UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias e Ingenierías

Propuesta de un modelo híbrido de producción Make-to-Availability y Make-to-Order para una empresa maderera a través de la metodología Sales and Operations Planning (S&OP).

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RESUMEN

Actualmente, mejorar la experiencia del cliente reduciendo a la par los costos de la cadena de suministro es un gran reto para las organizaciones, especialmente debido a la incertidumbre del mercado. Por este motivo, las organizaciones deben sincronizar los objetivos comerciales con las limitaciones industriales, minimizando al mismo tiempo las pérdidas de ventas. La técnica Sales and Operations Planning (S&OP) es una metodología de gestión de la cadena de suministro crucial para abordar estos desafíos. El aumento de la demanda de los clientes con plazos de entrega más rápidos ha incrementado la competencia en el mercado, así como la reducción de los precios de los bienes y servicios. Por lo cual, las organizaciones deben mejorar la eficacia de los procesos internos para seguir siendo competitivas. En consecuencia, se requiere un sistema interfuncional. Estos retos se analizarán en el presente estudio, considerando la gestión de la producción para pequeñas y medianas empresas (PYME) que operan en un mercado altamente competitivo. Este estudio presenta una propuesta tras analizar el caso de una distribuidora PYME ecuatoriana que forma parte de la cadena de suministro de la industria maderera. Para ello, se desarrolla una estrategia de producción híbrida que combina el sistema de producción make-to-order (MTO) y el innovador make-to-availability (MTA), basado en la teoría de las restricciones, siguiendo la metodología de S&OP. Como resultado, se obtienen políticas junto con estrategias de optimización de la producción que mejorarán el rendimiento de la empresa.

Palabras clave: Planificación de ventas y operaciones, MTA, MTO, PYME, modelo híbrido de producción, industria maderera

ABSTRACT

Nowadays, improving customer experience while reducing supply chain costs is a big challenge for organizations, especially due to market uncertainty. For this reason, organizations must synchronize sales principles with industrial limitations, while minimizing sales losses. Sales and operations planning (S&OP) is a crucial supply chain management technique for addressing such issues. The continuous growth of customer demands for faster turnaround times has increased market competition as well as lower prices for goods and services. Thus, organizations must improve the effectiveness of internal processes to stay competitive. Consequently, a cross-functional system is required. These issues will be analyzed in the study herein, considering the production management for small and medium-sized enterprises (SMEs) that operate in a highly competitive market. This study presents a proposal by reviewing the case of an Ecuadorian SME distributor part of the wood processing supply chain. By using a hybrid production strategy combining make-to-order (MTO) and the innovative make-to-availability (MTA), based on the theory of constraints, a proposal is developed, by following the S&OP methodology. As a result, system performance, policies, and optimization strategies are derived which will enhance the enterprise's performance.

Key Words: Sales and Operations Planning, make-to-availability, make-to-order, hybrid manufacturing, SMEs, lumber, wood processing industry.

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1. Introduction

A company has a competitive advantage in the market when two processes are successfully managed: one is the creation of client-oriented marketing plans that ensure the company has plenty of customers, and the second emphasizes that the company can meet demand at the promised service level. In other words, when customer's service expectations are met. Hence, the key is increasing demand and being able to supply it with the current companies' operations. Indeed, balancing operational constraints with sales requirements has always been essential for business success, especially for small and medium-sized enterprises (SMEs), which frequently struggle to meet customer demands due to a variety of challenges including limited resources, financial constraints, limited market reach, or technology adoption (Mukalay, 2020). In recent years, meeting customers' needs has become more challenging as they demand faster delivery times, forcing SMEs to seek ways to enhance their operational efficiency (Entringer & Ferreira, 2018). Besides, SMEs' supply chains are usually more vulnerable to fluctuations in demand due to insufficient coordination, reactive behavior, and a lack of flexibility (Darmawan et al., 2020). As a result, cross-functional coordination is now an essential requirement for gaining a competitive advantage in the market to effectively align production capabilities with the unpredictable market demand.

