Development of Tools and KPIs to Monitor Semi-finished Product Stock Replenishment in a Particle Board Company

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Abstract

In an environment increasingly characterised by competitiveness and dynamism, businesses must preserve a competitive edge by implementing appropriate methods for rapid adaptability to new circumstances and fostering consumer loyalty. A bottleneck in the planning, production, or storage operations can limit organisation's responsiveness and, as a result, the level of customer satisfaction in an industrial context. To reduce failures caused by production delays and to obtain a competitive advantage in lead time, many businesses maintain an inventory of semi-finished items. However, to effectively run a manufacturing system, it is essential to have the required stock levels in the proper locations.

This project concerned the semi-finished products' warehouse of one of the company's factories. This factory moved from an MTO only to an MTO-FTO stock management approach. Controlling and adjusting the stock levels of semi-finished products proved challenging with this change in strategy. This project focuses on determining and monitoring the stock levels of semi-finished items, and its goal is to design a solution that minimises stock shortages and surpluses.

Based on the literature review analysed in this report, a buffer was constructed for each product following established criteria and project restrictions. The size of the formed buffer zones varies based on data inherent to each product and this buffer is continuously checked.

Considering the need to make performance evaluations and thereby identify improvement needs, several performance indicators, such as the quantity of *Stockouts* and *Surpluses*, were produced based on the buffers developed. It was also analysed the product layout in the warehouse, controlling the number of positions that hold different products, which should be avoided in the context of this warehouse.

Since how information is presented has a considerable impact on how it is interpreted, various tools were developed in SAP to assist in visualising the generated data, allowing the information to be made available to everyone.

The attained results underlined the adaptability and applicability of the method to the problem initially presented, thus proving to be a suitable proposed solution for the company. *Stockouts* for these semi-finished products were reduced by 13 per cent, while *Surpluses* in m^3 were decreased by 64 per cent.

This project yielded satisfactory outcomes, including pertinent examples and recommendations for future developments.

Key Words: Stock Level Monitoring, Buffer Sizing, Key Performance Indicators, Visual Tools

Resumo

A adoção de estratégias adequadas que permitam uma rápida adaptação a novos contextos bem como a promoção de relações de fieldade com os clientes são fulcrais para que as organizações possam manter uma vantagem competitiva no ambiente vivido na atualidade, cada vez mais marcado por competitividade e dinamismo. A existência de um estrangulamento nos processos de planeamento, fabrico ou armazenamento num ambiente industrial pode limitar a capacidade de resposta da empresa e, consequentemente, o nível de satisfação dos clientes. Por este motivo, diversas empresas mantêm inventário de produtos semi-acabados com o fim de diminuir as falhas devido a atrasos na produção e para ganhar vantagem competitiva no lead time. No entanto, revela-se fundamental a capacidade de ter as quantidades necessárias de stock nos locais apropriados para gerir um sistema de produção.

O estudo deste projeto deu-se no armazém de produtos semi-acabados de uma das fábricas da empresa. Essa fábrica alterou de um sistema de produção de stock exclusivamente MTO para um sistema misto MTO-FTO. Nesta mudança de estratégia foi sentida uma dificuldade em controlar e ajustar as quantidades de stock de produto semi-acabado. Este projeto foca-se na determinação e monitorização dos níveis de stock destes produtos, sendo o objetivo do mesmo o desenvolvimento de uma solução que minimize situações de falta ou excesso de stock.

Com base na revisão de literatura estudada e apresentada neste relatório, desenvolveu-se um buffer para cada SKU de acordo com regras definidas tendo em conta as restrições deste projeto. O buffer desenvolvido é monitorizado e reajustado numa base contínua e o tamanho das suas zonas é variável e depende de dados intrínsecos a cada produto.

Tendo em conta a importância de fazer avaliações de desempenho e assim identificar as necessidades de melhoria, criaram-se diversos indicadores de desempenho com base nos buffers desenvolvidos, tais como a quantidade de *Stockouts* e de *Surpluses*. Estudou-se também a disposição dos produtos em armazém, tendo-se controlado a quantidade de posições que contém diferentes produtos misturados, o que é de evitar no contexto deste armazém.

Uma vez que a maneira como a informação é apresentada tem um impacto significativo na forma como é interpretada, foram desenvolvidas diversas ferramentas em SAP que ajudam à visualização da informação gerada, o que permitiu que as informações ficassem ao alcance de todos.

Os resultados obtidos sublinharam a adaptabilidade e aplicabilidade do método ao ambiente do problema, revelando-se assim uma proposta de solução pertinente para a empresa. Obteve-se uma redução de 13 por cento nos *Stockouts* relativos a este produtos semi-acabados e também uma redução de 64 por cento na quantidade de *Surpluses* em m^3.

Este projeto produziu resultados satisfatórios, o que suscitou exemplos e propostas relevantes para desenvolvimentos futuros.

Palavras Chave: Monitorização de Níveis de Stock, Dimensionamento de Buffer, Indicadores Chave de Performance, Ferramentas Visuais

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"I'm a greater believer in luck, and I find the harder I work the more I have of it."

Thomas Jefferson

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Acronyms and Symbols

BOM Bill Of Materials

DBM Dynamic Buffer Management

DDMRP Demand-Driven Material Requirements Planning

ERP Enterprise Resource Planning

FTO Finish-to-Order

IT Information Technology

JIT Just in Time

KPI Key Performance Indicator

MDF Medium Density Fibreboard

MRP Material Requirements Planning

MTO Make-to-Order

MTS Make-to-Stok

OSB Oriented Strand Board

PB Particle Board

SAP System Applications and Products in Data Processing

SKU Stock Keeping Unit

TMG Too Much Green

TMR Too Much Red

TOC Theory of Constraints

WIP Work-in-progress

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Chapter 1

Introduction

This chapter describes the context of the project discussed in this report and the project's objectives, motivation, and methodology. In addition, a description of the company where the project was conducted and the dissertation's organisational structure are provided.

1.1 Company Overview

This dissertation project was conducted at Sonae Arauco, a division of the Sonae Group. Sonae is a multinational firm headquartered in Portugal that handles a diverse portfolio of enterprises in the retail, financial services, technology, shopping complexes, and telecommunications sectors.

Sonae Industria, founded in 1959, is a worldwide manufacturer of wood-based panels. From the north of Portugal, it developed items for the furniture, construction, and decoration industries and exported them worldwide. Since its beginning, Sonae Industria has been devoted to sustainably utilising natural resources and minimising the environmental impact of its operations to the greatest extent possible.

Sonae Arauco was founded in 2016 due to a partnership with Arauco, one of the world's largest producers of forest resources. In addition to this strategic alliance, Sonae Industria now owns the largest particleboard manufacturing plant in North America and high-pressure laminate and furniture component factories in Portugal and Germany. Sonae Arauco currently has 22 industrial and commercial operations in 9 countries and 2 continents, employing around 3000 people globally. It exports its goods to more than 75 nations.

Sonae Arauco offers a wide variety of products, the most notable of which are particleboard (PB), medium-density fibreboard (MDF), and oriented strand board (OSD). All of these materials represent an adaptable and eco-friendly alternative to solid wood.

1.2 Project framework

This project was part of the Dissertation course, a component of the last year of the Integrated Master in Industrial Engineering and Management at the University of Porto's Faculty of Engineering. One of the primary goals of this internship was the development of professional skills, as well as the application and expansion of knowledge gained at the Faculty of Engineering. The project was developed in a business context at Sonae Arauco's Maia-based facilities in partnership with the Information Technology (IT) Department.

Sonae Arauco proposed the project intending to identify the relevant key performance indicators to monitor the system and develop visual tools to control the inventory quality, minimising stockouts and excess material inventory at one of the company's plants.

1.3 Project Motivation and Objectives

The primary areas of production management are the transformation of raw materials into completed goods and the administration of the production system, production planning, and business activity control (Grabot et al., 2014). The proposed challenge incorporates examining the production planning procedure as the second emphasis area.

Since its beginning, the factory where this project was implemented has utilised an MTO system. As its business volume grew over the years, the company constantly reacted to keep up, but it never attempted to predict or prepare for the future. The range of products expanded, but the business maintained the same production strategy.

In a market where customers are becoming more demanding and impatient, a disappointing performance may lead a company to lose market share by reducing its competitiveness. According to Mason-Jones and Towill (1999), market performance measures such as a high service rate and short lead times for customised items are a unique selling proposition and, thus, add value to a business.

A change in production was required to increase the company's operational performance. The deployment of a hybrid FTO/MTO production system was proposed in an effort to reduce uncertainty regarding production quantities and time, hence increasing its competitiveness. In situations like the one analysed in this essay, where a business has a broad product line and client base, the most effective approach to serve it is through an optimal combination of FTO/MTO systems (Kaminsky and Kaya, 2006). According to Kaminsky and Kaya (2006), hybrid systems perform significantly better than MTO or MTS systems when product features and demand parameters vary widely.

A redesign of the manufacturing strategy enabled a rise in production efficiency and a more rapid response to client requests.

Specific objectives were proposed in relation to this new transition of the production strategy from pure MTO to the hybrid FTO/MTO system. These were centred on the analysis of the semi-finished products in the Linares warehouse of the company's factory, with this analysis focusing exclusively on FTO products. Unwanted stockouts or surpluses were noticed in these FTO items, which was detrimental to the company. It was also highlighted that it was difficult to control these values due to the lack of a model that could quickly analyse these scenarios so that planners could perform corrective action.

The project's objectives include discovering a way for levelling semi-finished product stocks and designing a system that minimises circumstances of stock insufficiency or surplus in order to quickly define suitable dynamic stock levels based on demand data. Another aim is to design a procedure that identifies the required quantities for each product and, if necessary, the necessary adjustments.

1.4 Methodology Followed in the Project

In order to achieve the objectives described above, the project carried out at Sonae Arauco followed a methodology that can be divided into several phases, presented below.

In the beginning, to correctly comprehend the company's global operation, training was provided in many areas to increase the understanding of these. In addition, a visit to one of the company's factories provided insight into the type of products manufactured as well as their manufacturing method.

In the second phase, the focus was on collecting and analysing data. This information was derived primarily from Sonae Arauco's ERP system, *SAP*. The initial situation was then analysed through the observation of stock levels, enabling the development of key performance indicators such as the number of SKUs in excess or in stockout whose purpose was to be reduced or even eliminated.

In order to be able to address the presented problem, there was a period of research into stock management techniques, specifically systems for visual and efficient stock monitoring.

In the final phase, the many solutions discovered concerning the topic analysed in this study were adapted to Sonae Arauco's reality and implemented in the appropriate context. Finally, the outcomes gained through the various stock management monitoring tools employed were evaluated based on variables such as the number of stockouts and the quantity of excess stock.

1.5 Structure of the Dissertation

This dissertation consists of five chapters: introduction, theoretical framework, issue framework,

methodological approach, conclusions, and future work perspectives.

This chapter enables contextualising the business environment in which the project was created and describing the project's rationale, scope, and objectives. The definition of the methodology and the structure of the report are also briefly discussed here.

The second chapter, titled "Literature Review," combines all pertinent information regarding the issues discussed throughout the project, as well as a study of the current state of the art that contributes to the solution of the problem. It consists of academic material and practical applications.

Following the third chapter is a description of the company. The corporation Sonae Arauco's history, activities, and products are described. In addition, the company's planned case study and the research objective for this project are described. Potential improvement areas are also identified.

The fourth chapter presents the proposed and implemented enhancements to address the challenges discovered throughout the project, and the suggested measures are reviewed.

A summary of the completed work is provided at the end of the dissertation, in chapter five. This section analyses the achievement of the planned objectives. It establishes connections between the concepts and knowledge gained during the bachelor's and master's programmes and the work completed during this internship. Exposure is given to potential future projects that can be done and/or enhance the value of this project.

Chapter 2

Literature Review

This chapter revisits the theoretical principles that are thought to be framed in the project's areas of action and served as the basis for the project's goal achievement. Therefore, it begins with explaining the significance of monitoring inventory levels and their management models. In the following sections, ideas associated with the theory of limitations and DDMRP are defined. The relevance of information and its visualisation in businesses is then highlighted. Lastly, the importance of performance measurement in companies is discussed by establishing the idea of key performance indicators and explaining in detail the factors to be considered when choosing one.

2.1 Stock

Stock can be defined simply as everything that can be stored someplace within an organisation, whether these products' size is small, medium, or large, integrating the company's rotation and ensuring a quick and effective delivery (Souza et al., 2018). Generally, stock in an industrial context comprises products that contribute to or are part of the company's final product, such as raw materials, work in progress, components, consumables, semi-finished products and finished products (Jacbos and Chase, 2016).

Stock management is becoming a more central subject in organisations as it is a highly valued component of business management. It not only immobilises capital but also entails additional expenditures. As a result, it is critical to maintain a minimum stock level. However, this reduction may compromise product availability, thus compromising the company's sales.

Numerous factors contribute to businesses maintaining inventory, defined as the organization's stock of any product or resource used. An inventory system is a collection of procedures designed to govern inventory levels. In addition, it defines what stock levels must be maintained, when they must be supplied, and what order quantities must be placed. According to Jacobs et al. (2004), the primary reasons businesses hold stock are: to maintain operational independence, to comply with customer service standards, to cover unique circumstances such as unexpected demand and seasonal fluctuations, to provide scheduling flexibility by acting as a buffer between demand and supply, to react in the event of a supply or production failure and also to achieve economies of scale in purchasing.

Along with the numerous benefits associated with stockpiling, it is critical to emphasise that it requires a significant capital investment. As a result, maintaining high inventory levels is a substantial risk for the business and implies commitment, given the requirement to consume the products kept (Pinto, 2006). According to Yuan et al. (2003), the primary decision affecting stockpiling is between two distinct management approaches: maintaining a high level of inventory to meet peak demand and ensure availability, or maintaining a low level of stock to save money, reduce returns owing to obsolescence, expired shelf life or engineering changes, while maintaining quality.

Classification of Production Systems

As claimed by Soman et al. (2004), the vast majority of research on operations management classifies production systems as Make-To-Order (MTO) or Make-To-Stock (MTS).

MTS systems satisfy customer demand with stocked inventories of finished goods. Once the production process is complete, the finished product is stored until the customer's order is received. Any design or engineering process is completely avoided in this manufacturing system, as the product is assumed to be completely defined. Because the production of make-to-stock systems is driven by replenishment policy rather than demand, these systems are also called push systems. High storage costs, fast delivery times and limited customisation flexibility, according to Peeters and van Ooijen (2020), are all features associated with these systems.

A significant advantage of this system is that the lead time of the product after the customer's order is produced is far shorter than that assigned to other traditional systems, owing to material availability and the absence of design and engineering processes. However, this system has some associated downsides. Because this production system is highly dependent on the accuracy of the data utilised to generate the sales forecasts used to initiate production orders, any error in these estimates can result in either a shortage of finished material or extremely high levels of stocked product. Having a large amount of raw material, work-in-process, and finished products in storage directly impacts a business's cash flow, as all of these stored units are comparable to money sitting idle and waiting to be redeemed. This can become a problem for newly founded businesses, as many small and medium-sized businesses have had cash flow challenges at some point due to "stagnant" money in their warehouses (Morais Júnior et al., 2018). Another danger of this production technique is obsolescence or expiration of perishable goods.

In contrast to MTS systems, consumers' demand directly drives MTO systems, which results in products being manufactured in response to customers' requests. Since orders initiate production in a make-to-order system, these systems are also called pull systems. Pull systems, Peeters and van Ooijen (2020) claims, are distinguished by long delivery times, high flexibility, and cheap storage costs, as opposed to push systems. Kingsman et al. (1996) claimed that, due to the absence of inventory, research is typically focused on production control and order acceptance.

An advantage of the MTO system is that the costs of product storage at different stages of production tend to be zero or much lower than other methods such as MTS. This is because the product in process or work-in-progress will be limited solely to the units being produced, and the finished product inventory will be zero because those units have already been sold. Therefore, the inventory costs are reduced, and the risk of a product spoiling or deteriorating due to storage is relatively low. On the other hand, the company has no money tied up in inventory, and its cash flow is much better. The drawbacks can be boiled down to two critical areas. The first disadvantage is increased lead time because the product must be prepared from scratch. The second concern is that in the event of a spike in demand, it would be unable to respond, resulting in client loss due to a lack of response.

Although these techniques are widely discussed in the literature, in practice, production systems are increasingly adopting hybrid production systems, such as MTO-MTS or MTO-FTO strategies, rather than pure MTO or MTS strategies (Stevenson et al., 2005). The MTO-MTS technique is a hybrid of the two previously discussed strategies. By combining these two strategies, the strengths of these two methods can be leveraged, and their weaknesses minimised. This hybrid production enables businesses to reduce delivery time frames and inventory costs to capitalise on the advantages of delayed differentiation. However, this combination involves a trade-off, as it may increase complexity by requiring more objectives and constraints to be considered simultaneously (Peeters and van Ooijen, 2020).

Almost every industry is under intensive pressure from the market to reduce delivery times. It is difficult, if not impossible, for these businesses to change finished items to suit the specifications of newly received customer orders. Thus, rather than MTO, it is usual to begin production of conventional and routine items without receiving confirmed orders while maintaining an inventory of semi-finished goods. These semi-finished products are then customised to the specifications of the buyer (Fernandes et al., 2015). This manufacturing technique is referred to as assemble-to-order (ATO) or finish-to-order (FTO) and is frequently used combined with MTO production in these businesses (Blackstone and Cox, 2008). In industries with a high demand for customization and lengthy lead times, assemble-to-order is a very appealing method.

