamental to guarantee a high service level in the delivery demanded by customer, through the satisfaction of the requests in the correct place and at the desired lead time (Görener et al., 2013). According to Vachon et al. (2009), the increasing performance and efficiency of the productive systems are considered determining factors for obtaining competitive advantages and customer satisfaction. Thus, organizations have sought out different strategies to meet these new challenges (Zhang et al., 2012). The lean methodology, has been implemented in several industries and business areas. It has been presented as a strategy that allows companies to leverage their performance by increasing productivity, reducing lead time and costs, as well as increasing product quality and better services to the final customer (Shah and Patel, 2018).

Food processing industry has shown a high growth over the past years, driven by the increase of new market competitors and customer demand. The combination of these factors has changed industry trends and led to a constant need for optimization of production planning (PP) models. Therefore, the PP is considered one most important pillars for the management of these organizations, being responsible for determining both sequence and optimal quantity of the production cycles and ensuring an efficient inventory management (Fauza et al., 2015). Food processing industry companies have become more aware of the production planning (PP) impacts on achieving results, ensuring competitiveness to sustain their business. Company X is one of this companies. Nowadays, Company X is one of the largest tomato paste and fruit purées producer worldwide, that intend to develop an effective and sustainable methodology to assist the PP, based on the lean philosophy, in order to ensure the increasing demand and a high service customer level.

The application of lean methodologies and tools in PP for discrete production industries is very common. In the last years, the high number of successful cases in these industries has led several authors to make efforts to adapt the lean philosophy to the process industries (Abdulmalek et al., 2015). The particularities of these industries, coupled with the limited systems flexibility, demand variability, long production cycles and setup times, lead to the study and implementation of lean tools and methodologies to production planning inprocess industries. Therefore, this paper has two main goals: on a first stage, it aims to analyze the initial situation of the Company X, identifying limitations particularly focused on the production planning process, in order to highlight improvement opportunities and the optimization of operations to increase the service level. Later, the main purpose is to implement proposed improvements in the real context of the Company X and present the achieved results, promoting the application of lean methodologies in process industries.

The paper is structured as follows: On section 2, Company X is presented and a complete problem statement is presented. Then, on section 3, the lean methodology is characterized through the use of a literature review. On section 4 is design and implemented the new planning system, based on the pull flow. On section 5 the results are analysed and discussed. Finally, in section 6 some conclusions are drawn.

2. Problem statement

Company X is nowadays one of the largest tomato paste and fruit purées producer worldwide.

The company wants to provide a diversified portfolio of tomato products that meet the increasingly demanding needs of its customers in three different sectors: industrial, food service and retail. In order to guarantee a quality of excellence in the products delivered to the customer, the company has activities in four distinct business areas, which are part of the Company X value chain: 1) agricultural process; 2) industrial process; 3) retail process and 4) storage.

This set of activities allows to obtain different products and guarantees a complete control and traceability in the productive process, from the seed to the final product (Johnson et al., 2014). However, this paper will focus only on the retail process. Currently, Benavente's industrial retail unit has five filling lines available, which allow to pack the products, produced in the industrial kitchen, in glass, plastic, Tetra Pak and cryovac pouches. The focus of this work is the plastic line, since it is the only one to operate during three shifts a day (24 hours a day, 7 days a week) and is identified as the most constrained capacity flow.

As a result of the application of its strategies of growth and differentiation, the company has verified an increase in revenues, resulting from the increase in the number of items sold. However, due to its capacity limitation, the company currently has difficulties in meeting the demand of its customers. After analysing the number of stock-outs (occurred in 2017) in the four types of products that serve the retail & food service market, it is verified that 82% of total stock-out occur in the products produced in the plastic line. As a consequence, the Company X has a customer service level of 89%, which is reflected in an approximate monthly average of 58.000€ in loss of potential sales, associated with the non-satisfaction of 11% of orders placed by customers in the right quantity and no lead time agreed. The service level calculation is obtained according to Eq. 1, where S_i represents the total quantity sold and NS_i the quantity that is not available to satisfy the customers' orders in the desired lead time.

$$Service\ level = \frac{S_i}{NS_i + S_i} \quad (1)$$

Despite the positive evolution of Company X's sales, the high investment costs made it impossible to acquire a new filling line. In this way, the optimization of the existing line is presented as a solution for the medium term.