One approach to achieve this coordination is to integrate process planning to maximize efficiency and customer satisfaction. According to Wagner et al.(2014), the Sales and Operations Planning (S&OP) model is one such approach, since it balances supply and demand by aligning commercial strategies with operational constraints. S&OP has been successfully implemented in various industries resulting in increased efficiency, lower costs, and happier customers (Feng et al., 2008). The wood processing industry is not an exception of such situation, with numerous studies indicating its benefits (Ali et al., 2019; Azevedo et al., 2016; Sanei Bajgiran et al., 2016). Indeed, the wood products industry has grown in recent years due to its practical value and new trends (Azevedo et al., 2016), creating a significant need for contributing to the scope of how to enhance efficiency and profitability in the industry.

The company under study is a small enterprise located in Ecuador that is part of the wood products supply chain. To understand the role of the company in this supply chain, it is useful to describe it using the different supply chain stages, upstream. First, suppliers are companies that harvest wood from forests and sell wood logs; then, manufacturers process wood logs into lumber (large wood boards) (Gaudreault et al., 2009). Subsequently, distributors, usually called lumber stores, receive these large wood boards, and perform an extra process to cut the boards into the sizes desired by customers (Gaudreault et al., 2009). Finally, the customer segments are furniture markets, home decoration retail stores, and construction markets. The role of the company under study in this supply chain is that of a distributor that cuts the lumber and distributes the wooden boards to customers. The challenges in this specific role are 1) having the kind of board that the customer wants in terms of the type of wood, color, texture, and thickness, and 2) being able to cut it in the time the customer requires.

Furthermore, the company works with two customer segments: a B2B (business-to-business) and a B2C (business-to-customer) segment. B2B segments are characterized by catering the needs of other organizations and prioritizing long-term relationships with them; while B2C segments, focus on mass marketing, and providing smooth shopping experiences to individual consumers (Feliks, 2017). Thus, a further challenge for the company is being able to meet the demand and requirements of both customer segments. Indeed, the company under study is currently experiencing sales losses in both segments because of stock and time limitations. As a result, the objective of the study is to develop a hybrid production strategy of MTO (make-to-stock) and MTA (make-to-availability) by implementing sales and operations planning which will be helpful to minimize sales losses and maximize customer satisfaction in both customer segments.

2. Literature Review

According to Adamczak et al. (2013) sales and operations planning (S&OP) is the appropriate methodology for creating tactical plans that ensure a company's competitive advantage, based on the continuous integration of marketing plans and supply chain management. This view is supported by Pereira et al., (2020), who argue that S&OP aims to enable organizations to optimize their operations and make better-informed decisions based on a comprehensive understanding of market demand, supply chain capabilities, and financial resources. Certainly, by creating a detailed plan that integrates sales forecasts, production plans, inventory levels, and financial projections, S&OP helps organizations balance demand and supply, reduce inventory costs, improve customer service levels, and enhance overall business performance (Ávila et al., 2019).

Overall, S&OP has two major components: the sales plan, based on forecasted demand, and the manufacturing plan, which determines capacity requirements and inventory levels (Wagner et al., 2014). Traditionally, these plans are handled by different departments: sales and operations, which make daily decisions with poor coordination between them. As a result, numerous studies have implemented S&OP as an ongoing process of monthly planning, reviewing, and evaluation to generate one set of integrated profit-maximizing plans by ensuring the involvement of all key stakeholders (Entringer & Ferreira, 2018; Wagner et al., 2014).

On similar grounds, Kalantari et al. (2011) argue that to meet client demands, manufacturing organizations need to employ production systems that meet the manufacturing plan. Selecting the optimal production system for a company requires careful consideration of various factors such as demand variability, lead times, product types, inventory holding costs, customer service levels, and order frequency (Beemsterboer et al., 2016). According to Danilczuk et al. (2022) the most famous production systems are make-to-order (MTO) and make-to-stock (MTS). Make-to-Order (MTO) is a production strategy in which products are manufactured only after receiving customer orders. MTO is suitable for companies that have a wide variety of products and customer needs that require customization or personalization, as well as when demand is unpredictable (Raaei et al., 2014). On the other hand, a make-to-stock (MTS) strategy is suitable when the demand for a product is stable and predictable, and the lead time for manufacturing and delivering the product is short. This strategy involves producing products in anticipation of customer demand and keeping inventory in stock to meet that demand (Raaei et al., 2014).