An FTO system's advantage is that the product's lead time is slightly more competitive, falling between the MTS and MTO lead times. On the other hand, by using sub-assembled sets that do not belong to a single product, the risk of obsolescence is reduced, as the in-process product can be used to assemble other finished products if one of them in the line were to exit the market for any reason. However, as with the MTS strategy, there is a risk of product expiration and obsolescence. While it can be lessened by matching several final products, it still occurs when raw material is held.

2.2 Stock Management

The objective of selecting a stock management policy is to answer three essential questions: "How much to order?", "When to order?" and "Which products to maintain in stock?" - to save expenses, satisfy customers, and provide a desired level of service.

Two primary categories of models can be used to solve these questions: stochastic and deterministic (Ziukov, 2015). Deterministic models (single-period models) acknowledge that demand and supply are entirely understood and exhibit no randomness. Non practise, these models are inapplicable due to the inherent unpredictability of demand and lead time in the commercial environment. In contrast, stochastic models are utilised when a scenario contains randomness. Stochastic models are of interest in this project (Ziukov, 2015).

As mentioned by Jacbos and Chase (2016), there are two primary stochastic systems: the Continuous Review Model (or fixed point system) and the Periodic Review Model (or fixed interval system). These two aforementioned models share a similar premise: the idea behind inventory position (Simchi-Levi et al., 2004). The real-time inventory position comprises the actual stock at the facility plus any products requested but not yet delivered by the company, minus items on backorder.

2.2.1 Continuous Review Model

The maximum stock level "*S*" and the reorder point "*s*" are the two factors that define this inventory review model. According to Simchi-Levi et al. (2004), when the inventory level reaches or falls below the *Reorder Point*, on the image identified with the letter *s*, it should be executed an order to increase the stock to the order-up-to level, identified in the image with the letter *S*. An (*s, S*) policy is also known as a min-max policy. In a continuous review approach, the inventory level is shown in Figure 2.1.

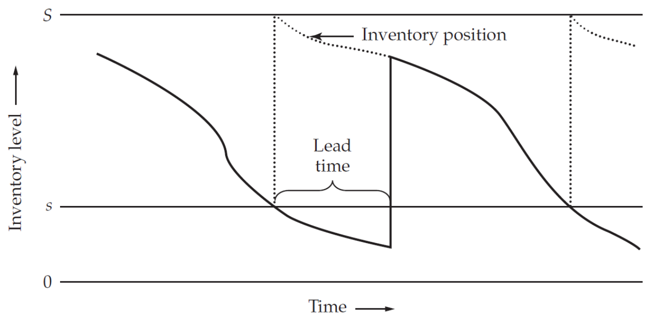


Figure 2.1: Inventory Level in a Continuous Review Model
Source: Simchi-Levi et al. (2004)

The reorder point (ROP) system calculates when should orders be placed depending on the number of component units available. There are two parts to calculate the *Reorder Point*. The average demand throughout the lead time comes first, followed by the safety stock (Davis et al., 1983). According to Blackstone and Cox (2008), safety stock is inventory held to defend against forecasting errors and absorb any demand or supply changes. ROP is computed using safety stock, average demand and lead time.

The fixed order quantity model has the benefit of allowing for lower average inventory levels. Hence, it should be utilised for more crucial materials. As these models demand constant inventory monitoring, they enable faster detection and resolution of potential stockout issues. The downsides of this model include the difficulty of usage when significant and frequent fluctuations in consumption occur and the challenge of grouping many different products in the same order (Reis, 2005). In a continuous review policy, such as the Reorder Point Method, the inventory level is continuously monitored, and orders are automatically generated when the stock level falls bellow a specific limit. This type of policy has a risk period equal to the supply lead time and entails less need for safety stock.

2.2.2 Periodic Review Model

In most practical settings, a constant review is impractical. More commonly, the inventory is evaluated at regular intervals. A periodic review policy has defined timings for checking the stock level and for an eventual allocation of orders, which happen with a certain periodicity. The risk period for this policy is equal to the time until the subsequent verification, added to the supply lead time, implying a greater need for safety stock. A periodic review model results in a larger amount of inventory, thus increasing procurement costs. However, the fact that the review of different items is done simultaneously can lead to the generation of joint orders, which can bring savings in production, purchasing and transport and can lower administrative costs. Therefore, the question of which model is best depends on each company's particular situation and each one's analysis of this trade-off (Ballou, 2004).

As mentioned by Blackstone Jr and Cox (1985), the inventory position is analysed at each review interval point. Then, a replenishment order is made for an amount necessary to restore the inventory level to the base-stock level, i.e., the target level. Figure 2.2 shows the inventory level in a periodic review model.

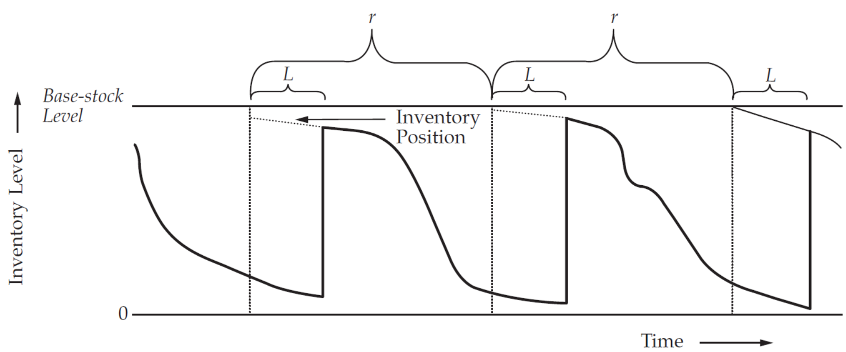


Figure 2.2: Inventory Level in a Periodic Review Model

Source: Simchi-Levi et al. (2004)

2.3 Theory of Constraints

Eliyahu M. Goldratt introduced the Theory of Constraints, often known as TOC, in 1984. Several principles related to organisations' continual performance improvement were introduced in the author's book "The Goal" The fundamental concepts of Optimised Production Technology (OPT), the Five Steps of Focus approach, the Drum-Buffer-Rope (DBR) production scheduling and control methodologies Buffer Management (BM) were written forth in this book (Ikeziri et al., 2019).

Goldratt considered TOC as "an overall theory for running an organisation". This is a technique for identifying and removing constraints to achieve organisational goals. According to Goldratt (1990), a constraint is anything that prevents an organisation or institution from progressing towards its goal. In accordance with the work's title mentioned above, the authors stated that an organization's objective is "to create more money today and in the future," which is the crucial concept of this strategy (Cox III et al., 2010).

TOC can be described in the following manner (Ikeziri et al., 2019):

- A minimum of one constraint must exist in every system. If this was not the case, a real system, namely a profit-making corporation, would be able to earn an endless amount of profit. Hence, a constraint "is anything that limits a system from achieving higher performance versus its goal" (Goldratt, 1990);

- To identify opportunities for improvement, the constraints serve as a reference point. This is why in TOC, restrictions are seen as constructive rather than detrimental. As a system's performance is determined by its constraints, gradually raising these constraints will result in an improvement in the system's performance.

The Theory of Constraints discusses the concepts of Dynamic Buffer and Dynamic Buffer Management in the context of Stock Management (Ikeziri et al., 2019). The TOC concept is to define a safety and to continuously monitor its use. This safeguard is referred to as a buffer. A buffer is a quantity of stock of a specific product that is kept on hand to mitigate the impact of a constraint observed during the manufacturing process (Schragenheim, 2006).

2.3.1 Dynamic Buffer Management

Dynamic Buffer Management (DBM) is a mechanism proposed by TOC for managing the size of the buffer. The DBM technique aims to track and alter the amount of SKU buffers based on their behaviour and demand responsiveness. This is why the buffer size is dynamic.

This model can assess the defined stock levels and indicate the need to revise them based on the demand behaviour and product stock evolution (Ikeziri et al., 2019). This methodology's primary purpose is to decrease the need for sales predictions and projections based on statistical studies and to ensure a more consistent and adequate response to demand changes.

TOC divides the buffer into three controlled areas: green, yellow, and red. One-third of the buffer is contained in each zone (Yuan et al., 2003), as seen in Figure 2.3. These colours correlate to the Buffer Status (BS), indicating the available stock amount. The BS of each product dictates its replacement priority (Takami Narita et al., 2021).

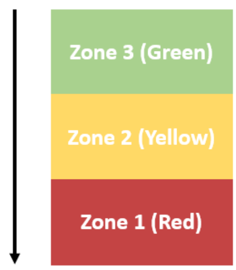


Figure 2.3: The three fixed zones in TOC' Dynamic Buffer Management

Source: Yuan et al. (2003)

The first section corresponds to the bottom boundary of the buffer, which is shown by the red zone. In this area, the inventory at the point of consumption is at risk of running out. This region suggests that the stock has a higher-than-anticipated consumption, signalling a potential risk of rupture. In these instances, it is crucial to evaluate the degree of penetration. If the buffer falls deeper into the yellow zone, caution and preparation are required. This region indicates that the stock is below the targeted level, suggesting a shift in demand or a one-time high in demand. The final zone corresponds to the green region, indicating that the buffer is sufficient to meet demand. However, if the buffer level continues in the green zone for a lengthy period, this could suggest that the buffer has to be readjusted to meet current demand (Cox III et al., 2010).

The DBM technique is designed to issue two warnings to the manager, one when the buffer size is too large and the other when it is too small.

The crucial value for determining whether the buffer size is too large is when the actual stock compared to the target is unreasonably high for an extended period of time (e.g., staying in the green region for three consecutive replenishment periods). When the buffer penetration of an SKU has been in the green zone for too long, the stock buffer limit for that SKU should be changed downward. Too Much Green is the name given to this situation (TMG).

A similar technique is utilised when deciding whether the buffer size is too small. Too Much Red (TMR) is the name for this situation. In other words, the actual stock amount remains in the red zone following repeated replenishments based on the stock buffer size. These algorithm settings differ from those used in TMG since the risk-seeking to minimise here is a stockout, whereas in TMG is to avoid overstocking. The TMR condition's core algorithm is to see if an SKU has been in the red for numerous days (usually using the replenishment time as the number of days parameter) (Cox III et al., 2010).

However, it is essential to note that resizing a buffer necessitates a large number of iterations to ensure that no actions are made prematurely or ineffectively (Yuan et al., 2003).

2.4 Demand Driven Material Requirements Planning

Demand Driven Material Requirements Planning, DDMRP, integrates new inventory management ideas and has MRP, JIT, and TOC as starting points. Businesses can better adapt to variable demand by adjusting inventory levels while preserving or even improving service quality thanks to the DDMRP (Orue et al., 2020). This approach includes five steps (Figure 2.4).

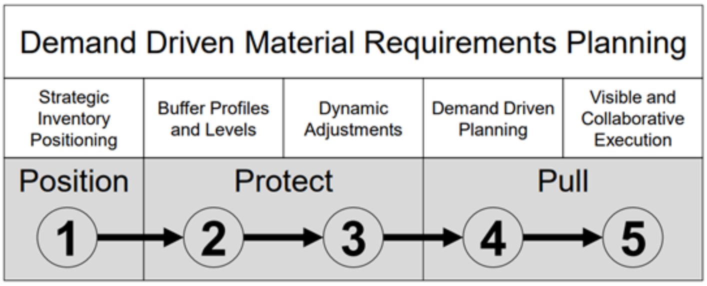


Figure 2.4: The five phases of DDMRP
Source: Ptak and Smith (2016)

Phase 1: The inventory is strategically positioned. In order to protect the flow of the supply chain, it is required to implement decoupling points, which reduce the impact of demand and supply fluctuation. To determine where these sites should be inserted in the supply chain, buffers must be applied to the raw materials, intermediate goods, and final products that pass through these points.

Phase 2: Buffer Profiles and Levels. At this stage, buffer zones are calculated separately for each position, and buffer group profiles are constructed to generate buffer zones with comparable features collectively. In this second phase, the level of protection at decoupling points is specified. Besides the risk of inventory obsolescence, maintaining excessive inventory levels necessitates an overabundance of funds, supplies, and storage space. Conversely, insufficient inventory might result in lost sales and costly rush orders (Ptak and Smith, 2016).

As seen in Figure 2.5, the DDMRP approach includes three buffer zones, each of which serves a distinct purpose. The purpose of this visualisation is to facilitate decision-making through visual management. To determine the size of each zone, variables such as average daily consumption, minimum order quantity and decoupling maturation period are utilised (Ptak and Smith, 2016).

The zones are designated as green, yellow, and red. Green indicates an inventory position that requires no action; yellow indicates a component that has begun its rebuild or replenishment, and red indicates a product that is in danger and requires immediate care. Once the net flow equation falls below the yellow zone's top, an order (replenishment or production order) is issued to bring it back to the green zone's top. In other words, the green zone reflects the typical frequency of orders and their quantity, the yellow zone represents orders that have yet to be delivered, and the red zone represents the safety zone, designed to absorb variability spikes. (Shofa and Widyarto, 2017).

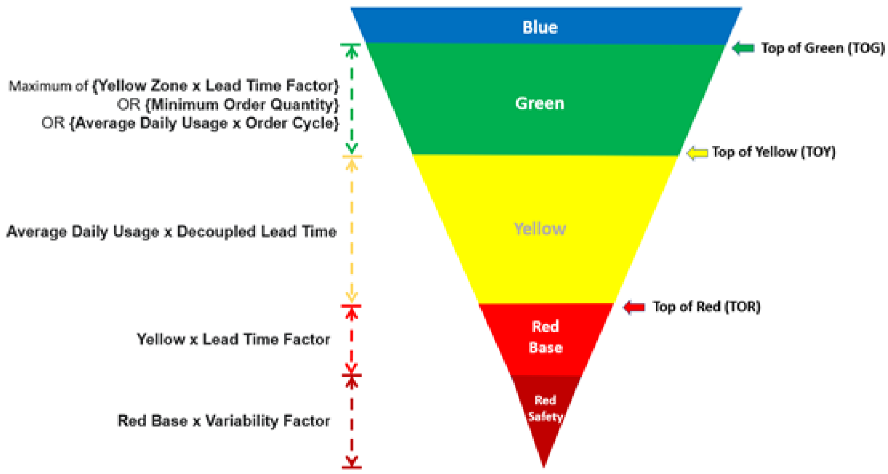


Figure 2.5: Division by Colour Performed in DDMRP

Source: Ptak and Smith (2016)

There may be additional colours available, as can be seen in Figure 2.5. The first additional zone denotes an overstocked position or On Top Of Green (OTOG). This area is light blue. This is referred to as the "white zone" by a few authors. Last but not least, the brilliant red zone indicates an out-of-stock issue with demand. This is referred to as the "black zone" by a few authors. This colour-coding system will be utilised for prioritisation management in both planning and execution as visibility is a key aspect of the DDMRP solution's effectiveness. The colour coding will indicate, from a planning standpoint, if additional supply is required based on the net flow position equation, seen in Equation 2.1 (Ptak and Smith, 2016).

$$(On-Hand)+(On-Order)-(Qualified\ Sales\ Order\ Demand)=(Net\ Flow\ Position) \quad (2.1)$$

Phase 3: Dynamic adjustments. To guarantee that the buffer is always appropriate in relation to demand, it must be dynamically modified on a daily basis to reflect market movements.To accomplish this goal, dynamic modifications are provided by DDMRP based on operational characteristics, market changes, and upcoming planned or known occurrences (Ptak and Smith, 2016).

Phase 4: Demand-driven planning. At this point, actual demand is factored into the calculation, determining when and how much should be refilled. The supply orders are generated by this component (production orders, purchase orders and transfer orders). DDMRP uses the net flow equation to provide the supply order suggestion signal for buffer replacement concerning time and quantity. When the net flow position value is entered in the refuelling zone, the DDMRP creates and recommends a supply order. The value is represented by the yellow buffer zone in the colour scheme, while the supply order amount reaches the top of the green dimension (Ptak and Smith, 2016).

Phase 5: Visible and collaborative execution. This approach differentiates between planning and execution. The planning phase concludes when the agreed proposals become open ministerial instructions. The management of open supply orders to protect and encourage inventory movement is referred to as execution. DDMRP employs distinct colour-coded warnings to enhance order visibility and prioritisation. The alerts draw attention to issues requiring an immediate response. According to Ptak and Smith (2016), in this approach, the corporation may effectively prioritise orders based on the state of the available buffer instead of depending merely on the delivery date.

2.5 Information

Currently, every area of management strongly depends on data. Information is a vital resource and is required for the development of other resources. Consequently, it must be managed like any other resource in an organisation to ensure its efficient use. According to Adeoti-Adekeye (1997), information is the element that ties an organisation together. Because it is intangible it is vital to identify the crucial distinctions between this resource and others when developing a management framework.

According to Stonecash (1981), information is the basis for making decisions, building knowledge and fueling the current organisation. Information management is essential when it is responsible for the generation, maintenance, retrieval, and on-time availability of accurate information for the right individuals, at the lowest possible cost, and in the most influential manner.

The organisation's structure, operations, and culture must be understood in order to determine how, when, and what information must be provided. Lastly, an information system may be conceived as a system that accepts data of interest as raw material and delivers information through one or more transmutation processes.

Information visualisation

How information is presented is crucial because it determines how it is viewed and facilitates the development of insight.