3. Literature review

According to the American Production and Inventory Control Society (APICS), a process industry is defined as "a business that adds value to the material through mixing, separation, formation or chemical reaction, where the processes can be characterized as continuous or discontinuous and generally require high capital investment" (APICS, 2016). The production systems of a process industry have a low flexibility, caused by the high production cycles associated with the long downtimes for setups (Abdulmalek et al., 2006; Pool et al., 2011). As a result of limited flexibility, the need for visibility and optimization of material and information flows throughout the supply chain becomes essential to ensure the level of service. In the same context, food processing industries are subject to significant challenges in production planning (PP), since this activity is responsible for determining when, where and how to produce the set of products (Carvalho, 2015). Over the last few years, the lean methodology has proven to be an alternative that guarantees quick results when it is appropriately adopted by different actors along the supply chain. The main advantages of implementing the lean philosophy are associated with increased productivity of systems and operations, cost reduction and lead time and quality improvement, delivering greater value to the products and services delivered to the customer (Hicks, 2007; Shah and Patel, 2018). The optimization of PP and inventory management are fundamental activities in the management of a supply chain. Sangeetha et al. (2015), Fauza et al. (2015), Liang (2013) and Soman et al. (2004) argue that production planning is one of the main activities in a food process industry, since these industries are characterized by high perishability of the products. In addition, the PP ensures that an organization has the necessary requirements to meet customer demand, in the desired lead time and in the right quantity (On Time In Full, OTIF), minimizing the total cost associated with inventory along the supply chain and maximizing profit, in order to guarantee the competitiveness of the business (Nagib et al., 2016; Liu et al., 2016). The pull system, also known as Just-in-Time (JIT), is identified as one of the pillars supporting the implementation of the lean philosophy (Liker, 2004). JIT arises with the objective of achieving continuous improvement in a production system, through the implementation of methodologies that allow production without inventory, which means, by supplying the necessary quantity at the right moment – just in time. In this sense, when the customer generates an order at the end of the chain, the item produced in the previous phase is transferred to replenish the finished product supermarket, and so on, so that each step operates in Just-in-Time to satisfy the downstream stage (Baykoç and Erol, 1998). In order to ensure the correct implementation of the JIT system, it is essential to use small production batches to maximize the material flow and minimize the Work in Progress (WIP) and the final product inventory, allowing that operations produce only what the successor operation requires (Alcaraz et al., 2014). This system therefore requires very short cycle times and setup times to ensure process flexibility (Cusumano, 1985). For the successful implementation of a pull system, MTS, MTO or MTS-MTO hybrid methods are used, as well as other lean tools, which highlight the kanban system and multiple production cycle planning techniques. At the same time, the SMED and TPM methodologies are fundamental in obtaining competitive advantages as tools to support the implementation of a pull system. However, there is also a lack of articles focusing on the implementation of lean tools in production planning in process industries. Thus, the study of this problem refers to the importance of developing a methodology with the potential to assist organizations in this decision making.

4. Proposed methodology and its characterization

The present section intends to describe the steps of the proposed methodology for solving the problem under study in the dissertation. The methodology used aims to design and implement a production planning system, based on the pull concept, to overcome not only the Company X challenges, but also other industries with similar characteristics. It is intended for this methodology to address in an integrated way the tools studied in the literature review, as well as aspects such as production leveling, inventory management and operational efficiency.

The methodology proposed for the problem addressed in this dissertation is divided into four main stages, as represented in Figure 1.

4.1. STAGE I – Value Stream Mapping (VSM)

In order to get a complete and detailed view of both materials and information flows along the value chain and to promote the development of an optimization strategy for Company X operations, the Value Stream Mapping (VSM) tool is used.

After this analysis it is concluded that the Company X presents itself as an organization with a flow totally inserted in a push system. In addition, the company is organized according to a functional model, which means that all productive tasks, from departmental organization (production, logistics, planning, etc.) to the shop floor, are separated by functions. A functional division isolates and creates waste (such as high stocks and lead time), increases complexity management and reduces the visibility through the chain.