However, academics and industry professionals have recently proposed a third production method called make-to-availability (MTA), derived from MTS (Cox III & Schleier, 2010; Schragenheim et al., 2009). As discussed in the book *Theory of Constraints* (2010), MTA results from the necessity to maintain the number of finished goods in storage at a level that minimizes the present value while still making the product immediately available to the consumer (Cox III & Schleier, 2010). Indeed, Ciechanska & Szwed (2020) performed a comparative analysis of MTS and MTA strategies using computational experiments. The models for both strategies were created using the same assumptions: external conditions as market demand and internal conditions such as the structure of the production process. Conclusively, according to the research, the MTA strategy produces significantly better results than the MTS strategy in most cases due to lower storage costs and the costs of non-fulfillment of customer demand (Ciechanska & Szwed, 2020). Finally, in line with previous studies, Buestan et al. (2013) demonstrate how the use of MTA in an Ecuadorian SME helps it manage customer inventory while maintaining excellent service levels and low inventory investment.

Furthermore, according to Mukalay (2020), in the last decade a new production trend has gained popularity among academics and industry professionals: hybrid manufacturing. Hybrid manufacturing is a production method that combines two or more manufacturing processes or systems; it integrates the strengths of different production systems to create a more flexible and adaptive manufacturing process(Mukalay, 2020). In hybrid manufacturing, different production strategies, such as make-to-order (MTO), make-to-stock (MTS), and make-to-availability (MTA), can be combined to achieve the desired production goals. Despite many advantages of hybrid systems, they also present challenges including capacity coordination, order scheduling, and cost increments, among others (Mukalay, 2020). There is a handful of research regarding hybrid manufacturing challenges. For instance, Beemsterboer et al. (2016), Z. Wang et al. (2019), and Yousefnejad et al. (2019) investigate which are the most effective methods for deciding whether to accept or reject incoming orders and establishing order due dates for a hybrid MTS/MTO system. Beemsterboer et al. (2016) created the Markov Decision Process model for a two-product hybrid system to decide when to produce MTS and MTO products. Wang et al. (2019) develop a hybrid algorithm to solve the order acceptance and scheduling (OAS) problem, described as a significant joint decision problem. Yousefnejad et al. (2019) focus on a food process industry that uses MTS, MTO, and MTS/MTO products. This is a case study that presents an optimal strategy for accepting or rejecting incoming MTO or MTS/MTO orders by using a simulation model created with Arena 10.0 software to model customers' satisfaction and ensure their loyalty to the business. Moreover, Mukalay (2020) employs a make-to-order and make-to-stock combination with a manual assembly line setup centered around worker movement as its foundation to improve the flexibility of small-to-medium-sized manufacturers. Besides, Danilczuk et al. (2022) proposed an algorithm for job scheduling in a MTO-MTS production system, which helps in decision making regarding what to produce.

2.1. Lumber Industry

Lumber is wood that has been processed into standardized boards typically used for construction, furniture making, or other building purposes (Gaudreault et al., 2009; Sanei Bajgiran et al., 2016). Marier et al. (2015) present the supply chain for lumber which involves the movement of timber from forest contractors to sawing facilities, value-added mills, and then through numerous distributor and wholesaler channels to reach the market. Indeed, the lumber supply chain is complex, and there are a handful of studies about production planning in this industry, see Appendix 1. Feng et al. (2008) discuss that in the last years, the lumber industry has been growing due to its usefulness and new trends, which creates an important necessity for contributing to the scope of how to improve the industry to be efficient in two primary components: supply and demand. A case study on softwood lumber producers in Eastern Canada was carried out by Ali et al. (2015) to evaluate the application of an MTO production system. The results showed that by using nested booking limits and keeping sales commitments in mind, it is possible to improve performance overall service level. Besides, it demonstrated how combining S&OP and revenue management ideas can lead to higher performance compared to standard demand management techniques. Furthermore, Marier et al. (2014) proposed a mathematical model that enables tactical planning of a network of sawmills' balance sales and operations, which demonstrated that production and inventory levels may be modified to boost sales income.