According to Spence (2001), visualisation is a cognitive activity performed by humans, not computers. In accordance with Chen (2010), information visualisation is a computer-assisted method for translating abstract data into visual-spatial shapes in order to provide insights into an abstract event. Information visualisation aims to make the most of our perceptual and visual-thinking abilities for events that are not easily represented graphically. Visualisation promotes cognition not because of a particular metaphysical superiority of images over other ways of thinking and communication but rather because it benefits the user by making the external world a resource for thought in certain ways.

Visualisation amplifies cognition by (a) improving the amount of memory and processing capacity available to users, (b) minimising information search, (c) utilising visual representations to improve pattern detection, (d) improving perceptual inference operations, (e) monitoring utilising perceptual attention mechanisms and (f) encoding information in a material that can be manipulated (Gershon et al., 1998).

Not only does information visualisation involve the generation of visual images, but also the interaction with such images to solve problems. The compelling power of interactive information visualisation derives from the rapid reciprocal reaction between the development of images by machines and the selection and parametric adjustment of those images, resulting in the creation of new images.

Information visualisation concerns new types of data and their corresponding analytic activities in the business and information technology sectors. The combination of scientific visualisation, human-computer interfaces, data mining, imagery, and graphics is known as information visualisation. In contrast to most scientific data, information visualisation emphasises abstract information. Due to this fundamental distinction, many relevant data lack a natural and evident physical representation. Discovering new visual metaphors for information representation and determining the analytical activities they serve is a crucial research challenge.

2.6 Performance Indicators

An organisation uses performance indicators for three primary purposes: control, communication, and improvement. Through the evaluation of indicators, the organisation gains control over the performance of its employees. Indicators are an essential method of expressing the present state of the organisation and the supply chain. Finally, they enable the identification of performance disparities between actual and expected results. The gaps between the current status and the proposed goals indicate the need for adjustments (Franceschini et al., 2007). According to Franceschini et al. (2007), performance indicators should adhere to the following standards:

- Be representative;
- Easy to interpret;
- Quick to update;
- They must be sensitive to changes within or outside the organisation;
- Easy to process and collect;
- Being able to indicate trends.

Choosing the appropriate indicators is crucial. However, it is not a simple task (Harold, 2017). Choosing a reliable indicator is vital for the success and growth of an organisation. The selection of inappropriate KPIs can lead to unproductive behaviour and suboptimal results (Bauer, 2004). The optimal set of KPIs should be constructed with a focus on the outcome, keeping in mind what the organisation desires to achieve.

Indicators are powerful forces that can induce change inside an organisation, but only if the appropriate indicators are developed and utilised (Gabčanová, 2012). Consequently, companies must always have a creative and adaptable approach while designing performance indicators (Baroudi, 2014). Even though that there are no universal and organic procedures for defining indicators (Franceschini et al., 2007), there are common characteristics that should be considered while picking them.

Peter Drucker created an acronym (SMART) for goal setting in 1995. According to him, it is necessary to establish certain guidelines for goal design to achieve the specified goals. Setting SMART objectives involves elucidating ideas, concentrating efforts, utilising time and resources effectively, and enhancing the probability of achieving what was previously established. It is essential to ensure that the performance metrics adhere to these principles and that the objectives correspond to what is actually desired. To ensure that performance measures are understandable and attainable, each should be:

1. Specific – straightforward, sensible and meaningful. They must be explicit and unambiguous;

2. Measurable - significant and motivating. It is essential to ensure that they can track progress and quantify results;

3. Achievable – agreed and attainable. They should be ambitious, but never insurmountable;

4. Realistic - reasonable, pertinent, resourced, and based on outcomes. To quantify them, there must exist the necessary resources and abilities;

5. Time-bound - dependent and constrained by time and time-sensitive. There should be a deadline for completing them.

SMART is a well-established method for setting and achieving objectives. Using it, makes it possible to build clear, attainable, and meaningful objectives by developing the motivation and action plans necessary to achieve them. In addition, the metrics must be included in a performance evaluation system that enables individuals and groups to understand how their behaviours and activities contribute to attaining the organization's overall objectives (Neely, 1999).

Chapter 3

AS-IS Analysis

To better understand some approaches to the case study, it becomes essential to describe the company's products, production processes and information system used at Sonae Arauco.

As mentioned before, Sonae Arauco has a vast selection of products, the most prominent of which are particleboard/chipboard (PB), medium density fibreboard (MDF), and oriented strand board (OSB). These materials can be seen in Figure 3.1. Besides this, the company also manufactures melamine-faced panels of PB and MDF, PB and MDF wood veneer, and painted MDF.

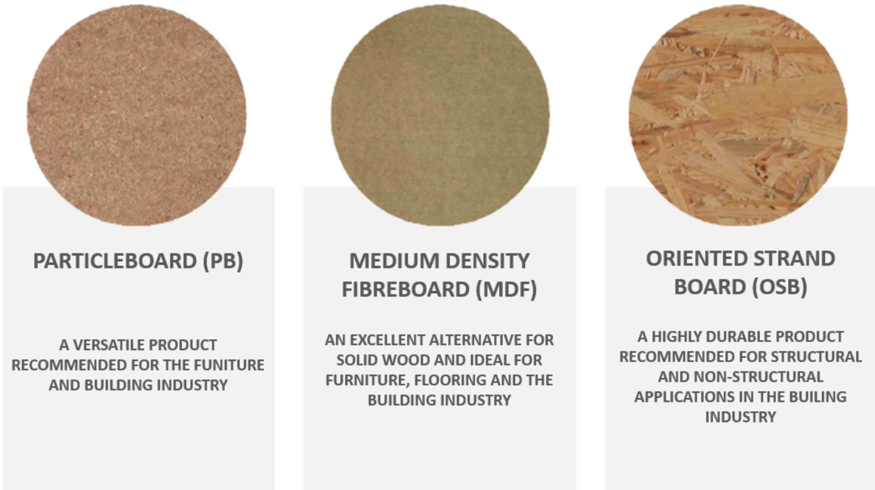


Figure 3.1: Characteristics of PB, MDF and OSB

This chapter begins with a brief description of the existing processes at the plant where the study for this project was carried out, in the Linares production plant.

The Linares plant of the company produces particleboard (PB) and also has an impregnation line which allows the production of melamine-faced chipboard (MFC) and melamine-faced MDF (MFMDF).

The flowchart in Figure 3.2 illustrates the essential manufacturing procedures at the present Linares' facility, which includes the production of Outside Agglomerate, used as a raw material in the Inner Agglomerate section for board formation. When in the Board Formation section, the result will be combined with the impregnated paper generated in the Paper Impregnation section. Here is where a large majority of the line's end product is created.

In addition to the final product, specific consumers also purchase semi-finished goods, i.e., raw particleboard. Most of these raw boards are sold already sanded. However they can also be sold unsanded, representing a small portion of the market.

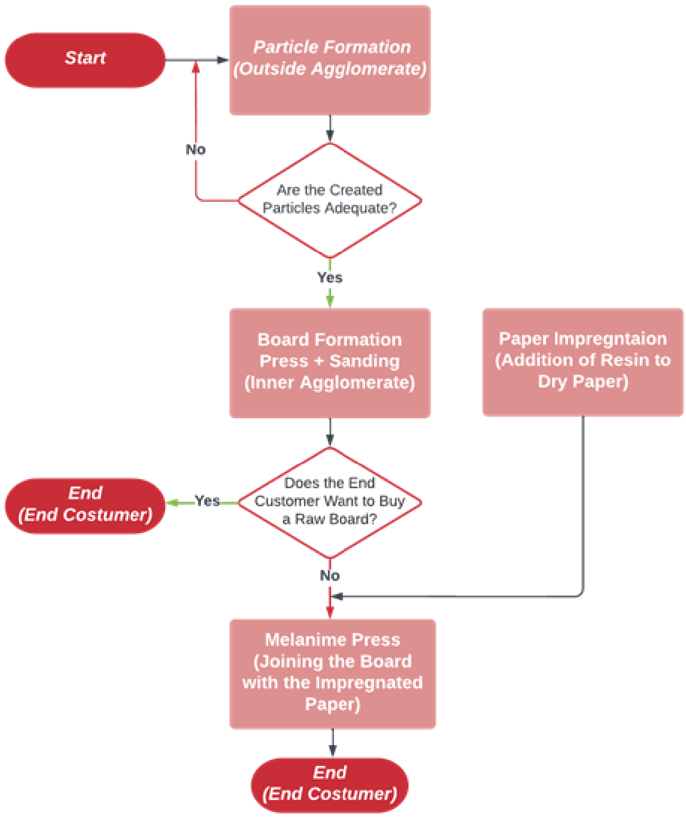


Figure 3.2: Main Production Processes at the Linares Industrial Unit

3.1 Production Process in Linares Plant

The agglomerate is made up of millimetre-sized particles that are glued together using synthetic urea-formaldehyde resins under pressure and heat. It usually has three layers: two outer layers with smaller particles and an inner layer (core) with larger particles. It is a product intended for furniture, construction, carpentry, decoration, and a variety of coating applications.

The manufactured panels can be water-repellent, allowing them to be used in situations with a danger of humidity, or fireproof, exhibiting increased resistance to fire.

Additionally, boards might be raw, i.e., uncoated or melamine. A melamine surface board is simply the combination of a raw board (substrate) – PB, MDF – with a sheet of decorative paper on either face. This decorative paper is impregnated with melamine resin and "glued" to the board by a hot pressing technique. The aesthetics of a large selection of designs and patterns increase the strength and versatility of the raw plates, resulting in decorative goods that are easy to use and maintain, with excellent scratch and abrasion resistance. Figure 3.3 depicts a coated board. Only chipboard is manufactured in Linares. The MDF (medium density fibre) boards are acquired from other plants, tendentially from the Mangualde plant, and then coated in Linares.

Figure 3.3: Constitution of a coated plate

The manufacturing process consists of five stages: preparation of particles and construction of the "mattress," pressing, finishing (sander) and cutting, impregnation, and lastly, coating (melamine).

The production process begins with the supply of raw materials. In the production of particleboard, the raw material (roundwood from pine, eucalyptus, or other species) is successively reduced in size through physical and mechanical processes. From this reduction process, tiny particles are obtained, which are then dried in a dryer and sieved to remove sand and unwanted products and separate the particles by size. The final step in manufacturing Agglomerate Exterior consists of storing the chips in distinct silos depending on their granulometry.

There are two inputs in the manufacturing of Inner Agglomerate: particles held in silos (from the Outside Agglomerate process) and resins from external vendors. Here, the resulting particles are blended with adhesives in the form of urea, formaldehyde, and other chemicals in the binder. The particles are stacked by gravity through the forming machinery to obtain wood shavings. The particleboard is then shaped in mattress formers, where the mixture is evenly spread to create a mattress structure. The outer layer of manufactured particleboard comprises the tiniest particles, assuring a smooth surface. In the inner layer, particles with a larger granulometry (coarser material) are utilised. After the production of the agglomeration mattress and to remove the existing air between the particles, the mattress is subjected to a pre-press for consolidation and reduction in thickness. It then enters a continuous press, which ensures its physical-mechanical properties. Parameters including density, humidity, press speed, and the temperature gradient along the press are adjusted to achieve this.

At the end of the press, the board is cut to the dimensions requested by the customer. A board cooling system follows this. After this process, the panels are left to rest for a minimum of 12 hours in the semi-finished products' warehouse. It should be noted that batches are formed before being sent directly for finishing or stored in the warehouse.

After the boards have cooled, they are sanded and trimmed with longitudinal cutting saws in the finishing stage. Since the boards leave the press oversized in order to optimise the production process, they are trimmed to commercial sizes at this step described in the technical data sheet. Before coating, they are either stored in the semi-finished products' warehouse (overhead crane) or shipped immediately.

As mentioned before, the coating process is the one that adds value to the boards. At the impregnation line, dry paper is turned into melamine paper, which is then used to cover the panels. Raw boards (PB or MDF) are decorated with melamine on the melamine lines using impregnated paper from the impregnation process.

At the Linares facility, the primary focus is on the overhead crane of the semi-finished products' warehouse mentioned above, where stock-level issues have been identified, intending to balance these out. Here, both MTO and FTO goods can be found. There are two possible destinations for these items after the crane: the cutting line, where they are cut to size for more specific orders or the melamine line, as previously explained. This study concentrates on the FTO items present in this overhead crane.

3.2 Information system

This report details a project developed and presented in partnership with the IT Supply Chain Planning department. *SAP* is the information system utilised by this department and the Sonae Arauco Group overall. *SAP* is an Enterprise Resource Planning (ERP) system that integrates, in a single software package, the information flow from diverse company domains, including production, distribution, accounting, and human resources. According to Jacobs et al. (2004), these systems have the primary benefit of eliminating unnecessary jobs, improving overall operations.

In addition to the previously mentioned tasks, *SAP* enables the export of various types of data (in multiple formats, especially *Excel*), such as forecasts, consumption history, and classification of materials, allowing for more in-depth studies to be conducted to identify and evaluate potential improvement measures. *SAP* was used extensively for the work developed in this dissertation, permitting the exportation of a set of data that was afterwards analysed and processed in order to fulfil the specified objectives.

3.2.1 Production planning - *SAP APO*

Production planning is supported by the *SAP APO* application (Advanced Planning Optimizer), an advanced detailed planning tool. This is a tool that helps organisations manage their supply chain.

SAP APO works as an integrated extension to *SAP R/3*. *SAP R/3* has planning functionality, but it is on an elementary level. According to *SAP*, the *APO* application is designed to help an organisation improve production planning and scheduling, shipping and pricing.

The *APO* system can be integrated in R/3 and has several modules. Among them, we can highlight Demand Planning (DP), Supply Network Planning (SNP), Production Planning and Detailed Scheduling (PP/DS) and finally, Global Available to Promise (GATP), as shown in Figure 3.4.

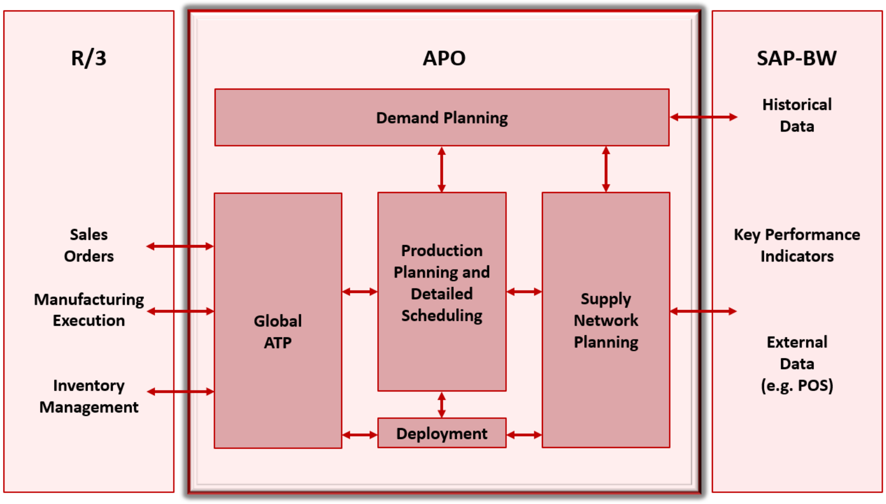


Figure 3.4: Interconnection of *SAP APO* components

The Demand Planning module allows the market forecasting of products. It is a module that operates over the long term and analyses product historical characteristics such as trends, seasonality, etc.

Next, the Supply Network Planning module integrates supply chain processes from purchasing, manufacturing, distribution and transport. In other words, it takes into account the forecasts from DP and forecasts according to stock, production and customer portfolio. It is a module that works in the medium-long term, and from it, one can create SNP planned orders that analyse essentially critical components and the duration in days.

The PP/DS module is even more detailed and works on a short-term basis. Here the planned orders already come with detail to the second at time level and enter all components, critical and non-critical.

The Global Available to Promise module allows to check the availability of the product or components in real-time through simulations. It is divided into three parts: Available to Promise (ATP), Capable to Promise (CTP) and Product Allocation (PAL).

ATP checks, based on what is planned and in stock, whether or not the product is available. The CTP checks production capacity, when it can be produced and suggests a delivery date. The PAL restricts demand by quotas. In other words, it works like a filter where, for example, we have $x\ m^3$ of capacity in a month and a $y\ m^3$ of quantity is set for a more important customer and a $z\ m^3$ of quantity for another less important customer. Through these allocations, it checks the availability of production.

3.2.2 Master Data Definition - *SAP R/3*

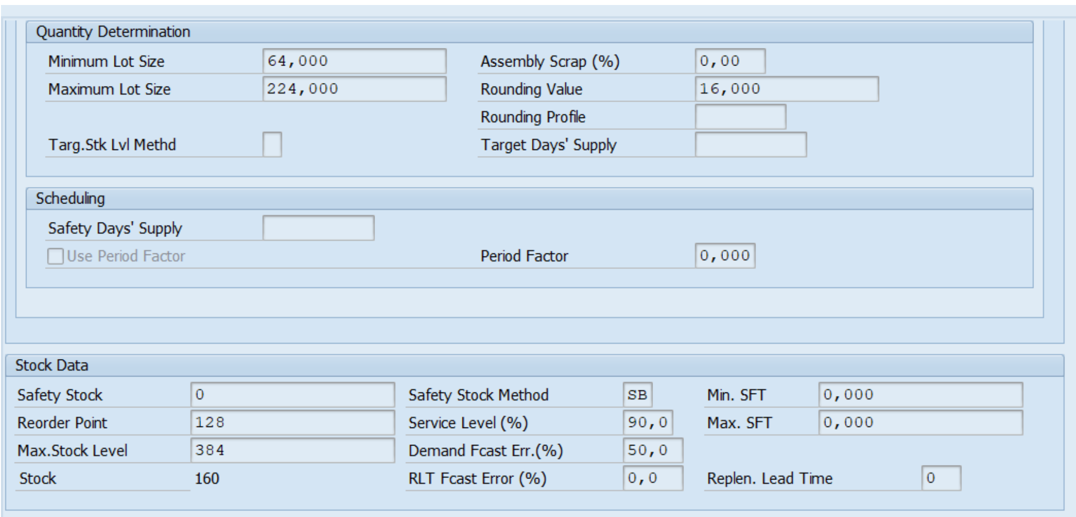
Planning in *SAP APO* begins in *R/3* with the entry of the master data, the critical business data. Here the existing lines in the plant are defined.