It is also relevant to identify the key critical points in the efficiency of the plastic line and at the management of the finished inventory products that compromise the ability to respond to customer orders. Thus, the main inefficiencies and improvement opportunities were identified during the development of the VSM:

- Limited Production capacity by the level of resources, since the plastic line operates 24 hours a day, throughout the year;
- The setup time is the main factor responsible for downtime of the line;
- Finished product inventory misaligned with customer demand;

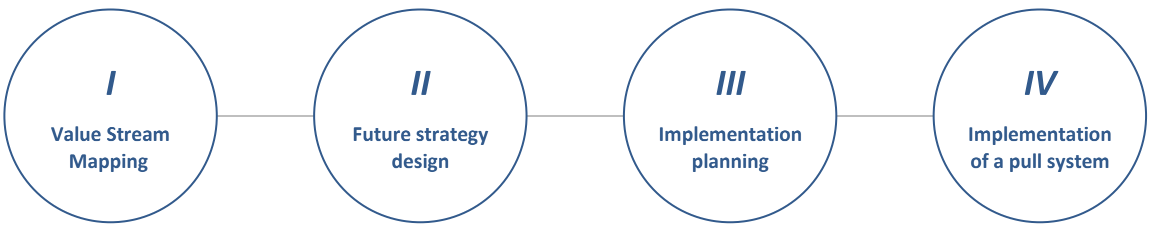

Figure 1 – Etapas da metodologia utilizada para a resolução do problema em estudo na presente dissertação.

- Lack of a planning tool that supports the decision-making process on the development of the weekly production plan;
- Sharing information is time-consuming and inefficient;
- Constant changes in the proposed production plan, whose seriously undermines the stability of operations along the value chain.

4.2. STAGE II – Company X future strategy design

As stated in the VSM, the production planning of the Company X follows a push philosophy, characterized by launching production orders and creating stock of PA based on the demand forecast of company's customers. Among the several opportunities identified, the implementation of a pull philosophy in the value chain stands out in the scope of this dissertation. Therefore, it is intended to implement a pull system that operates according to the actual customer demand, either in MTO (make-to-order) products through Just-in-Time production, or in MTS (make-to-stock) through the creation of a FP supermarket. However, the full change of the planning system to a pull philosophy implies the adoption of new rules and the definition of strategies for line capacity sizing, inventory control and customer communication.

Based on the finished product stock level is carried out the release of production orders. Thus, it becomes essential to change the way of managing the company's inventory. Therefore, the stock definition of each reference appears as an extensive study of several factors in order to ensure the inventory leveling over time, avoiding the occurrence of stock-out.

The new inventory management strategy that is intended to be implemented is called supermarket.

The new pull planning process, proposed for the Company X, assumes a MTS-MTO replenishment method, identified as a hybrid strategy that allows the adaptation of MTS and MTO replenishment methods to a given product profile.

In order to obtain a successful implementation of this strategy, it is necessary to study all FP references of the plastic line and classify them in MTS or MTO according to the ABC-XYZ classification model.

The FP supermarket model, to be implemented during the improvement project for MTS products, presupposes the quantification of the following parameters for each one of the references: replacement level, batch size, safety stock and maximum quantity of stock. In the future strategy it is intended that when the stock of a given MTS reference exceeds the calculated value for the replenishment level, an electronic *kanban* is launched. This *kanban* acts as an alert for a new production order of that reference. The main difference between the new model and the push system (used in a first stage by the company) is to restore the inventory according to the customer's real demand. In this way, the stock remains leveled over time and the safety stock level helps to overcome unexpected situations.

Finally, in order to facilitate the complete control of the production planning operation of the Company X, it is suggested to develop a production planning support tool (PPTS), an operational dashboard that aims to integrate the set of tools designed to the pull system and streamline the flow of information. PPTS intends to include MTS's supermarket management and electronic *kanbans's* control, MTO's order management, levelling box and production sequencing with the incorporation of setup times between the various references. PPTS has as main output the weekly production plan.

The pull planning system in parallel with PPTS facilitates the integration of all operations and allows the company to benefit from numerous advantages, namely reducing management complexity, increasing the visibility of information along the value chain, and in the increase of the service level in the delivery of the final product. Following the future state mapping, the results that are expected to be achieved after the implementation of the proposed solutions are established. The defined Key Performance Indicators (KPI) are used to evaluate the performance of the company during the improvement project and allow to compare the results obtained with the initial situation of the Company X.

Table 1 summarizes the three KPIs defined to evaluate the project. A weekly periodicity was defined for the collection of the results of each of the indicators, so as to monitor their evolution on a regular basis, ensuring that they achieve the desired results.

Table 1 – Project's KPIs.

Key Performance Indicator	Baseline	Target
Forecast accuracy planning (%)	N/A	90%
OEE (%)	68%	75%
Service level (%)	89%	98%

4.3. STAGE III – Implementation planning

This section aims to plan, over a time horizon, the various phases of the implementation strategy, through the sequencing of proposed improvement activities, in section 4.2. Although applied to the Company X, the strategy is defined and presented in a generic way, so that it can be adapted and replicated in companies with similar challenges to those identified in this case study, namely in food processing industries. For this purpose the concept of Gantt chart, much used in the context of project management, is used. The Gantt chart allows project managers to accurately map in a visual way the different stages of the project, from their main objective to the detail of each activity (Steinfort, 2017).