The contributions to sales and operations planning, as well as the different strategies to address production management, are broadly present in the literature. However, to the best of our knowledge, there are no studies that present a hybrid MTO and MTA production strategy, especially, within the wood industry. This study aims to propose a hybrid production model combining make-to-order (MTO) and make-to-availability (MTA) strategies by using sales and operations planning methodology. This will be applied in a real case study of a wood boards distributor company to minimize sales losses and increase customer satisfaction.

3. Case Study and Methodology

In this section, first, the company under study will be introduced along with the identified problem to be addressed in this study. Secondly, the proposed methodology is described.

3.1. Case Study

This study analyses a medium-sized Ecuadorian company called Emfalu that commercializes wood boards. Emfalu's business model is that of a franchise of one of the largest lumber manufacturers in Ecuador, acting as the distributor of its products as presented in Figure 1. Emfalu currently has two distribution centers (DCs), a workforce of 17 employees, and handles around 727 items. Besides, it offers three main services: cutting, laminating (to place edge to the board), and hinging (to perforate).

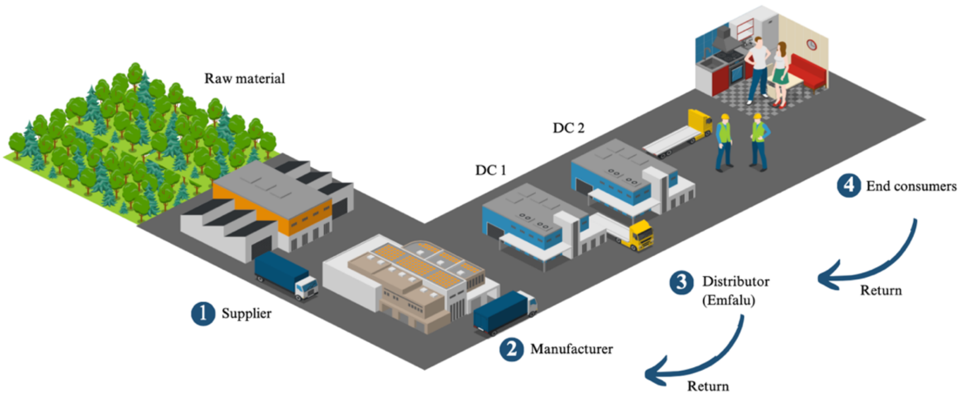

Figure 1: Supply Chain overview of the company under study (Emfalu)

3.1.1. General Process of the Company

The initial stage in the process for Emfalu, is unloading the raw materials. It starts once the lumber or wood boards arrive at either distribution center. This activity is documented for inventory count and boards are stored vertically in racks. Once there is a production plan or customer order, different processes are performed depending on its requirements, see Appendix 6. These processes include modulating, cutting, laminating, hinging, and packaging. Finally, the products are distributed by truck, or the customer picks up the order.

3.1.2. Current Situation: Problem

Company executives mention that the company is struggling to meet customer demand; as a result, an analysis of the company's current situation was performed. First, it is important to mention that the company's customers can be divided into two main customer segments. The first segment is a B2B (business-to-business) segment in which Emfalu sells its products to a hardware and house decorations retail store. This company, which will be refer to as Company A for confidentiality conditions, orders the same kinds of items regularly from Emfalu. On the other hand, the second segment is a B2C (business-to-customer) segment in which various kinds of end-customers order products from Emfalu. After performing a financial analysis of the company for the year 2022, it was obtained that 58% of the profits come from Company A, B2B segment, while 42% come from the B2C segment. Consequently, it can be said that both customer segments are important for the organization as they have almost the same contribution to the gross profits.