Next, the process routings of the product are created. The setup times of the lines to start production, which articles to produce, and which lines will be used are defined. For example, products with dimension x can only be produced on line y and products with dimension z can be produced on any line.

A Bill of Materials (BOMs) is also created per SKU. The BOM details the materials required to produce the article. For example, article x requires a board y and two impregnated papers z.

Once these components are defined, a production version is created per SKU based on the routings (where it will be produced) and the BOMs (which materials will be produced). Since the possibility of having n production versions exists (equivalent to the possible combinations between routings and data sheets), it is possible to define a priority production version to, as the name suggests, give production priority to the version defined as such. These versions are then sent to APO.

It is possible to enter product-related data in the Master Data. In Figure 3.5 an example is shown of a view in *SAP* that concerns information related to the properties of each SKU. The figure shows data such as *Safety Stock*, *Service Level*, *Reorder Point*, *Maximum Stock Level*, *Minimum* and *Maximum Lot Size*, etc. The Service Level and Demand Forecast Error (%) values are manually introduced, while the software automatically calculates the *Safety Stock* and *Reorder Point* values. These calculations performed by the software will be explained below.


Quantity Determination

Minimum Lot Size	64,000	Assembly Scrap (%)	0,00
Maximum Lot Size	224,000	Rounding Value	16,000
		Rounding Profile	
Targ.Stk Lvl Methd		Target Days' Supply	

Scheduling

Safety Days' Supply			
Use Period Factor		Period Factor	0,000

Stock Data

Safety Stock	0	Safety Stock Method	SB	Min. SFT	0,000
Reorder Point	128	Service Level (%)	90,0	Max. SFT	0,000
Max.Stock Level	384	Demand Fcast Err.(%)	50,0		
Stock	160	RLT Fcast Error (%)	0,0	Replen. Lead Time	0

Figure 3.5: *SAP* view of information regarding each SKU

3.2.3 Group, Family and Type of Materials

Sonae Arauco has developed a coding system for materials in order to facilitate and accelerate their identification. Figure 3.6 shows an example of this coding system.

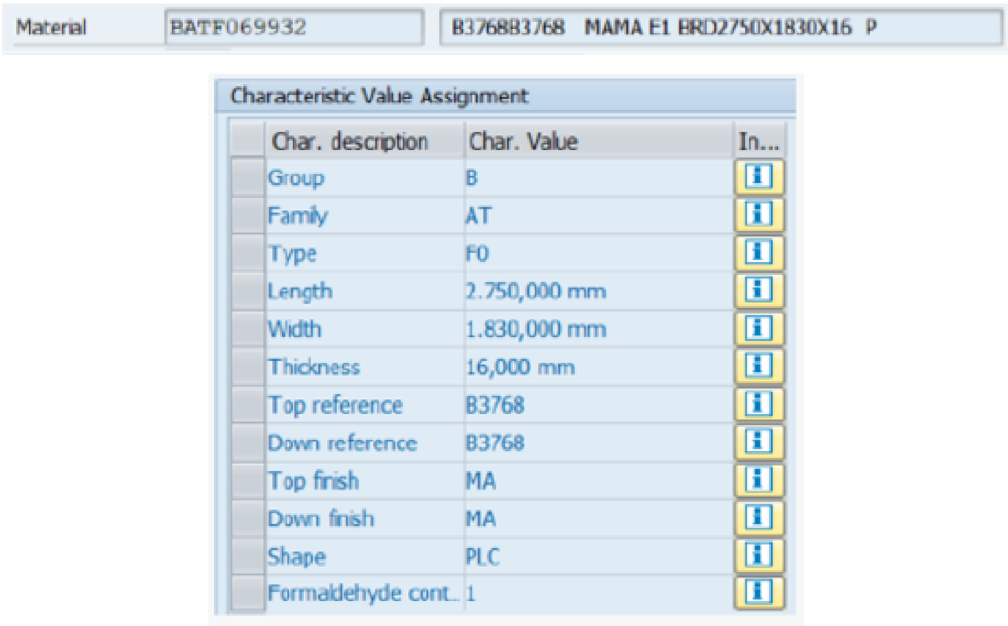


Figure 3.6: Group, Family and Type of Materials

This code is based on a ten-digit code, with the first digit representing the material group, the following two representing the material family, and the subsequent two representing the material type. The remaining five digits are sequentially generated random numbers. The format of the code will then be G FF TT NNNNN.

The group identifies the raw material, such as whether or not it is raw board or paper. The family consists of a combination of commercial brands and material-based distinctions. In turn, the type refers to the physical-mechanical features, such as the formaldehyde content.

Currently, each feature combination corresponds to a unique SKU. That is valid for finished products, semi-finished and raw materials. The same SKUs might be either finished or semi-finished goods.

3.3 Computation

This section will describe the operational features of Sonae Arauco's planning processes, including how the Reorder Point and Safety Stock levels are determined as well as the Reorder Point Planning Procedure.

3.3.1 Automatic Reorder Point Planning

SAP offers an integrated forecasting tool that provides automatic planning for reorder points. This option determines both the reorder level and the safety stock level.

To predict future needs, the system analyses historical data, namely consumption data from the past. The MRP controller's service level and material replenishment lead time are sent to the material master, allowing the system to determine both the reorder and the safety stock levels based on these forecasted values.

This forecast is carried out at regular intervals so that the determined values (reorder level and safety stock level) can be continuously updated to reflect actual consumption and delivery conditions, thereby contributing to the maintenance of low inventory levels (SAP, 2019).

3.3.2 Reorder Point Planning Procedure

The continuous review policy is employed at Sonae Arauco. This system calculates the stock level each time a product is transferred into or out of the system in real-time. This may result in an order for more stock if the calculated stock level drops under a particular Reorder Level.

In this policy, there are two decisions to be made. First, it is crucial to determine when to order, often known as the reorder level. As stated previously, the system automatically calculates this value.

Additionally, the order-up-to level, or how much to order, must be determined. There are particular methods for calculating this value for this model policy of continuous review. However, this project was developed in the semi-finished products' warehouse, which is equipped with an overhead crane and where there are finite positions for the materials. Since the capacity of the crane is finite, this order to level is limited by the available space. In this crane, the bins have been previously specified for each SKU; therefore, the order-to-level value is based on the number of bins defined for that particular product.

The *SAP* software's implementation of the continuous review model will be described in more detail. Continuous monitoring of the warehouse's available inventory is performed for inventory management. The system determines whenever a material is withdrawn from the warehouse if the removal causes the stock level to go below the Reorder Point. In this situation, the system adds an entry to the planning file for the subsequent planning run.

When products are returned to the warehouse, a similar check is performed to determine if the inventory level surpasses the Reorder Point. If so, an entry is made in the planning file to remind the planning run to delete purchase offers that are unneeded. If scheduled orders are no longer required, for example owing to material returns, the system suggests that these orders be cancelled. In this situation, the MRP controller must meet with the Purchasing or Manufacturing department to assess whether the purchase or manufacturing order can be withdrawn.

Then, net requirements are estimated by the system by comparing available stock at the plant level, including safety stock, and anticipated fixed receipts (fixed purchase requisitions, purchase orders, etc.) with the Reorder Point.

Considering the lot size specified in the material master, the system then determines the supply quantity. For Reorder Point planning, the system uses information regarding set lot sizes and replenishment up to the maximum stock level.

Finally, the system schedules the purchase proposal. It calculates the dates by which the purchase order must be delivered, production must begin, the supplier must provide the products, and production must have the goods ready (SAP, 2019).

3.4 Inventory monitoring transaction

In order to monitor the stock level a transaction was created in SAP, which will be called *Transaction X* from now on. This is the transaction used by planners and those on the shop floor to access details about materials, such as *Reorder Point* and *Maximum Stock Level*. Other fields can be observed here. This subchapter describes in detail how each field of this transaction is calculated.

Transaction X contains these fields: *Reorder Point (RP), Maximum Stock Level (Max. Stock), Order Quantity (Order Qty), Supermarket Quantity (Spmrkt Qty), Requirements (Requir.), NFP* and *Warehouse Stock (Whse Stock)* as it is possible to see in Figure 3.7.

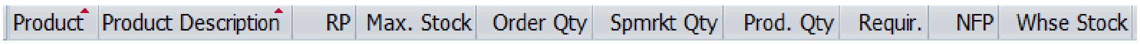


Figure 3.7: Existing fields in *Transaction X*

It has already been explained how the *Reorder Point* and the *Maximum Stock* Level values are calculated.

The *Requirements* corresponds to the quantity forecasted by the programme that will be needed over the horizon selected when entering the transaction. On the Figure 3.8 it is possible to see the choice accessible when entering the transaction linked with the definition of the end of the time horizon. There is a field for the date and another for the hour.

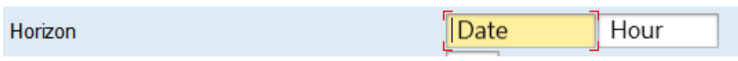


Figure 3.8: Field used to define the end of the horizon in the entrance of *Transaction X*

Warehouse Stock is the on-hand stock, the quantity of stock physically present. This stock can be separated into two categories: Order Quantity and Supermarket Quantity.

Order Quantity is the amount of stock that exists on-hand but is intended to fill orders.

Supermarket Quantity is the amount of stock in the warehouse, that is not intended to be ordered, i.e. the amount of stock that is free within the selected horizon. This calculation can be done through:

$$Supermarket\ Quantity = Warehouse\ Stock - Requirements \tag{3.1}$$

Production quantity is the total quantity of outstanding fixed supply elements.

The *Net Flow Position, NFP*, is calculated based on the following formula:

$$\begin{aligned} Net\ Flow\ Position &= On-hand\ Stock(Warehouse\ Stock) \\ +Open\ Supply(Production\ Quantity) &- Qualified\ Demand(Requirements) \end{aligned} \tag{3.2}$$

3.5 Semi-Finished Products' Warehouse

Linares' warehouse for semi-finished goods is composed of an overhead crane. An overhead crane is a component of heavy machinery capable of transporting cumbersome items and equipment from one area to another in a safe and precise manner. Figure 3.9 shows an example of an overhead crane. These cranes utilise the factory's airspace and are precisely configured and intended to accommodate a certain type of load application due to the nature of their work.

In a safe manner, overhead cranes may raise, lower, and travel horizontally along a rail or beam while lifting extremely heavy items. The installation of an overhead crane is recommended for various reasons, but two of the most important ones are efficiency and safety. They are substantially more efficient than devices on the ground. Furthermore, in hazardous and extreme situations, such as the presence of heated metals, chemicals, or toxic materials, overhead cranes may securely transport these products, thereby safeguarding personnel.

Figure 3.9: Example of an overhead crane

Source: Peng et al. (2019)

3.5.1 Warehouse Layout

In the past, when the company primarily utilised a make-to-order system, all the available slots on this overhead crane were assigned to these items. Management was conducted solely to prevent the mixing of SKUs. Adopting the hybrid MTO/FTO system, the previous arrangement had to be modified. At the outset of this project, some positions were assigned to MTO products and others were reserved for FTO goods, with no mixing of the two article categories or SKUs, even if they were all MTO or FTO.

It was determined that 83 places of the semi-finished products' warehouse would be designated for FTO materials, with an additional 5 positions serving as a buffer for a total of 88 usable positions.

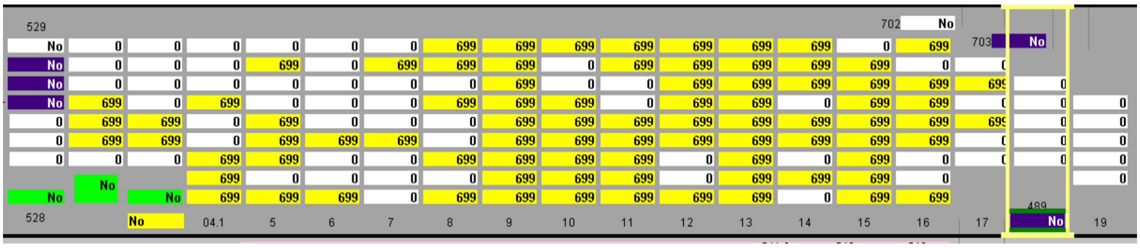


Figure 3.10: Initial layout adopted in the semi-finished products' warehouse

Figure 3.10 depicts the initial arrangement of semi-finished goods in this warehouse, where the locations marked with the number 699 are destined for FTO articles and the places marked with the number 0 are destined for MTO articles or other exceptions. As shown in the picture, the roles were first filled based solely on the available positions when the transition to the hybrid MTO/FTO system occurred, without any logical structure.

Initially, fixed places were established for each SKU. In other words, if one specific SKU had two designated positions, these positions were specified instantly and were exclusive to this SKU.

3.5.2 Positions per SKU

A planner is responsible for deciding the number of positions each SKU is allocated. Currently, this task is performed in *Microsoft Excel*, with the sales history from previous months and the lead time history connected with each product serving as the basis for the planner's calculations.

Additionally, this document, which will hereafter be referred to as DOC 1, includes product specifications such as length, width, and thickness. With this information, the planner conducts calculations for each SKU such as the average of the last 12 months' sales history, standard deviation and height required to have the associated quantity of boards in stock.

This semi-finished product storage facility is restricted because the boards can only be stored to a certain height. Due to safety concerns, the bridge's height is limited to 8,5 metres. Given that each batch of panels has a maximum height of 1.2 m, it would be able to install no more than six batches of 1.2 m per position. The number of panels in each batch, the number of panels per position, and the number of positions necessary for each SKU are determined based on each plate's thickness and other dimensions, taking the aforementioned safety limits into account.

3.6 The Challenge

Before the start of this project, the company at the Linares plant in Spain was operating solely on an MTO basis, and the aim was to redefine that production strategy by implementing a hybrid MTO/FTO system. This implementation had already been carried out at the time of joining the project. However, changing a production strategy is not an easy task. Such a change has implications across numerous company divisions and may require the formation of new departments, operating procedures and support systems.

Following this setup, an abundance of stockout products and instances of overstock were observed. As there were no obvious measurements or indicators that could lead to this conclusion, identifying this information proved to be a time-consuming task, as it was difficult to control these figures due to the absence of a model capable of quickly analysing these scenarios so that corrective or preventive measures could be taken. It was then concluded that a monitoring tool would help the perception of the existing stock levels and quickly draw attention through some visual tool to specific cases needing maintenance or adjustments. Monitoring stock levels was a critical problem to be solved in this factory.

It is of utmost importance to minimise overstocking and the risk of stockouts causing delays in the production of finished products and, consequently, in the service level provided to Sonae Arauco's customers. Thus, the main objective of this study is to define a dynamic and adaptable process to monitor the sizing of stock levels of semi-finished products,

As previously mentioned, the semi-finished products' warehouse under study consists of an overhead crane. With the redefinition of the production strategy, there was also the need to readjust the positions used and the layout of this overhead crane. The occupation of these positions were studied and some measures were adopted in order to optimise their use.

Chapter 4

Implemented Solutions and Results

This project arose from the necessity to establish visual tools and KPIs that would enable the rapid and effective detection of problems, such as shortages and surpluses so that corrective and preventive action could be taken in the semi-finished products' warehouse in Linares. Initially, there was no support tool in place to provide such assistance. This chapter will describe the primary steps taken to address the issues analysed in Chapter 3 of this work.

4.1 Buffers Creation

As stated in the second chapter, information must be simple to comprehend to expose existing problems and drive their resolution. Also, indicators are crucial components in the process of a company's continuous improvement because they permit establishing the objectives of what is intended and quantifying what has actually been done. Therefore, it is vital that these tools are developed for this project.

This study's primary objective was to establish a dynamic and adaptable process for monitoring and sizing the inventory levels of semi-finished products in order to assist decisions regarding their readjustment within the context of Sonae Arauco's stock management area.

For this purpose, a number of theoretical contributions from the current literature were considered. Specifically, in this study, two separate visual tools, which were previously referenced and described in greater detail, were utilised as a basis: the Dynamic Buffer Management of Theory of Constraints (TOC) and the DDMRP.

The primary objective of the TOC stock management system Dynamic Buffer Management is to monitor and adjust inventory levels based on actual usage. In this case, the buffer is divided into three equal zones. High stock, often displayed by the colour green, allows people to work with a lower stock level since the buffer dimensions can be recalculated if the system recognises that a particular product has remained at that level for numerous replenishment cycles. The colour yellow indicates that stockpile quantities are sufficient to meet demand. Nonetheless, caution is required because the stock is below the target level. The colour red denotes inventory that demands the manager's immediate attention. When this occurs, there is a risk of stock-outs and, as a result, a decline in sales.