Following future state mapping and taking into account the macro context of the project, the implementation of the proposed solutions is divided into three vectors of action:

1) Increased line efficiency:

In order to increase the efficiency of the line, the SMED tool and the TPM methodology are used in the first three phases of the improvement project. At the end of the third phase, the results obtained are collected, which allow updating the calculations made in the sizing of the productive capacity.

2) Implementation of a pull planning system:

For the effective implementation of a new planning model integrated in a pull system it is necessary to carry out a set of actions. In the first phase, the company has to make decisions regarding the production strategy of each

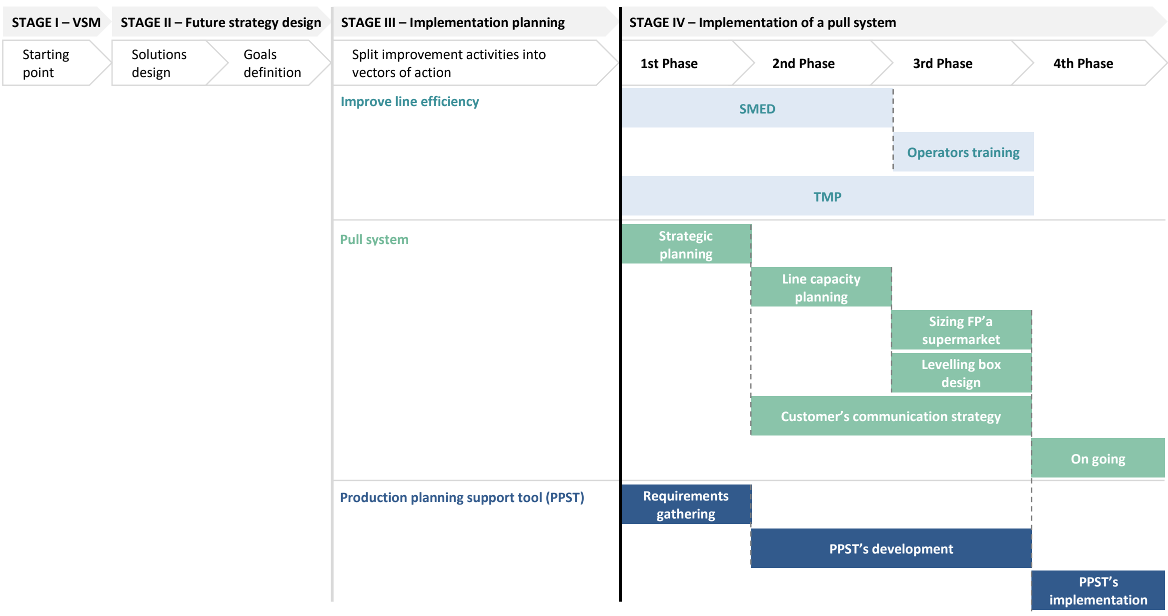

Figure 2 – Improvement project's implementation strategy.

reference, namely if a given product is defined as MTS or MTO. For this purpose the ABC-XYZ classification will be used. Next, capacity planning is developed in order to size the respective production capacity of the filling line. In the third phase, the finished product's supermarket is dimensioned in parallel with the design and construction of the levelling box. In addition, during the second and third phases the new customer communication strategy is put into practice. Finally, the new pull system is integrated with PPST.

3) Development and implementation of PPST:

In order to build the PPST, it is necessary, in the first instance, to collect the main requirements that should be considered. Subsequently, during the second and third phases, development takes place. Finally, and after the previous steps, the tool is implemented in the business context of the Company X. The implementation proposal is shown in Figure 2.

4.4. STAGE IV – Implementation of a pull system in the plastic line

In this section, the improvement activities in the business context of the Company X are implemented. In this stage, lean methodologies and tools are applied in order to overcome the identified limitations.

4.4.1. Increase line efficiency

After the implementation of tools such as SMED and TPM, a 35.7% reduction in the average setup time was obtained, and decrease of 20% in downtimes was verified. In this sense, the line performance indicator, OEE, increased by 8.8% over its initial value, which means an increase of 8.8% in the production capacity of the plastic line.