Additionally, the sales department gathers each month a list of sales that were lost for both segments including the potential price of the sale and the reason why it was lost. After analyzing the list for all months in 2022 it was noted that the sales losses for the year represent 5% of the company's total income. This means that the company could have had an increase of 5% in its income if it could have completed these orders. Besides, the reasons for the loss were analyzed based on financial impact. The Pareto analysis of the financial impact per reason suggests that four reasons including high price followed by no stock at the supplier level, no stock at the company and large processing time, represent 96.29% of the total sale losses. See Appendix 2. Thus, focusing on preventing them will help towards reducing these losses. Now, three of these reasons, including no stock supplier level, processing time, and no stock at the company, are all related to production planning. As a result, the present study will focus on solving these three causes of sales losses. Lowering the price is not within the scope of the study.

3.2. Methodology

According to Wagner et al. (2014), the S&OP methodology involves an iterative and cross-functional planning process that will guide an organization toward a better-aligned strategic plan. Literature on this topic is ample in which different authors propose various steps for executing S&OP in an organization. Nevertheless, in this study, it was implemented a combined methodology derived from framework proposals by Wagner et al. (2014) and Entringer & Ferreira (2018). The steps are described below.

3.2.1. Step 1: Maturity Model and Product Review

In this first step, it was implemented the Maturity Model proposed by Wagner et al. (2014) to evaluate the level of application of S&OP in the company under study. The model uses a scoring guide that will place the company in one of five levels: “Level 0-Undeveloped”, “Level 1-Rudimentary”, “Level 2-Reactive”, “Level 3-Consistent”, “Level 4-Integrated”, and “Level 5-Proactive.” To perform the classification, four dimensions are evaluated in-depth including “process effectiveness”, “process efficiency”, “people and organization” and “information technology”. Process effectiveness describes all characteristics and activities the S&OP process should include. Process efficiency evaluates how the company integrates and aligns the set of plans. The People and Organization dimension measures the degree of commitment and support for S&OP processes by the human decision-making side. Finally, Information Technology evaluates the systems, integrations, and data that support S&OP (Wagner et al., 2014). Essentially, each level within each dimension has unique characteristics that differentiate one level from another, see Appendix 3. As a result, each dimension is classified at a level depending on the characteristics of the company. Subsequently, the overall level is selected depending on the most common level classification.

Furthermore, a product review is performed in which, first, the company's products that will be evaluated in this study are selected and, second, they are clustered into product families. Indeed, S&OP should work with product families to maximize forecast accuracy and simplify product management, thus, improving efficiency (Entringer & Ferreira, 2018).

3.2.2. Step 2: Demand Planning

In the demand planning step, historical information on monthly unit sales is first gathered. Secondly, there is a thorough analysis of the data gathered to generate a demand forecast of at least 12 months. These demand forecasts will support the rest of the S&OP stages (Wagner et al., 2014). Several forecasting methods will be tested, selecting the one with the best forecasting accuracy.

3.2.3. Step 3: Supply Planning

The supply planning step begins with a review of key supply chain information (Entringer & Ferreira, 2018). The company will provide information regarding procurement, production, and distribution planning. For procurement the information provided will be related to supplier lead times, raw material inventory capacity and holding costs, transportation costs, and restrictions on order size. In terms of production planning, it was received process flow charts, historical production data, and current available production capacity. Finally, for distribution planning, the information will be on warehousing, capacity and holding costs; and shipping including alternatives, costs, and capacity. Subsequently, a supply chain strategy is developed using Fisher's (2004) conceptual framework for building the right supply chain for your type of product. Hence, first, each of the selected products under study will be divided into two types: innovative or functional (Fisher, 2004). Then, depending on this classification the supply chain strategy will be developed considering inventory strategy, manufacturing focus, and lead-time focus.

3.2.4. Step 4: Inventory Planning

Following the supply chain strategy developed in the previous step, at this point, the strategy is applied through the proposal of two production systems, one for each type of product (Fisher, 2004). Each production system has an inventory policy either for finished products or raw materials. Within each inventory policy, researched methods are proposed to answer the key inventory planning questions: when and how much to order.

3.2.5. Step 5: Balancing & Decisions

In this step, the proposed production systems are combined into a single hybrid production system for the company under study. The key decision to implement a hybrid production system is capacity coordination (Danilczuk et al., 2022). As a result, an order queueing system will be proposed including decision-making algorithms and technological tools to apply the system.