The creators of the DDMRP approach also advocate introducing three security levels: green, yellow, and red. In contrast, each zone serves a different purpose and varies in size and proportion dependent on the "buffer profile" to which a buffered part is assigned. The buffer profile is a collection of settings that are applied to a group of parts that have similar characteristics, such as part type (made, purchased, or distributed), lead time category (long, medium, short), variability category (high, medium, short), and batching constraints (significant minimum order). The safety criteria are calculated using mathematical calculations and evaluating characteristics specific to each item.

After absorbing this information, the development of this project proceeded with the aid of *Microsoft Excel* software. Each day, information about stock quantities in the semi-finished products' warehouse in Linares was extracted from *SAP* regarding the FTO products. Following a thorough review of the retrieved data, it was possible to conclude that shortages and surpluses were occurring but were hard to identify. Hence their resolution was taking longer than anticipated.

Produced at early or intermediate phases of production, semi-finished goods correspond to components required in making other semi-finished or finished goods. The availability of these products in the warehouse directly impacts the company's level of service. The presence of inventory in warehouses across the manufacturing chain is crucial for the company, as it functions as a buffer to absorb demand fluctuations and shorten production lead times.

The assessment and sizing of an SKU's buffer must be in accordance with consumption needs, preventing both overstocks and stockouts. Nonetheless, the absorption of demand changes intrinsic to various markets, in addition to fluctuating waste and production flaws, requires ongoing study and monitoring of stock levels established in prior periods.

The initial step was to establish a variable-sized buffer specific to each SKU. For this reason, a team meeting was held to clarify the guidelines for creating buffers. The established criteria are displayed in Figure 4.1 and can be summarized as follows:

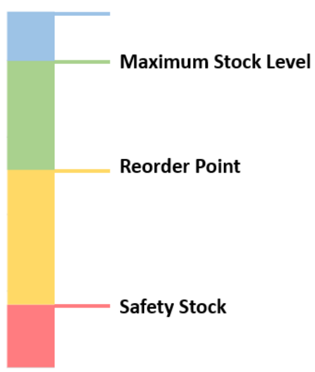


Figure 4.1: Criteria defined for the buffer created

- Red: below Safety Stock;
- Yellow: below the Reorder Point value;
- Green: between the Reorder Point value and the defined Maximum Stock value;
- Blue: above the defined Maximum Stock Value.

Then, in order to quickly identify the status of each product, it was decided to assign a colour to each cell based on the stock position according to the previously specified rules.

The allocation of colours according to the positioning of the stock level was first done in the software *Microsoft Excel*, as it can be seen in Table 4.1. To conduct this colour assignment, the *Warehouse Stock* cell (hereafter referred to as *Whse Stock*), whose calculation was described in the preceding chapter, is compared with the Maximum Stock Level, Reorder Level, and Safety Stock levels.

Table 4.1: Colour assignment of cells in *Microsoft Excel*

Product	Reorder Point	Maximum Stock Level	Warehouse Stock	Warehouse Color
BATB032546	39	53	52	Green
BATB032549	45	70	0	Red
BATB032571	0	24	0	Red
BATB032652	39	47	26	Yellow
BATB032828	54	293	36	Yellow
BATB036701	81	359	0	Red
BATB053475	45	68	90	Blue
BATB053748	54	88	107	Blue
BATB054379	0	34	0	Red
BATB057419	1	863	1 236	Blue

If the value of *Whse Stock* is greater than the *Maximum Stock Level*, the blue colour is displayed to indicate an excess of this product in the warehouse.

In case the *Whse Stock* value falls between the *Maximum Stock Level* and *Reorder Point* values, a green colour is applied to represent an inventory position that requires no action, suggesting that the buffer is adequate to meet demand.

If the value is within the range of the *Reorder Point* and *Safety Stock* levels, a yellow colour is displayed to indicate a product that has begun to be replenished, as this replenishment model is similar to the Minimum-Maximum model seen before in the literature review. The creation of these zones helps visually to decide on the replenishment of the buffer. In this specific case, whenever the inventory enters the yellow zone, that is, whenever the inventory level is below the *Reorder Point*, a replenishment order is placed to reach the maximum level of the green zone, thus reaching the target level, which is the *Maximum Stock*. The yellow colour is as a warning but is not yet a product requiring immediate attention. This region may suggest a demand shift or, alternatively, a demand peak.

The colour red is detected if the *Whse Stock* value falls below the *Safety Stock* value established for that SKU. Red signifies that a component's inventory at the point of consumption is in jeopardy of depletion, necessitating immediate action. This region indicates that the stock's consumption is more than anticipated, meaning a potential risk of breakage.

The flowchart in Figure 4.2 describes the steps that must be followed in this colour assignment process according to the level of stock in the warehouse and what actions must be taken according to each case.

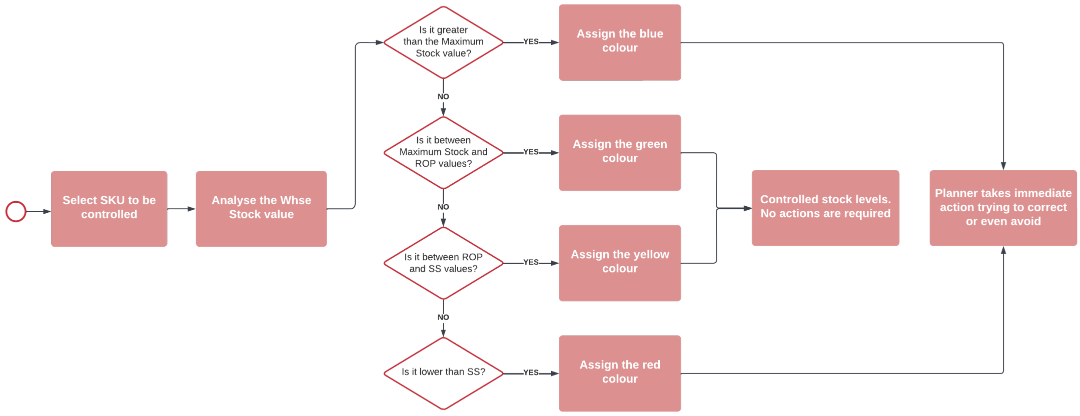


Figure 4.2: Process of colour assignment to each SKU

As stated previously, information visualisation aims to enhance our perceptual and visual reasoning abilities, which this application does. Implementing this optical colour information system has facilitated decision-making through visual management. It enables the rapid identification of problematic situations, and by observing the colour, it is possible to identify the problem in which a particular SKU is, thereby facilitating immediate corrective action.

4.2 Development of KPIs Concerning Stockouts and Overages

After allocating colours to cells based on the location of the Whse Stock value in the buffer defined for each SKU, it was possible to determine the number of SKUs in each colour, this is, in each situation.

The crucial key performance indicators that can be taken from the colour assignment that was made earlier is the number of SKUs both in the blue zone and the red area, as these indicate the number of surpluses and stockouts, respectively. Thus, the goal is that there are no SKUs in either of these zones.

To more easily visualise the information from these KPIs, a chart was created where it is possible to follow the amount of stock in each buffer zone (red, yellow, green and blue), where each colour has the meaning explained above. In other words, in this chart is possible to see, by day, the number of SKUs that are in excess or stockout. The chart inicially developed in *Microsoft Excel* can be seen in Figure A.1 in Appendix A.

The aim is to work towards zero values for red and blue zones so that in this graph, only yellow and green zones are obtained, as these colours are not indicative of danger.

As noted previously, at the beginning of this project, data was taken daily from *SAP* and imported into Microsoft Excel, where it was originally analysed, and some developments were established. Nonetheless, in a team meeting, it was determined that all enhancements should be incorporated into the ERP itself to make the transaction useful and easily accessible for all users. In order to accomplish this, it was required to store all of the data in the system, so a job has been developed in *SAP* that allowed the storage of this data in the ERP, enabling the beginning of system development.

Later, with the help of an *SAP* developer from the team, all ideas initially developed in *Excel* as well as those specifically designed for *SAP*, were implemented in the ERP.

The graph initially developed in *Excel* was later deployed in *SAP*. Figure 4.3 demonstrates the outcome.

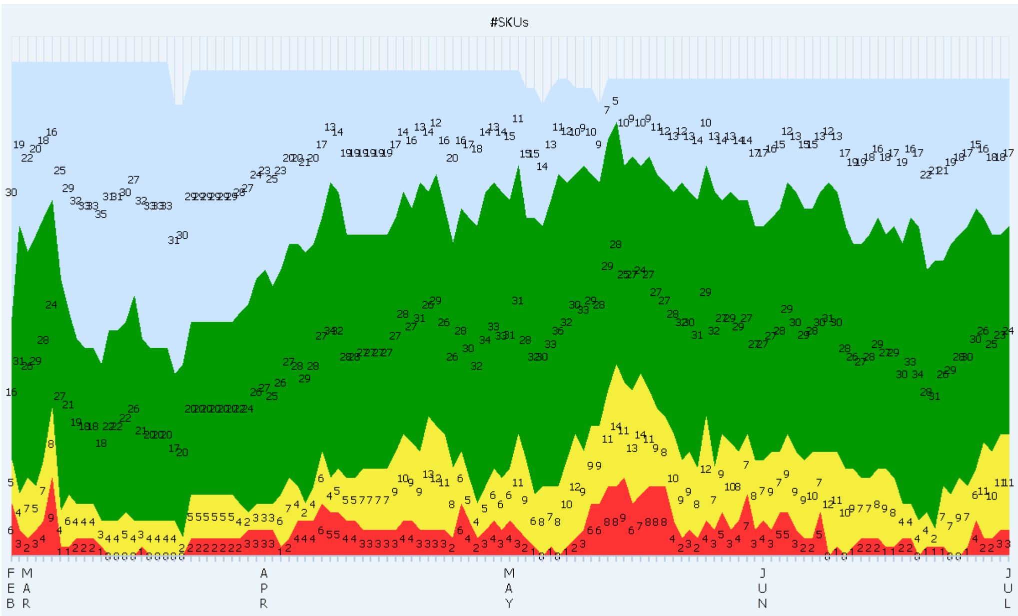


Figure 4.3: Created graph exhibiting KPIs for the number of SKUs in each zone of the defined buffer

This graph provides a visual representation, per day, of the number of SKUs that meet or do not meet the requirements. This methodology enables higher efficiency in replenishing items, rapid response to market fluctuations, the assurance of product availability, and quicker detection of problems compared to the old style of management.

As already indicated, this warehouse for semi-finished goods is composed by an overhead crane with limited locations, some for MTO materials and others for FTO products. The number of positions allotted to each SKU is generally between one and two, as determined by a previous analysis of storage requirements.

The data in the graph of Figure 4.3 may not be sufficiently informative, and it may even prove fallacious in some specific situations. Since what is reported is the number of SKUs that do not meet standards and not the stock quantity of each SKU, an example of this issue that can occur is having a relatively small number of excess SKUs in the warehouse that take up a considerable volume. In other words, there may be only one SKU with a stock quantity exceeding the defined maximum. Still, it is unknown whether this is due to the product occupying one or more locations over those designated for it.

There could be further types of erroneous circumstances. Each slab pile has a total number of metres to be filled with panels. However, while determining the maximum number of panels for each pile, a portion of the overall area is left unused for safety reasons. In case there is an SKU marked as overstocked, but it has a tiny surplus of m^3, arranging the surpluses in the same board pile as the overstocked SKU may be reasonable, thereby not occupying additional positions. Thus, even though this SKU will display a blue colour indicating surplus stock, this excess value is not a cause for immediate concern because it does not occupy more warehouse space than it intended.

To be able to control this type of circumstances, a chart with the same logic as the one before was created, allowing for an analysis of the quantity of stock above the stated maximum stock level. Nonetheless, the information in this graph is displayed in m^3.

This graph was previously created in *Microsoft Excel*, as the one before (Appendix A, Figure A.2), and then it was developed in *SAP*, as seen in Figure 4.4.

This chart contains two new KPIs, similar to the previous ones, but this time in m^3. The green bars represent the m^3 that are only occupying the space granted to them, and the blue bars represent the m^3 that are actually occupying more space than they were expected. Hence, the target is that there are only green bars.

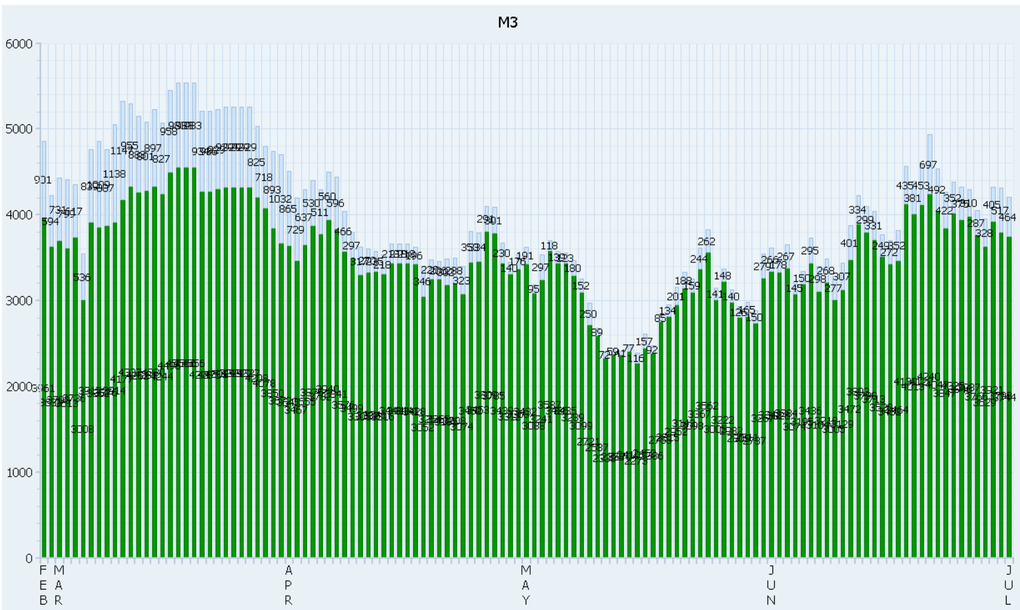


Figure 4.4: Graph exhibiting the m^3 occupied in the semi-finished products' warehouse

4.3 Further Development of Tools

In addition to allocating colours to the *Whse Stock* column, which refers to the available stock, the *NFP* value, which corresponds to the forecasted inventory at the end of a specific period, was also coloured. On this basis, it was possible to evaluate if the values were in accordance with the buffer defined for each SKU and the predicted values at the end of the specified period. Thus, the *NFP* column now also displays the previously explained red, yellow, green, and blue colour system.

This implementation may once again be flawed and prove to be fallacious. This occurs when *Whse Stock* and *NFP* values display the colour green, indicating that the inventory values associated with this SKU are apparently within the expected range. However, it is possible that an excess or insufficiency occurred during this period, but by the end of this span of time, the values had returned to normal.

To have control over these situations, two new fields called *Min NFP* and *Max NFP* were developed in *Transaction X*. As the name suggests, this column displays the minimum and maximum values, respectively, that the *NFP* value has taken in the time frame previously established in the transaction based on the system's projections, allowing the discovery of stockouts or overstocks. The same colour coding discussed above for the *Whse Stock* and *NFP* columns has been allocated to these two new columns, enabling colour-based analysis of these data. Both red and blue have negative connotations that should be avoided (shortages and overages, respectively), indicating that they should be reviewed or that special attention should be paid to those specific SKUs. In contrast, yellow indicates a state of alert, and green indicates that values are as expected. Figure 4.5 represents the outcome of this *SAP* implementation.

NFP	%	Min NFP	%	Max NFP	%
30-		30-		743	69
319	44	14	2	494	69
244	36	244	36	244	36
214	38	214	38	288	51
237-		237-		690	55
296	52	296	52	296	52
1 532	38	778-		2 927	73
566-		1 413-		2 456	60
734	102	734	102	922	128
102	14	102	14	820	114
255	32	255	32	255	32

Figure 4.5: Implementation of additional transaction columns, *Min NFP* and *Max NFP*, and colour coding of these columns in *Transaction X*

This implementation has become effective in the sense that it is now possible to quickly and accurately detect which SKUs, according to the system's forecast, will fail to meet expectations. This allows the planner to investigate the cause of this failure, attempting to solve and perhaps anticipate more cases like this by modifying manufacturing orders, for instance.

A common occurrence is the existence of peak orders in the melamine line's production schedule, which is located after the semi-finished products' warehouse. To reduce setup time, identical goods are grouped together, which justifies these order peaks on the melamine line. By being able to make many orders with the same style of finish, setup time is decreased, hence optimising plant output.

Typically, melamine lines are segmented by type of finishing, as changing plates requires the most setup time (plates are changed each time the type of finishing is changed). Additionally, there is a setup period for the temperature rise and decline. It takes roughly 2 min/ºC to increase the temperature, whereas it takes about 6 min/ºC to reduce the temperature. Changing boards and sheets take, in each case, about 6 minutes. The longest setup time is approximately 20 minutes for the finishing plate change. Due to the same shape type of the plates, the plate-changing time remains constant regardless of the finish. Therefore, the effort is to group by type of finish during planning. Due to the impossibility of simultaneously producing products with various finishes, production times can be reduced by manufacturing identical boards and cutting them asymmetrically to generate two different items.

Taking into account all of these criteria, the system occasionally creates production orders for melamine in quantities that exceed the maximum stock values of each SKU and those that are actually required, resulting in stockouts of a particular product during or at the end of the given horizon. Assigning colours to these situations enables the planner to determine which cases require more attention, and the planner can determine if it was indispensable to produce such a large quantity at the moment or if orders and production could be organised in a different manner to avoid stockouts and overstocks.