4.4.2. Implementation of a pull planning system

The steps developed in this section aim to implement a new planning system in the value chain of the plastic line, based on the concept of pull supply and adapted to the needs of the Company X.

1) Strategic planning: In order to redefine the company's planning strategy, the ABC-XYZ classification model was used, based on the 2017 consumption. The two criteria used for the ABC-XYZ classification of the products are: the total volume consumed in 2017 (in €) and the frequency of consumption. As a result, 58% of the total references are MTS and 42% are MTO. The strategic planning of finished products (FP) references allowed Company X to change its inventory management model. In addition, a procedure was developed to update the ABC-XYZ classification in each semester, given the constant changes in the market. The tool was developed and implemented in Excel in order to facilitate its use.

2) Capacity planning: The sizing of the installed productive capacity had as main result the determination of the Every Part Every Interval (EPEI) value for the line under study. EPEI is considered fundamental for the later calculation of the several parameters associated with the implementation of a pull system. After completing the necessary calculations it is concluded that the plastic line has the capacity to produce all the references in cycles of 37 days.

3) Sizing of the FP's supermarket with incorporation of kanban system: Following the strategic definition of references, it is necessary to create inventory management standards for products classified as MTS. The new concept of inventory management implemented in the Company X is designated as a supermarket. For its implementation, the parameter values for each of the 55 current references of the portfolio of plastic line products were defined: replenishment level, batch size and safety stock. The implementation of the FP's supermarket for the MTS references of the plastic line allowed to size the replacement levels and lot sizes according to the actual demand of the market and installed productive capacity of Benavente's factory. These parameters, when calculated individually for each reference, led to a reduction in the risk of stock-out as well as a reduction in the need to constitute stock to combat this risk. In addition, the definition of batch sizes according to the EPEI concept allowed to align the frequency of rotation of the products with their typology of consumption, ensuring a higher level of rotation.

4) Levelling box: The levelling box is a component of the pull system that aims to facilitate the production planning. This tool contains time divisions over the stipulated production period (e.g. one day, one week, etc.) that allows to plan the production according to factory's installed capacity. The filling of a portion of the box is calculated taking into account the speed of the line, its efficiency, as well as the quantity needed to produce. The levelling box allows to be displayed in a visual form the following information: product sequence to be produced on the plastic line; time and day of entry of each reference in production; time and day of the setups. The levelling box's upload developed for the plastic line is made through the *kanbans*, which are triggered from the P supermarket designed for the MTS references and by introducing the production requirements for the MTO orders. After the identification of the references that exceeded the replacement level, it is necessary to sequencing them in the time horizon. In this sense, two fundamental rules have been defined that allow to optimize the sequencing of the production, in order to increase the efficiency and the capacity of the line: to group references of the same format in order to reduce the change of format' setups; and sequencing the references within the same format in order to decrease the washing setups of the tubes and the filler. The new method of sequencing the references decreased the total time spent with the plastic line' setups.

4.4.3. PPST's development and implementation

The production planning support tool (PPST) was created with the objective of integrating all the tools that make up the pull planning system, into an operational dashboard, in order to speed up the analyses of information considered relevant to the preparation of the weekly production plan. In a workshop where the Company X's project team and an internal element of the Kaizen Institute (myself) were present, all the information requirements that the tool should contemplate were defined. During the second and third phases of the implementation phase, several meetings were held with the information technology (IT) team where, in an iterative process, the functionalities of the tool were discussed, in order to accommodate all the requirements defined initially. These interactions with the IT team also played a key role in supporting the development of PPST in the supermarket management module and levelling box, facilitating the process of integrating information extracted from the ERP. A tool utilization standard was developed to help the planning department develop the production plan weekly. The sequence of steps for the development of the production plan is represented in Figure 3. Nowadays, with the implementation of PPTS, the planning team has a set of tools that allows them to elaborate the production plan through a visual and objective approach. This solution has improved the effectiveness of the production planning process on a weekly basis and will have enormous medium-term influence given the major change in the company's management paradigm that has ceased to work under "infinite capacity".