3.2.6. Step 6: Maturity Model Re-evaluation

Finally, to measure the impact of the plan proposed in the study, the maturity model proposed by Wagner et al., (2014) will be used to re-evaluate the company considering the proposal is applied.

4. Results

4.1. Step 1: Maturity Model and Product Review

4.1.1. Maturity Model

First, for evaluating the maturity model framework by Wagner et al. (2014), a focus group analysis was performed including nine members of the organization. The nine members were selected from various positions from top management to operators, as recommended by Lawless & Heymann (2010), to include a diversity of opinions and get the most unbiased evaluation of the current stage of the company. Henceforward, employees with the following positions participated in the focus group meeting: CEO, CFO, head of sales, sales representative, sales coordinator, sales lead, production coordinator, production operator, and supply coordinator.

The results obtained from the focus group meeting were evaluated in terms of the different levels, dimensions, and sub-dimensions of the S&OP Maturity Model proposed by Wagner et al. (2014):

Process Effectiveness

- The Sales department has monthly planning meetings, even though it was mentioned that those meetings are sometimes postponed. Only members of the sales department are included in these meetings in which they discuss monthly budgets, sales targets, reasons for lost sales, and problems.
- There is also a monthly planning meeting of the heads of departments that include operations, sales, finance, and the general manager. In these meetings, they revise the strategic plan for the next month including budgets, targets, and policies. Also, they evaluate progress toward yearly financial goals and discuss problems.
- The production department does not have meetings at all, what usually happens is they receive a production plan from the sales department. What happens is sales asks production how long it will take to fulfill an order and production calculates subjectively this time, that is the only discussion about the capacity they have. This time is very important for sales for their B2C segment because customers are sensitive to time.

Process Efficiency

- The information shared from sales to operations is the production order and from operations to sales is a subjective processing time. At the time of the focus group meeting, they started to have some discussion about capacity and how to plan based on that. Besides, it was mentioned that frequent re-planning is necessary to fulfill orders from the B2B segment that exceed capacity. Capacity is adjusted in these cases through extra working hours.

- Strategic plans are held at the administrative level and not shared with the whole organization. Besides, each department has its plan spreadsheets that are usually not shared between departments. If they are shared, they have a high probability of error since they are done manually.
- The heads of departments work with basic financial KPIs. For example, sales targets and budgets per area. The only way of tracking performance is through sales numbers.

People and Organization

- The company has a sales department with sales representatives and a sales head, an operations department with production coordinators and operators plus the general manager and the financial manager. Roles and responsibilities seem to be clearly defined and each head of the area is accountable for their performance.
- There is no person dedicated to aligning sales plans with production capacity, in fact, at the time of the focus group meeting the production coordinator and the head of sales began the discussion about capacity.

Information Technology

- All plans are done using Excel spreadsheets, with master data that comes from customer invoices, or the accounting system. Not all employees have access to this data.
- Spreadsheets must be updated manually and sometimes they are shared with errors.
- Some plans implement basic statistical analyses.
- The company has an application where sales representatives could upload production orders and operations should mark them as complete, it is like a queueing system to see the workload in each production facility. Nevertheless, both sales and operations

representatives mention they usually forget to upload information. There are no way sales know in real time what is being produced.

The observations per dimension lead to the decisions about the maturity of the organization displayed in Appendix 3. The statements highlighted in black are the ones that apply to the company's current stage. The current level per dimension, highlighted in yellow, was selected based on most statements that apply. Finally, the overall level is selected based on the most common level per dimension. Hence, the company is currently at level 2, reactive.

4.1.2. Product Review

First, for selecting the products, it was implemented a Pareto Analysis (Darmawan et al., 2020) so that the selected 20% percent of all products represent 80% of the company's profits in the most recent year. The present study will be performed using information about these products so that the implementation of the results has a greater impact on the profitability of the organization and simplification. Hence, 114 items will be used in the study.