The previously implemented enhancement, which resulted in the development of the Min NFP and Max NFP parameters, enabled users to evaluate whether stockouts or overages would occur within a specific time frame. Nevertheless, it was not possible to determine when. Even though this would aid in identifying which SKUs may not meet the buffer requirements, the planner would still need to examine the entire specified time horizon to determine when this event would occur.

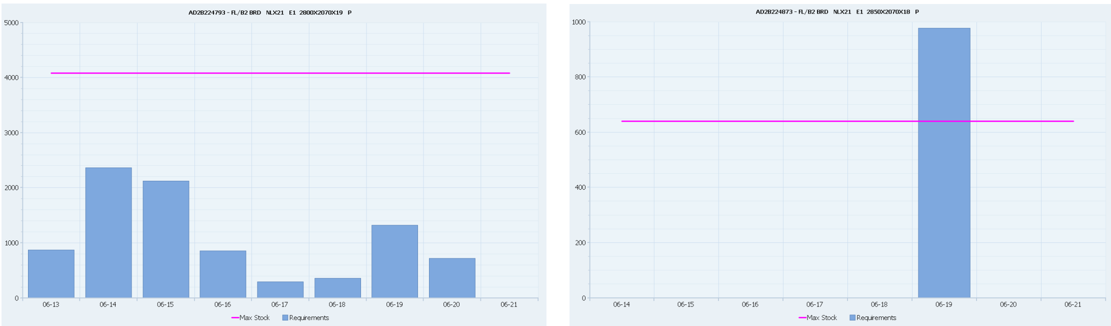
To assist the examination of this and other circumstances in which *Requirements* in a given time window exceed the maximum stock amount, *SAP*'s *Transaction X* was implemented with a colour scheme once more. This time, if the *Requirements* value exceeds the *Maximum Stock* value for a certain SKU, the corresponding cell will become red, as can be seen in Figure 4.6.

Requir.
633
889
1 524
1 365
4 898
1 614
405
127
195
1 260
652
0
149

Figure 4.6: Colour coding of the *Requirements* column

This colour coding facilitates the identification of SKUs that require particular attention promptly. In addition, it was developed a pop-up window that provides access to a bar chart with *Requirements* data for each day within the set time horizon, as well as the maximum stock defined for each SKU, by selecting any cell in this *Requirements* column, as these are underlined (Figure 4.6). These graphics are represented in Figure 4.7.

These graphs allow the planner to determine in advance which materials will have *Requirements* exceeding their maximum stock, as well as the day on which this is anticipated to occur, allowing the planner to make any necessary adjustments. In the scenario depicted in Figure 4.7a , the *Requirements* do not exceed the Maximum Stock value on any day within the specified horizon. On the graph 4.7b , it is possible to see that on 06/19 there will be a peak where the *Requirements* will exceed the *Maximum Stock*.



(a) *Requirements* do not exceed *Maximum Stock* (b) *Requirements* do exceed *Maximum Stock*

Figure 4.7: Graph developed to observe the *Requirements* compared to the *Maximum Stock* value in a certain time frame

The depiction of both the past and future projections made by the system was also identified as a challenge by the team before the beginning of this project. To improve this situation, a graph per SKU was generated by opening a pop-up window when clicking on the highlighted cell of the NFP column (Figure 4.8).

NFP
1 750
482-
734
102
252
10

Figure 4.8: *NFP* column

The created graphs, presented in Figure 4.9, include two reference lines, one representing the Reorder Point value and the other representing the Maximum Stock value.

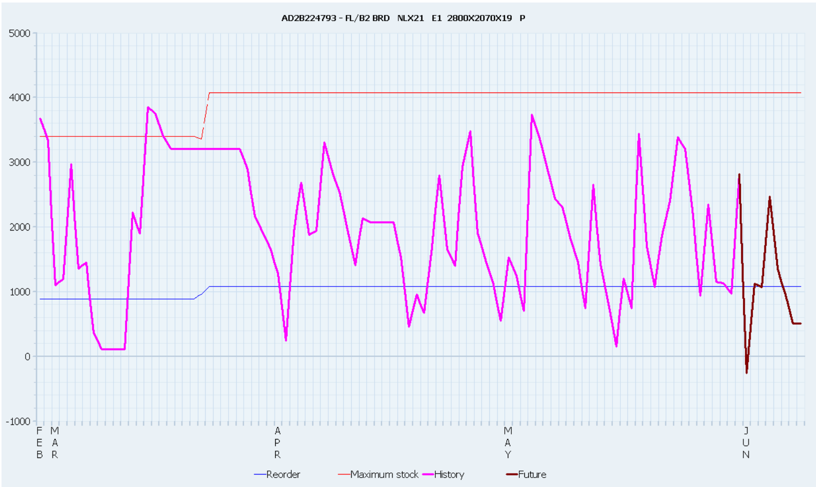


Figure 4.9: Graph developed with historical data and forecasts for the future

The target would be for both historical and future forecast lines to remain between the two above-mentioned reference values, as the zone inside these boundaries corresponds to the buffer's green area. To improve the readability of this graph, it was decided to separate the historical and future projections with separate lines: the pink line reflects historical data, whereas the brown line depicts future ERP forecasts, as depicted in Figure 4.9.

An overview of the final appearance of *Transaction X* after all these modifications can be seen in Appendix B in Figure B.1.

4.4 Continuous Monitoring of Buffer Levels

The dynamic environment inherent in the reality of this industry requires that any decision made at a previous point in time be evaluated and re-analysed on a regular basis to guarantee that it is reliable and up-to-date. As a result, the defined stock levels must be monitored and, when required, adjusted after a given length of time or whenever there are significant changes in the prior scenario.

The proposed enhancement is installing a monitoring procedure that includes criteria for positioning SKUs concerning pre-established control zones that track the performance evolution of the defined stock levels across the period under consideration. Despite being accepted, this modification did not have time to be implemented in this project. However, it will be explained further down.

This monitoring follows the SKU buffer level in the company, placing the item's stock on one of four monitoring levels, as mentioned in the preceding section, emphasising the need to review them. This phase aims to ensure that excessively high or deficient stock levels are not maintained at any given time. Because the sizing and monitoring processes must be continual, the outcomes are only short-term.

The green zone generally implies that stock levels are adequate when supply and demand realities are considered. On the other hand, keeping a maximum stock value, which is the target level, too high for numerous different items, has apparent negative consequences, as replenishments are produced when there is no real need for them. As predicted by Cox III et al. (2010), "Too Much Green" events may emerge when the buffer level remains over the green zone's upper limit for more than five consecutive periods. Depending on the extent of penetration, this permanence may suggest the need to review the stock levels established.

Remaining in the yellow zone alerts that stock levels may need to be reviewed. This scenario may represent consumption peaks or buffer replenishment delays. This intervention, however, is only required if this scenario is detected for more than three consecutive sessions. Otherwise, the SKU should be identified in order to ensure tighter control of it.

In contrast to "Too Much Green", there is also "Too Much Red". The red zone may also indicate that stock levels need to be reviewed. Nevertheless, premature decisions should not be taken. Only after the buffer level has remained in the red zone for three consecutive periods is it essential to take action to overcome this scenario. Nonetheless, depending on buffer level's penetration in the red zone, this may imply "Too Much Red" issues or ruptures, requiring critical and urgent resizing. As a result, increasing the maximum stock level is the best strategy in this scenario. Thus the planner must manually make adjustments to the Material Master Data as needed and replace the numbers estimated by the system with those generated by his calculations that he believes most appropriate.

The stock levels defined must therefore be monitored and, when applicable, adjusted after a certain period or whenever significant changes occur in the previous scenario. However, as stated, this task demands a vast amount of data.

Figure 4.10 depicts a flow chart demonstrating how this monitoring should be carried out.

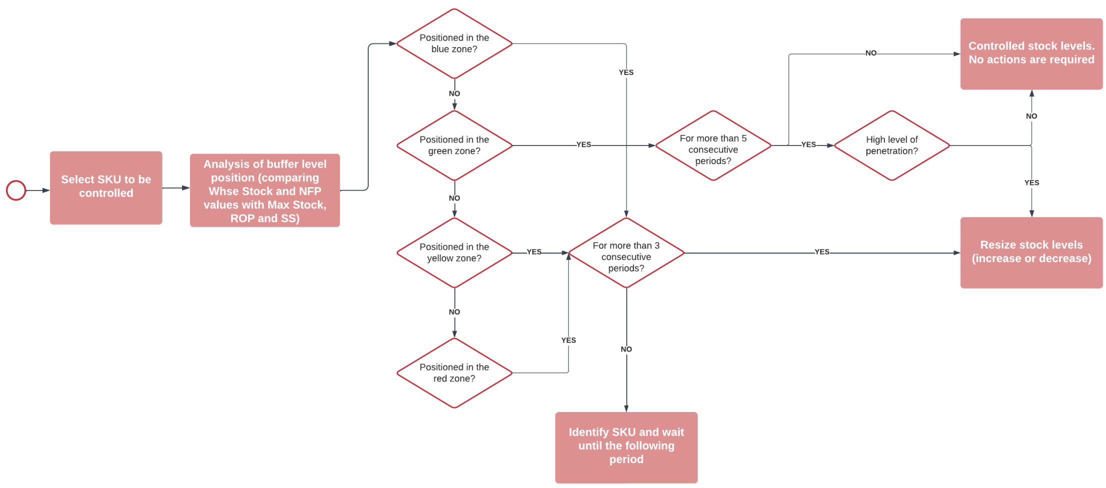


Figure 4.10: Process for monitoring stock

It should be noted that if it becomes essential to adjust the stock levels, it may also be necessary to adjust the number of available slots for each SKU. Therefore, when revising stock levels, the planner must also consider warehouse constraints.

4.5 Development of KPIs Concerning the Occupancy of the Semi-finished Products' Warehouse

Daily data were collected from *XR* Software and imported into *Microsoft Excel* so that a more in-depth investigation of what was occurring in this warehouse of semi-finished products could be conducted. Again, it proved challenging to make conclusions on the disposition's management, as there were no indicators that would allow for a quick and effective verdict. The team decided that iterative adjustments would be made to the warehouse's structure and the management of warehouse positions until an efficient method of managing the available space was discovered.

The warehouse for semi-finished goods is followed by the production line area where cutting and melamine can be performed. Together, the production planning and shop floor teams determined that it would be more advantageous to optimise the line if all FTO article positions were located at the exit of the overhead crane, thereby minimising response time and obtaining an even more competitive lead time for these articles. The arrangement of positions following this alteration is depicted in the Figure 4.11.

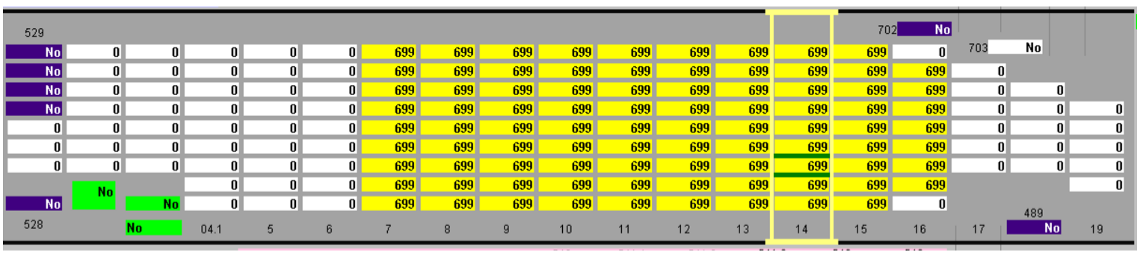


Figure 4.11: Final layout adopted in the semi-finished products' warehouse

Additionally, it was agreed that there would be no more fixed positions for each SKU. Thus, all yellow slots are now available for FTO materials, whereas the remaining positions are available for MTO materials. Consequently, the decision of where to place which material became the responsibility of the shop floor, based on necessity and availability, as long as materials are placed in the space designated for that material type. The work developed within this warehouse aims to control whether the quantity of positions assigned to each SKU by the planner is being used, or whether fewer or more positions than expected are being used. Additionally, there is still the aim of preventing the mixing of distinct items in each position.

The extracted data from the *XR* software, which can be seen in Table C.1 in Appendix C, were processed in *Microsoft Excel* to analyse these circumstances. Some information was extracted from the previously stated DOC 1 developed by the planner, such as the m^3 per board, the maximum m^3 per position, and the number of reserved positions for each SKU. With this information and the data retrieved from XR software on the number of positions and the m^3 occupied by each SKU, Table 4.2 was created. *Expected Pos* is a column that, based on the value of the m^3 occupied in the warehouse, calculates the expected number of positions that the material should occupy.

Table 4.2: Information regarding the amount of positions held by each SKU

SKU	Dimensions	M3/board	Max M3	Max Pos	11/mai	12/mai	13/mai	16/mai	17/mai	18/mai	19/mai	20/mai	M3	Expected Pos
AD2B130	4880x2070x10	0,10	65	1	1	1	1	1	1	1	1	1	42	1
AD2B130	5600x2070x10	0,12	150	2	2	2	1	1	1	1	2	2	111	2
AD2B130	4880x2440x10	0,12	77	1	1	1	1	1	1	1	2	1	38	1
AD2B224	2800x2070x16	0,09	376	5	2	1	1	2	1	3	1	3	184	3
AD2B224	2800x2070x19	0,11	450	6	1	0	4	0	1	2	5	1	40	1
AD2B224	2440x2070x16	0,08	65	1	1	1	0	1	1	1	1	1	8	1
AD2B224	2850x2070x16	0,09	76	1	1	1	1	1	2	1	1	1	15	1
AD2B224	3660x2070x16	0,12	98	2	1	1	1	1	1	1	1	1	1	1
AD2B224	5600x2070x16	0,19	150	2	1	1	0	3	1	1	2	2	32	1
AD2B224	2440x2120x16	0,08	134	2	1	1	1	1	1	2	2	2	93	2
AD2B224	2850x2120x16	0,10	313	4	0	1	1	1	3	2	1	1	32	1
AD2B224	3660x2440x16	0,14	174	3	0	1	1	1	1	1	1	1	6	1
AD2B224	4880x2440x16	0,19	154	2	1	1	0	1	1	0	0	0	0	0
AD2B224	2800x2070x16.5	0,10	75	1	1	1	1	1	1	1	1	1	65	1
AD2B224	4880x2440x16.5	0,20	76	1	1	1	1	1	1	1	1	1	48	1
AD2B224	2800x2070x18	0,10	150	2	2	2	1	2	1	3	1	3	145	2
AD2B224	2850x2070x18	0,11	76	1	1	1	1	1	1	1	1	1	3	1
AD2B224	2440x2120x18	0,09	67	1	1	1	1	1	1	1	1	1	36	1
AD2B224	2440x2070x19	0,10	65	1	1	1	1	1	1	1	1	1	23	1
AD2B224	2850x2070x19	0,11	76	1	1	1	1	1	1	1	1	1	82	2
AD2B224	3660x2070x19	0,14	54	1	1	1	1	1	1	1	1	1	47	1

Combining all the data from the table, distinct KPIs are calculated for each day. The constructed Table 4.3 currently stores daily information regarding these indicators. The developed indicators are as follows:

- *Available Pos* indicates the number of positions available for the FTO materials;
- *Available Pos + Buffer* corresponds to the number of positions that are available for the FTO materials with the addition of the spare positions;
- *#Non-Mixed Positions* indicates the number of positions that do not contain mixed SKUs, the intended value of which would be the same as that indicated in Available Pos;
- *Mixed Piles* refers to the number of positions containing mixed SKUs. The objective value is zero since there should ideally be no positions with mixed products;
- *Stockout* indicates the number of SKUs that are not occupying any position, even if expected;
- *Below Max* counts the number of SKUs that are below the defined maximum number of positions for that SKU, i.e. the number of SKUs that do not occupy more positions than the defined maximum and that are actually occupying any position (*Total Number of SKUS - Stockout - Above Max*);
- *Above Max* concerns the number of SKUs that occupy more positions than initially predicted by the planner;
- *More Positions than Expected for m^3 in stock*. A situation that occurs and that is crucial to control is the fact that, according to the information of the m^3 that are being occupied on that

day, indicated in Table 4.2 by the column M3, it would be expected that a certain number of positions would be enough. However, more positions are being filled than expected, even though the total volume in stock would fit in the positions already assigned to that SKU. The quantity of SKUs in this situation is indicated in the table as More Positions than Expected for m^3 in stock. The aim for this value is to be zero, as well as in the case of the *Stockout* and the *Above Max* values.

Table 4.3: Developed KPIs for positions held in the warehouse of semi-finished goods

Available Pos	83	83	83	83	83	83	83	83	83	83	83	83
Available Pos + Buffer	88	88	88	88	88	88	88	88	88	88	88	88
#Non-Mixed Positions	76	77	70	70	60	61	58	63	64	64	64	64
#Mixed Piles	2	2	0	0	0	0	0	0	0	2	2	2
Stock Out	1	0	1	1	4	4	7	3	2	3	4	3
Below Max	46	48	46	48	47	47	44	47	48	48	48	48
Above Max	9	8	9	7	5	5	5	6	6	5	4	5
More Positions than Expected (for m^3 in stock)	8	8	5	5	5	7	5	4	3	5	5	4
	05/mai	06/mai	09/mai	10/mai	11/mai	12/mai	13/mai	16/mai	17/mai	18/mai	19/mai	20/mai

Again, a colour scheme was assigned to this table so the data could be quickly interpreted via its visual representation. When comparing the value in the *Expected Pos* column with the value in the Max Pos column, blue is assigned if more positions are filled than the planner anticipated. The colour red is exhibited when an SKU does not occupy any position. Yellow represents the situation described above by the KPI *More Positions than Expected for m^3 in stock* in the case where an SKU occupies more positions than expected according to the m^3 that are being occupied in the warehouse by that product. Green represents the opposite situation. In this case, fewer positions than expected are being occupied according to the calculations conforming to the value of m^3 in storage. The team should also assess these scenarios since they may be justified by the usage of the space left used due to safety concerns, for example.