5. Conclusions and future work

The application of lean tools and methodologies in a cohesive and integrated way allowed Company X to implement in the value chain referring to the plastic line, a pull planning model aligned with the actual behaviour of the consumer. After analysing the initial situation and designing the future strategy, the improvement activities were grouped into three main vectors and were implemented in parallel over four phases. The methodology used had a positively impact in the result of the three important performance indicators established for the improvement project. However, it should be noted that the results presented do not depend only on an applied tool or methodology, but rather on the set of improvement activities implemented throughout the process. After the implementation period of the proposed improvement activities, the service level for the plastic line increased 9.0%, the OEE increased 8.8% and the forecast accuracy planning indicator increased 38.8%. There were also gains in reducing the inventory management complexity and increasing the visibility of information flow along the supply chain. The results of the KPIs monitored during the improvement project on a weekly basis are summarized in Table 2.

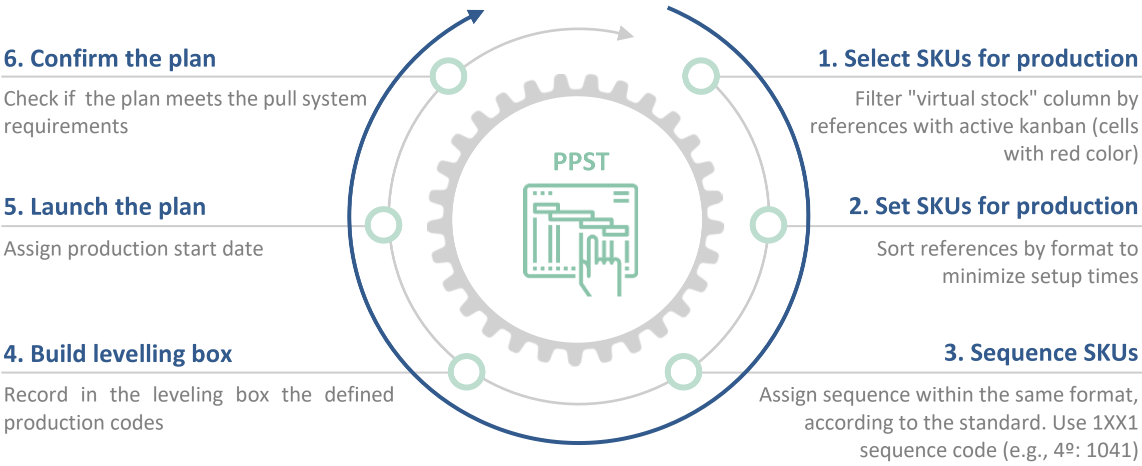

Figure 3 – Steps for the development production.

Table 2 – Results of project's KPIs.

Key Performance Indicator	Baseline	Target	Last 4m (average)	Variation
Service level (%)	89%	98%	**97%**	**+9,0%**
OEE (%)	68%	75%	**74%**	**+8,8%**
Forecast accuracy planning (%)	67%	90%	**93%**	**+38,8%**

The value of the final result of each KPI is calculated according to the average of the last four months, so that the sample is solid and comparable to the value of the baseline that was calculated based on the results of the six months prior to the beginning of the project. Regarding the results established for the project, the indicators of service level and OEE did not reach the objectives initially proposed, despite their significant increases. On the other hand, KPI forecast accuracy of planning that exceeded the defined objective. In this context, due to the limited duration, some further improvement opportunities are to be considered in future work.

First, it is essential to continue the work developed during the improvement project in order to ensure that the results achieved so far can be amplified in the future. The efficiency activities of the plastic line should be carried out in a cyclical way to ensure the continuous improvement of the processes and operations. In addition, the information used for the implementation of the pull system must be updated over time so that the parameters defined throughout the process follow the evolution of the market conditions, as well as the improvements made to the level of production efficiency.

The scope of the present work had as its main focus the plastic line due to its capacity constraints. However, as future work it is suggested that the work presented throughout the dissertation be replicated, with the appropriate adaptations, for the remaining lines of the plant: glass line, Tetra Pak line and cryovac pouches line. With the implementation of the pull system in the remaining lines it is expected to obtain significant results in the overall service level of the plant, since 18% of the verified breakages correspond to the non-sale of products from these lines.

In addition, the scope of work was restricted only to the production process and inventory management of the finished product. However, it was verified in the initial situation study that the process of acquiring and managing the inventory of raw material (RM) and packaging material (PM) is not standardized, compromising the stability of production planning. In this way, it becomes relevant to extend the pull system upstream of the supply chain, and extend this concept to the process of purchasing RM and PM. Using the supermarket's implementation method of finished product in the plastic line, this methodology can also be applied to the inventory that supplies the production line. In addition, changing supplier relationships can lead to the introduction of a Just-in-Time model in the supply of materials, leading to a significant reduction in warehouse's stock and consequently to a decrease in costs.

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