Furthermore, these items were classified into product families following the methodology proposed by Reeb and Kline (2002) in their study on structural lumber. The results of this study showed that it was effective in grouping structural lumber into product families based on physical properties. It was applied the methodology as follows:

1. Define product attributes: This step involves identifying the physical properties of the lumber that are important for grouping it into product families, so it was identified wood type, color, texture, and thickness for each item.
2. Measure product attributes: In this step, information regarding each attribute was obtained.
3. Develop classification scheme: Based on the measured product attributes, a classification scheme was developed to group the lumber into product families. For our classification scheme, first, it was divided into items per wood type which resulted in four groups as

portrayed in Table 1: MDF, MDP, PLYWOOD, and PVC. Second, since group MDP had too many items, it was further divided and classify them using an ABC classification as recommended by (Wang et al., 2018). This classification is based on volume unit sales where A is high volume, B is medium, and C is low.

4. Develop product specifications: Once the product families have been defined, product specifications are developed for each family. These specifications can include allowable defects, moisture content, and strength requirements. It just included a brief description of each product family. (Reeb and Kline, 2002)

Table 1 shows the final product family division for the selected items and the number of items per family. Hence, in this study, it was worked with 6 product families.

Table 1: Product families

Product Family	**MDF**	**Plywood**	**PVC**	**MDP A**	**MDP B**	**MDP C**
# of items	7	14	12	20	25	36

4.2. Step 2: Demand Planning

In this step, the following process was applied for forecasting demand for the 12 months of the year 2023 per product family.

1. Gather information: Unit sales information was gathered for the years 2018 until 2022. It is important to mention that Emfalu continually changes its product catalog to meet new customer trends. Therefore, there are many new products released in 2021 that were not commercialized before that year. For this reason and for misguiding sales information in the year 2020 of the covid pandemic, it was decided to use only historical information from the years 2021 and 2022.
2. Aggregate demand: Unit sales were aggregated by product family per month, to maximize forecast accuracy (Entringer & Ferreira, 2018a).

3. Outlier analysis: A boxplot was graphed to spot outliers in the data. When outliers have an assignable cause, it is recommended that they are adjusted to reflect common values (Nahmias & Lennon, 2015). Hence, in this step, if an outlier was found it was adjusted depending on the trend analysis that follows.
4. Trend analysis: To select appropriate models for forecasting the time series under study, first, a trend analysis should be performed (Nahmias & Lennon, 2015). This trend analysis will reveal the time series behavior including if it is stationary, seasonal, random, or if it has a trend. Two trend analysis techniques were applied:
   a. Graph demand using a time series line graph to see trends visually.
   b. Man-Kendall Trend test was performed using the software Minitab to test if data had an upward, downward, or no trend. The null hypothesis is that data has no trend, and the two alternative hypotheses are ha1) there is an upward, and ha2) there is a downward trend. An alpha of 0.05 was used to test the significance(Puga et al., 2020).
5. Several forecasting methods were selected and implemented by the product family depending on the time series main features revealed by the trend analysis. Appendix 4 displays the time series methods that are more appropriate to use depending on the main features of the time series. This table was used to select the appropriate forecasting methods.
6. Model Selection: Model accuracy was evaluated based on MAPE. The model that minimized MAPE was selected also considering that a forecast with MAPE of less than 10% is considered an excellent forecast (Nahmias & Lennon, 2015).

4.2.1. Forecasting Results

Table 2: Demand planning results

Product Family	**Outliers**	**Mann-Kendall Test (Units vs Month)**	**Forecasting Models Applied**	**MAPE**

MDF	No atypical values in the time series	There is a downward trend in the data.	• Double Exponential Smoothing (Holt) • Triple Exponential Smoothing (Holt-Winters)	• 45.62 • 5.32
MDP A	No atypical values in the time series	No trend in the data	• Simple Exponential Smoothing • Triple Exponential Smoothing (Holt-Winters)	• 31 • 0.10
MDP B	No atypical values in the time series	No trend in the data	• Simple Exponential Smoothing • Triple Exponential Smoothing (Holt-Winters)	• 40 • 1.38
MDP C	An outlier of more than 4 thousand units sold in June 2021. Regression analysis	There is an upward trend in the data.	• Regression • Triple Exponential Smoothing (Holt-Winters)	• 36.4 • 8.97
Plywood	No atypical values in the time series	No trend in the data	• Moving Average • Triple Exponential Smoothing (Holt-Winters)	• 22 • 2.7
PVC	No atypical values in the time series	There is an upward trend in the data.	• Regression • Triple Exponential Smoothing (Holt-Winters)	• 26 • 6

To observe graphs reference Appendix 5.