The construction of these KPIs has been valuable as it allows the values to be controlled. In case these KPIs start to have values outside of what is intended, it is easy to reassess the layout adopted and, if necessary, the buffer of each product, modifying it to a more appropriate value.

To make it even easier to visualise these KPIs, two separate graphs were developed. The graphic in Figure 4.12 depicts two limits: the line representing the number of available positions (83) and another line representing the number of available positions plus buffer (88). Thus, observing the overall number of positions utilised per day is feasible. The grey bars represent the number of positions that do not contain mixed SKUs, whereas the yellow bars represent the number of positions with mixed SKUs. The aim is to have no positions with distinct SKUs. That is, there should be no yellow in the bars. Observing the numbers in this graph, it is clear that improvements have been made, but warehouse improvements are still required to ensure that there are no mixed product positions.

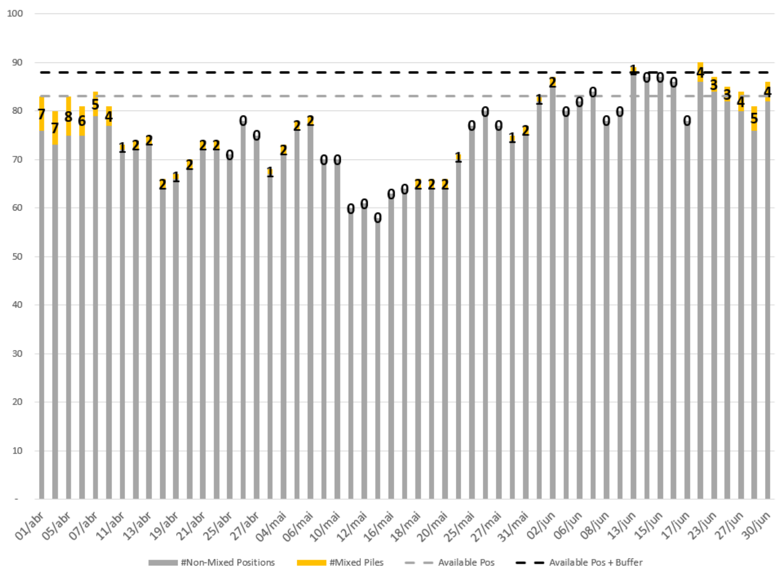


Figure 4.12: KPIs developed to monitor the quantity of stockpiles containing mixed SKUs

The second graph, in Figure 4.13, contains information on the number and behaviour of SKUs in stock. The green region represents the number of SKUs whose positions correspond to those predicted by the prior study made by the planner. Red represents the number of SKUs not occupying any position despite being required. Blue represents the number of SKUs that occupy more places than anticipated. Finally, the yellow line reflects the number of SKUs filling more spots than expected for the m^3 occupied in the warehouse. This line represents the previously defined KPI, *More Positions than Expected for* m^3 *in stock*.

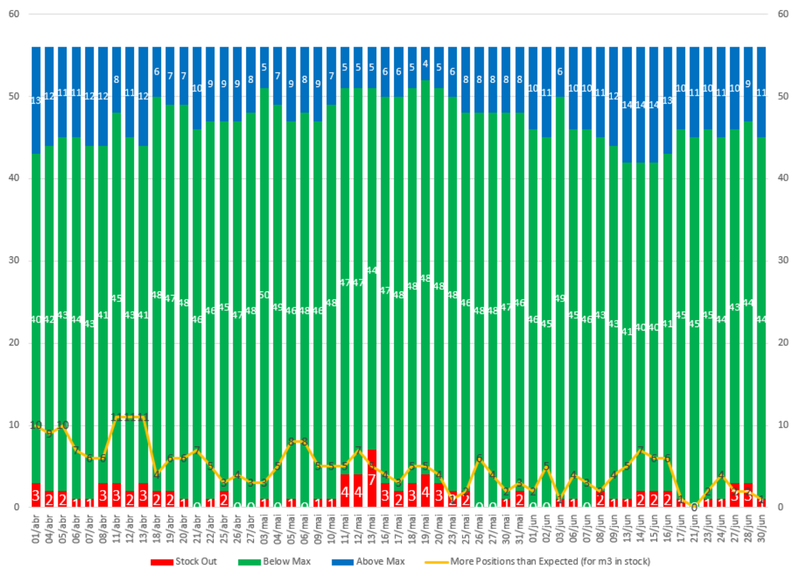


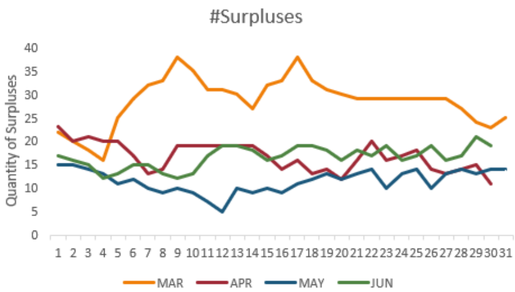
Figure 4.13: KPIs developed to monitor the quantity of SKUs in line with the study previously carried about the occupied positions in the warehouse

4.6 Results

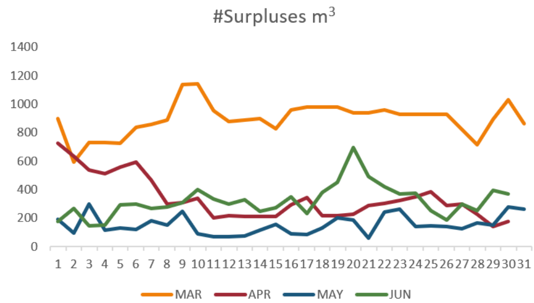
To observe the progression of the produced KPIs, graphs were constructed using data from the beginning of the project until its conclusion. These graphs are displayed in Figure 4.14. The established KPIs reflect if the implemented enhancements provide value to the organisation and contribute to the project's objectives.

Observing these graphs, it is possible to deduce that both *Surpluses* and *Stockouts* have decreased throughout this project. It is essential to note, however, that external factors influenced these values. As a result of Russia's invasion of Ukraine in 2022, this project encountered a more challenging period. This war had global repercussions and affected the results of this project in particular due to a transport strike in Spain, where this storage for semi-finished goods is located.

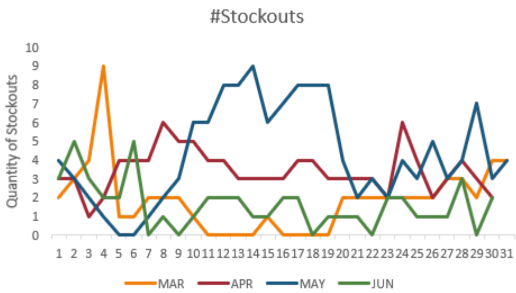
The Surpluses' graph, in Figure 4.14a, reveals that the month with the highest surplus stock values was March and that the subsequent months have steadily decreasing values.



(a) Number of SKUs that had *Surpluses* during the project's duration



(b) Quantity in m^3 of *Surpluses* observed during the project's duration



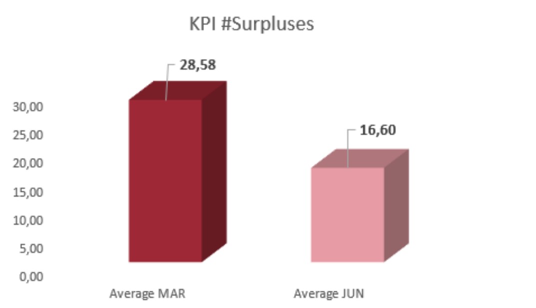
(c) Number of SKUs that had *Stockouts* during the project's duration

Figure 4.14: Performance of the KPIs implemented throughout the project

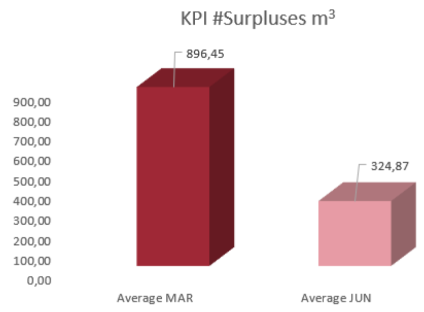
Another graph displaying the average KPIs for the project's beginning and ending months, March and June, respectively, was also generated.

Comparing these average data, in Figure 4.15a, in March, when the project began, and June, when it was concluded, a decrease of 42 per cent in *Surpluses* can be observed. Comparable behaviour may be observed when examining the graph in Figure 4.15b for *Surpluses*, which contains information about m^3 rather than the number of SKUs. Over this project's months, a gradual decline and a 64 per cent fall in these values are also noted in this regard.

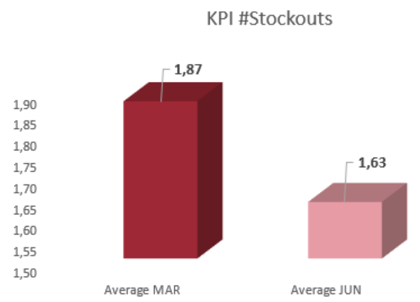
Due to the above-mentioned external circumstances, it is clear to observe in the graph represented in Figure 4.14c that *Stockouts* did not experience the same gradual drop as *Surpluses* over the course of the months. Nevertheless, when comparing the average number of *Stockouts* in March and June, it is possible to conclude that this number decreased by 13 per cent, as seen in Figure 4.15c.



(a) Average number of SKUs that had *Surpluses* in the initial and final project months



(b) Average quantity in m^3 of *Surpluses* in the initial and final project months

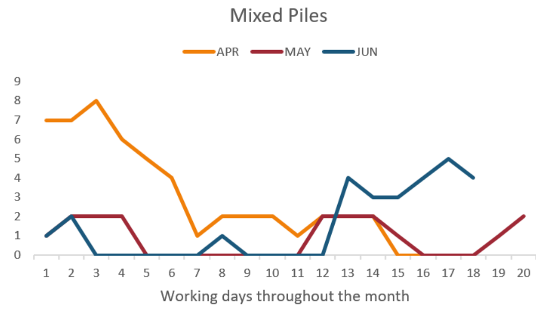


(c) Average number of SKUs that had *Stockouts* in the initial and final project months

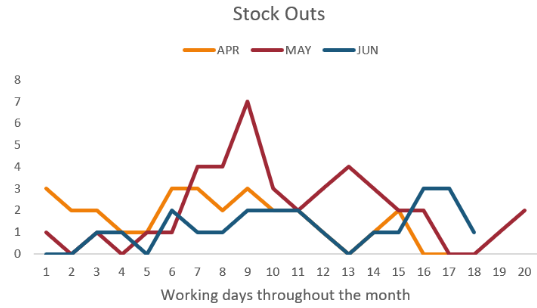
Figure 4.15: Arithmetic mean of the KPIs developed in the initial and final months of the project

In addition, the KPIs generated in the context of the semi-finished products' warehouse's layout were analysed. However, this record only began in April, and only happened on business days.

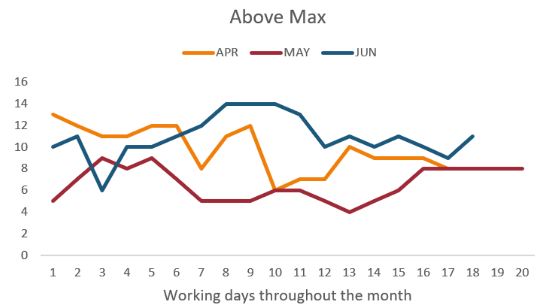
As observed in the preceding graph in Figure 4.12, KPIs *Available Pos* and *Available Pos + Buffer* are constant, and the goal is for them to remain constant. The objective for *#Non-Mixed Positions* and *Below Max* is to equal the value of *Available Positions*. *Mixed Piles*, *Stockouts*, *Above Max*, and *More Positions than Expected* are the most crucial KPIs to monitor, as they all have the same objective: to reach zero. Consequently, graphs of these four KPIs were generated, seen in Figure 4.16.



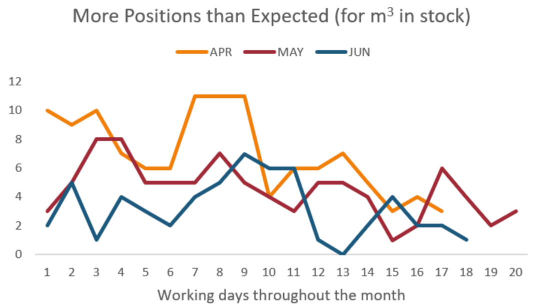
(a) Number of mixed piles



(b) Number of SKUs that do not occupy any position



(c) Number of SKUs occupying more positions than expected



(d) Number of SKUs occupying more positions than expected acording to the m^3 that are being occupied

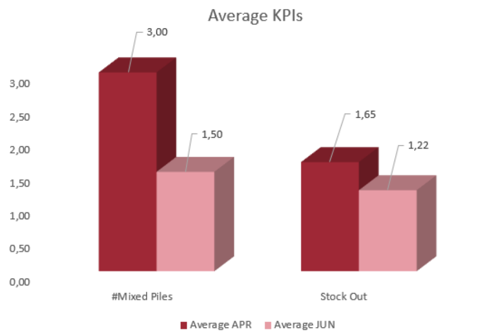
Figure 4.16: Performance of the KPIs implemented in the context of warehouse layout throughout the project

Regarding the *Mixed Piles* and *More Positions than Expected* graphs, Figure 4.16a and 4.16d respectively, it is evident that April, the first month this data was collected, had the worst outcomes. At first glance, it is impossible to make conclusions from the remaining KPIs' graphs so it is important to continue to monitor these in the future. It is crucial to reiterate that the transport strike that occurred had a significant impact on these findings since it prevented the outflow of items from the warehouse for several days and even halted production.

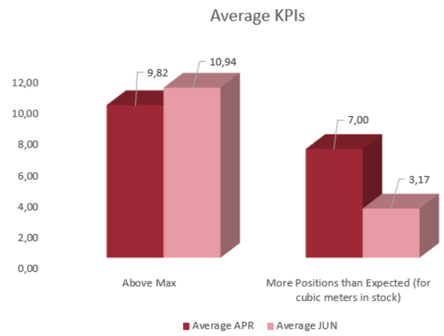
In addition, graphs depicting the average values of these KPIs for the months of April and June were constructed and can be seen in Figure 4.17. These months are the ones in which the registration of these KPIs began and the project ended, respectively.

In these graphs it is possible to observe a 50 per cent decrease in Mixed Piles, a 26 per cent decrease in *Stockouts*, and a 55 per cent decrease in *More Positions than Expected*. The Above Max KPI had a 11 per cent increase.

In this warehouse, a decline in the *More Positions than Expected* KPI is noteworthy since it indicates that fewer and fewer positions are being overfilled for no apparent reason. The KPI *Above Max* represents the number of SKUs occupying more positions than expected, but because there is effectively more material than supposed, a problem that is crucial to solve in order to reduce the number of surpluses. This value is also meant to be zero, as stated previously.



(a) Average number of *Mixed Piles* and *Stockouts*



(b) Average number of *Above Max* and *More Positions than Expected (for cubic meters in stock)*

Figure 4.17: Arithmetic mean of the KPIs developed in the context of warehouse layout in the initial and final months of the project

Chapter 5

Conclusion and Future Projects

The increasing difficulties that businesses encounter today make it imperative for them to utilise solutions that assist the continual monitoring of decisions made in the past. In addition, businesses must have well-defined procedures that answer the questions what, where, when, why, by whom, and how a given activity or function should be carried out (Trkman, 2010).

In this project a study was made to find a method for levelling semi-finished product inventories, developing a solution that minimises situations of stock insufficiency or surplus in order to define optimal dynamic stock quantities based on demand data in a short period of time. The objective was to develop a procedure to enable the identification of the amounts required for each product and, if necessary, to identify the adjustments needed.

A recent change at this factory necessitated an adjustment to the new circumstances. Initially, just an MTO production system was used in the plant where this study was conducted. In the meanwhile, modifications were made, and production on an FTO-MTO system commenced. When this transition happened, undesired levels of stockouts and surpluses were seen, along with the difficulties of regulating and correcting them. At this time, it was crucial for the corporation to monitor and, if necessary, adjust its stock levels to accommodate this development.

Thus, the primary objective of this project was to establish a dynamic and adaptable procedure for sizing and monitoring the inventory levels of semi-finished items in order to enable decision making regarding their readjustment within the context of Sonae Arauco's stock management area. To this end, several theoretical contributions present in the literature reviewed were studied about Dynamic Buffer Management based on Goldratt's Theory of Constraints and also about Ptak and Smith's DDMRP. Having these two philosophies as a basis, a buffer was developed for each SKU according to rules defined, taking into account the constraints of this project.

The enhancements were developed in conjunction with the other theoretical contributions on information and on the significance of its visualisation.

For any operation with strategic ramifications, it is necessary to conduct performance evaluations, enabling the identification of improvement requirements in areas that warrant it (De Araújo et al., 2014). To this purpose, a set of Key Performance Indicators essential to the administration of this facility was developed, such as the number of *Stockouts* and *Surpluses*. These indicators were generated based on the developed buffers.

A study was also conducted on the layout used in this warehouse, and other Key Performance Indicators were developed for this topic, such as the number of positions containing different products mixed together, which should be avoided in the context of this warehouse. These indicators have proven indispensable for the proper administration of the aforementioned warehouse.

Since the presentation of information has a considerable impact on how it is interpreted, several tools were developed in SAP to aid in the visualisation of generated data. With the goal of maximising the growth of these indicators, the development of these tools made the information accessible to all, enabling the identification of crucial situations requiring repairs and modifications.

Within the scope of this project, the military conflict that accompanied Russia's invasion of Ukraine in 2022 caused considerable difficulties. This had global ramifications and particularly affected the outcomes of this investigation in Spain, where the study was conducted, due to a traffic strike. Nonetheless, the results reported demonstrate that the current implementations have already enabled the achievement of favourable outcomes. The number of stockouts and surpluses has already decreased compared to the initial values at the start of the project. Moreover, and with regard to the management of the semi-finished products' warehouse itself, there has been a significant improvement in the KPIs created as there has been a decrease in the number of warehouse positions that contain mixed SKUs, the number of positions that are empty, and the number of positions occupied in excess compared to those initially predicted in the positions' study.

A 13 per cent reduction in *Stockouts* was accomplished for these semi-finished products, as well as a 42 per cent reduction in the number of SKUs with surpluses and a 64 per cent reduction in the quantity of *Surpluses* in m^3. The number of mixed material positions decreased by 50 per cent due to an improvement in warehouse management. Furthermore, a 26 per cent decrease in *Stockouts* and a 55 per cent decrease in *More Positions than Expected* KPI were observed.

To the context of the problem presented, the attained outcomes indicated the adaptability and validity of the process, hence showing to be a relevant solution proposal for the company.

In conclusion, all the objectives specified for the development of this project were successfully attained, resulting in satisfactory and pertinent outcomes for the organisation. Thus, it is believed that the specified procedure meets all proposed objectives in an effective and transparent manner. It is characterised by its agility, dynamism, and focus on minimising the danger of stockouts, delays, and overstocks in the Linares warehouse for semi-finished goods.

By integrating this project, it was feasible to gain a realistic understanding of the business environment's existing dynamism. What is regarded correct and optimum currently, and the path that appears to be the correct one to pursue, may not be the most appropriate tomorrow, since a mindset of continual development must be adhered to. An organisation must have this adaptability in order to be skilful and able to respond to potential changes.

As part of future developments, continuous monitoring of buffer levels could be integrated into *SAP*, with the ability to adjust them after a specified period of time or if there are significant changes to the previous scenario. It would also be important to make the warehouse layout KPIs' accessible to all, once, currently, these are only recorded and updated in a *Microsoft Excel* file. Additionally, and in a more general sense, all of these technologies, or the ones that make more sense in each scenario, could be implemented in the warehouses and distribution centres of the company's other plants. In order to achieve this, it is necessary to take into account all of their limitations and modify the model in this project so that appropriate tools can be developed for each case and which ones actually allow for an optimisation of the management of these warehouses, therefore making it possible to reduce the number of Stockouts and Surpluses.

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Appendix A

Graphics Initially Developed in *Microsoft Excel*

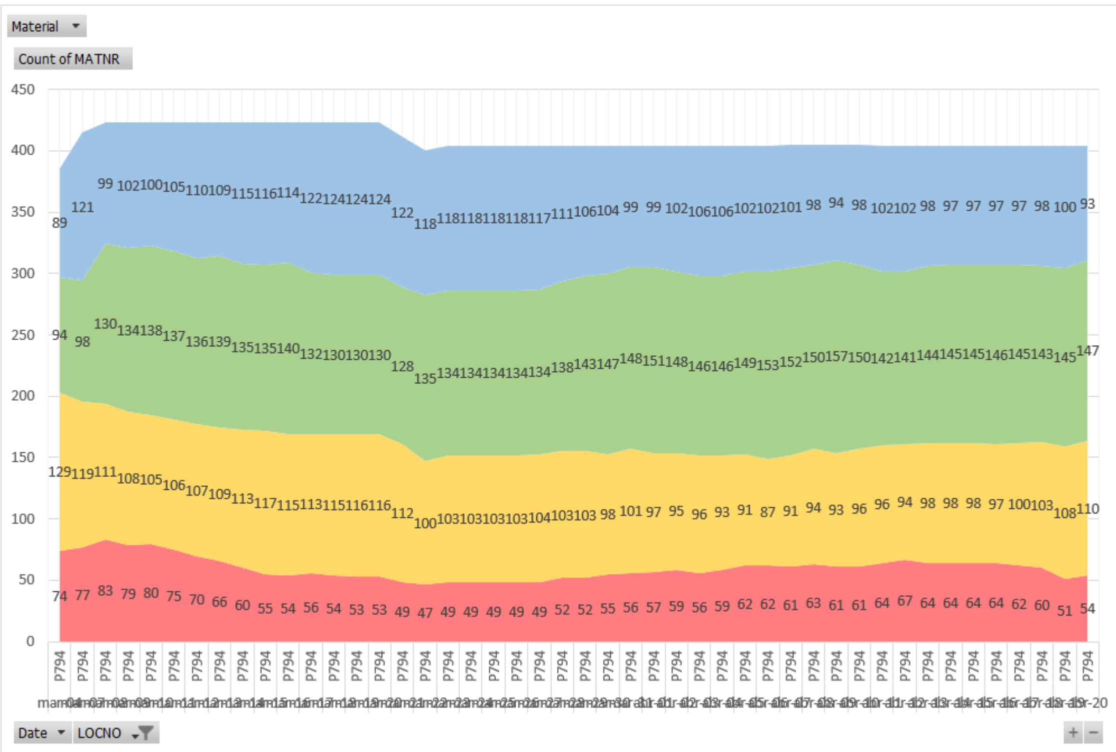

Figure A.1: Graph exhibiting KPIs for the number of SKUs in each zone of the defined buffer first created in *Microsoft Excel*

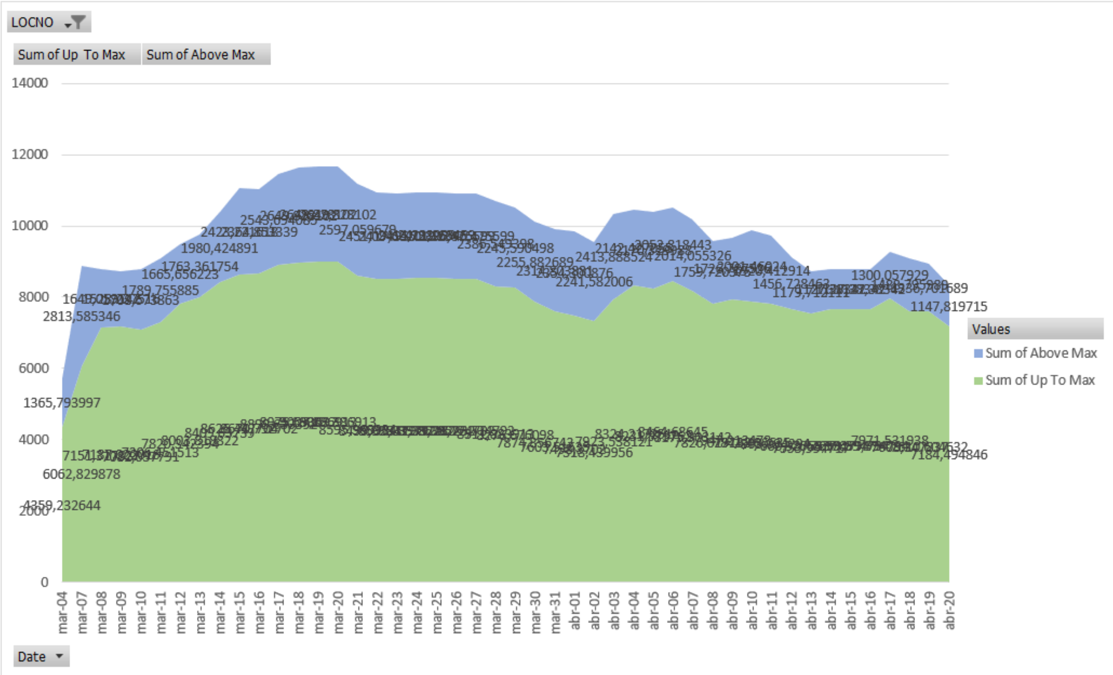

Figure A.2: Graph exhibiting the m^3 occupied in the semi-finished product warehouse first created in *Microsoft Excel*

Appendix B

Final Transaction X Overview

Product	Product Description	RP	Max. Stock	Order Qty	Spmrkt Qty	Prod. Qty	Requir.	Whse Stock	%	NFP	%	Min NFP	%	Max NFP	%
AD2B13...	ST/B1 BRD NLX21 ...	360	1 080	480	0	263	773	480	44	30-		30-		743	69
AD2B13...	ST/B1 BRD NLX21 ...	240	720	307	0	480	468	307	43	319	44	14	2	494	69
AD2B13...	ST/B1 BRD NLX21 ...	228	684	31	244	0	31	275	40	244	36	244	36	244	36
AD2B13...	ST/B1 BRD NLX21 ...	228	570	99	214	0	99	313	55	214	38	214	38	288	51
AD2B13...	ST/B1 BRD NLX21 ...	342	1 254	423	0	700	1 360	423	34	237-		237-		690	55
AD2B13...	ST/B1 BRD NLX21 ...	228	570	16	296	0	16	312	55	296	52	296	52	296	52
AD2B22...	FL/B2 BRD NLX21 ...	1 152	4 032	2 062	0	6 040	6 570	2 062	51	1 532	38	778-		2 927	73
AD2B22...	FL/B2 BRD NLX21 ...	1 080	4 080	2 769	0	4 801	8 136	2 769	68	566-		1 413-		2 456	60
AD2B22...	FL/B2 BRD NLX21 ...	288	720	188	14	720	188	202	28	734	102	734	102	922	128
AD2B22...	FL/B2 BRD NLX21 ...	288	720	100	0	720	718	100	14	102	14	102	14	820	114
AD2B22...	FL/B2 BRD NLX21 ...	216	792	0	255	0	0	255	32	255	32	255	32	255	32
AD2B22...	FL/B2 BRD NLX21 ...	216	792	808	0	428	1 226	808	102	10	1	10	1	934	118
AD2B22...	FL/B2 BRD NLX21 ...	432	1 584	318	0	2 201	2 159	318	20	360	23	175	11	2 376	150
AD2B22...	FL/B2 BRD NLX21 ...	864	3 168	902	0	4 152	3 238	902	28	1 816	57	496-		2 907	92
AD2B22...	FL/B2 BRD NLX21 ...	360	1 152	4	0	2 152	799	4		1 357	118	205	18	1 357	118
AD2B22...	FL/B2 BRD NLX21 ...	216	792	227	0	0	318	227	29	91-		91-		214	27
AD2B22...	FL/B2 BRD NLX21 ...	280	700	564	90	0	564	654	93	90	13	90	13	466	67
AD2B22...	FL/B2 BRD NLX21 ...	140	350	363	0	390	403	363	104	350	100	350	100	753	215
AD2B22...	FL/B2 BRD NLX21 ...	384	1 408	1 497	0	512	2 326	1 497	106	317-		317-		1 261	90
AD2B22...	FL/B2 BRD NLX21 ...	256	640	977	1	0	977	978	153	1		1		327	51
AD2B22...	FL/B2 BRD NLX21 ...	256	640	369	325	0	369	694	108	325	51	325	51	325	51
AD2B22...	FL/B2 BRD NLX21 ...	256	768	632	0	512	744	632	82	400	52	186	24	698	91
AD2B22...	FL/B2 BRD NLX21 ...	240	600	63	250	0	63	313	52	250	42	250	42	250	42

Figure B.1: Transaction X overview after all implementations

Appendix C

Imported Data from Software *XR*

Table C.1: Data exported from *XR* Software to *Microsoft Excel*

Linares 0 Página:1
DBtron/L Lin ares Fecha: 18.04.22

Fl.HI.PL:	Sec	Largo	Ancho	Espe	s XYZ	Tipo	Nº-I	Orden de	▲	SSDT	Canti	m^3	Fecha f	Edad	Desc	Pos	FTO
56 11 10	3	5800	2800	0	0	FIL	PBA60(	9,007E+09	1		40	0.04	01.02.22	105		56 11	
56 08 11	3	5800	2800	0	0	FIL	PBA0242970		1	7,942E+09	60	0.07	01.03.22	77		56 08	
09 08 07	1	3660	2070	19	699	NLX	AD2B2:	40765593	1	41722670	18	2.59	01.04.22	46		09 08	FTO
54 10 03	3	5800	2800	0	0	FIL	PBA6000611		1	7,942E+09	52	0.05	01.04.22	46		54 10	
03 09 02	1	3660	2100	25	0	NLX	AD2B2:	40765952	1	7,942E+09	13	2.50	01.05.22	16		03 09	
08 01 01	1	5700	2070	16	699	NLX	AD2F2:	40765963	1	80079836	72	6.68	01.05.22	16		08 01	FTO
08 01 01	1	5700	2070	16	699	NLX	AD2F2:	40765963	1	80079837	72	6.68	01.05.22	16		08 01	FTO
08 01 02	1	5700	2070	16	699	NLX	AD2F2:	40765963	1	80079838	31	2.87	01.05.22	16		08 01	FTO
08 01 02	1	5700	2070	16	699	NLX	AD2F2:	40765963	1	80079839	31	2.87	01.05.22	16		08 01	FTO
54 13 01	3	5800	2800	0	0	FIL	PBA6000595		1	5,51E+09	532	0.63	01.05.22	16		54 13	
56 02 04	3	5800	2800	0	0	FIL	PBA6000331		1	9,007E+09	12	0.01	01.05.22	16		56 02	
56 08 06	3	5800	2800	0	0	FIL	PBA0242442		1	7,942E+09	43	0.05	01.05.22	16		56 08	
56 11 07	3	5800	2800	0	0	FIL	PBA6000316		1	7,942E+09	12	0.01	01.05.22	16		56 11	
17 05 06	1	4890	2450	30	0	MU	AD2VPI	40661031	1	77788956	32	11.50	01.09.21	258	Tapas para Giben	17 05	
06 05 01	1	4890	2445	10	699	MS	AD2F2:	40764873	1	9,007E+09	16	1.91	02.02.22	104		06 05	FTO
06 05 02	1	4890	2445	10	699	MS	AD2F2:	40764873	1	9,007E+09	120	14.29	02.02.22	104		06 05	FTO
54 10 07	3	5800	2800	0	0	FIL	PBA6000490		1	7,942E+09	66	0.06	02.03.22	76		54 10	
10 04 01	1	3660	2070	10	699	NLX	AD2B1:	40765598	1	7,942E+09	83	6.29	02.04.22	44		10 04	FTO
10 04 02	1	3660	2070	10	699	NLX	AD2B1:	40765598	1	7,942E+09	114	8.64	02.04.22	44		10 04	FTO
10 04 03	1	3660	2070	10	699	NLX	AD2B1:	40765598	1	7,942E+09	114	8.64	02.04.22	44		10 04	FTO
10 04 04	1	3660	2070	10	699	NLX	AD2B1:	40765598	1	7,942E+09	41	3.11	02.04.22	44		10 04	FTO
14 02 01	1	5100	2070	19	699	NLX	AD2B2:	40765611	1	7,942E+09	60	12.03	02.04.22	45		14 02	FTO
14 02 02	1	5100	2070	19	699	NLX	AD2B2:	40765611	1	7,942E+09	60	12.03	02.04.22	45		14 02	FTO
14 02 03	1	5100	2070	19	699	NLX	AD2B2:	40765611	1	7,942E+09	60	12.03	02.04.22	45		14 02	FTO
14 02 04	1	5100	2070	19	699	NLX	AD2B2:	40765611	1	7,942E+09	60	12.03	02.04.22	45		14 02	FTO
14 02 05	1	5100	2070	19	699	NLX	AD2B2:	40765611	1	7,942E+09	14	2.81	02.04.22	45		14 02	FTO
16 09 03	1	5800	2070	15	0	MU	AD2VPI	40664591	1	77905269	39	3.45	02.04.22	45	tapas con melamina	16 09	
16 09 04	1	2850	2070	15	0	MU	AD2VPI	40664591	1	77905264	71	6.28	02.04.22	45	tapas con melamina	16 09	
54 11 07	3	5800	2800	0	0	FIL	PBA0239749		1	7,942E+09	36	0.04	02.04.22	45		54 11	
56 09 04	3	5800	2800	0	0	FIL	PBA0238910		1	7,942E+09	19	0.02	02.04.22	44	arcoiris	56 09	
54 05 04	3	5800	2800	0	0	FIL	PBA0242326		1	7,942E+09	80	0.08	02.05.22	15		54 05	
56 06 11	3	5800	2800	0	0	FIL	PBA0243222		1	7,942E+09	45	0.06	02.05.22	15		56 06	
56 08 10	3	5800	2800	0	0	FIL	PBA0243225		1	9,007E+09	172	0.24	02.05.22	15		56 08	
02 07 05	1	5605	2070	30	0	NLX	AD2B7:	40764032	1	9,007E+09	34	11.82	02.12.21	165	RELIJADO	02 07	