4.3. Step 3: Supply Planning

4.3.1. Emfalu's: Supply Chain

The company under study is part of the wood products supply chain. Talking about this supply chain upstream, starting with stage 1, suppliers, these are companies that harvest wood from forests and sell wood logs. Then, in stage 2, manufacturers process wood logs into lumber (large wood boards). There are different types of lumber boards depending on the manufacturing process they went through and the particles, fragments, and sheets that were added to the wood. The most common types for furniture making and decorations are MDF (medium-density fiberboard), MDP (medium-density particle board), and Plywood (Gaudreault et al., 2009b). Subsequently, in stage 3, distributors, usually called lumber stores, receive these large wood boards and perform an extra process to cut the boards into the sizes desired by customers (Feliks, 2017). The role of the company under study in this supply chain is that of a distributor. It offers four additional services including modulate measures, cut board, laminate board with edges, and perforation, in its two distribution centers (DCs). In terms of the end customers, in stage 4, the company has two customer segments. The first is a B2B segment in which a retail store, denominated Company A in this study because of confidentiality, buys standard products from the company continuously. The second is a B2C segment in which random customers contact the company under study to buy wood boards cut and adjusted to their needs. So, this is an order or project-based segment. See a graph of the supply chain in Figure 1 and obtain information about procurement, production, and distribution planning in Appendix 7, 8, and 9, respectively.

4.3.2. Product Classification

According to Fisher (2004), a product can fall into two broad categories: innovative or functional. Several factors can determine this including demand predictability, product life cycle, profit margin, required lead time, product variety, and service level. In this study, the aspects of demand predictability, contribution margin, and required lead time were used to classify products because there is data available to measure them quantitatively. Besides, customer segment distinction was included since for the company in the study each customer segment expects a different service level and requires different planning strategies. The B2C is an order-based customer segment that expects the completion of the order in the shortest time. Besides, there is no way of predicting what will be ordered since it's entirely customized to customer needs. On the other hand, the B2B segment expects the order to be delivered in full one day after the order was sent. Nevertheless, Company A orders products from a group of standardized items; therefore, it is possible to forecast demand and have a final product inventory. Hence, it was important to add this distinction to the product classification model.

First, to measure demand predictability, the conventional measure in operations management literature was used: the coefficient of variation (CV). CV is equal to the annual unit sales mean divided by the annual unit sales standard deviation (Mahdavi et al., 2023). Second, the contribution margin is calculated as the price of the product minus variable cost divided by the price, and it is expressed as a percentage (Fisher, 2004). Third, the lead time was calculated using the time interval the supplier takes to fulfill an order of an item. Table 3 provides the representative thresholds to classify products into each category based on recommendations by the most recent study found on the topic by Mahdavi et al. (2023). Based on these thresholds, the 114 items under study were classified.

Table 3: Thresholds for product classification

	Functional Product	**Innovative Product**
CV	< 60% (predictable demand)	> 80% (uncertain demand)
Contribution Margin	<20%	>20%
Lead Time Supplier	More than two weeks	1 day to two weeks
Customer Segment	B2B	B2C

4.3.3. Supply Chain Strategy

Fisher's (1997) conceptual framework of building the right supply chain for your product is one of the earliest and most widely discussed guidelines in supply chain management (Mahdavi et al., 2023). In this framework, Fisher (2004) argues that the supply chain strategy should be aligned with the nature of the product and its market. Hence, a functional product characterized by predictable demand, low-profit margins, and a long-life cycle should have an efficient supply chain, whose purpose is to supply this predictable demand at the lowest cost. On the other hand, an innovative product characterized by uncertain demand, high-profit margins, and a short life cycle should have a responsive supply chain that aims to respond quickly to unpredictable demand to minimize lost sales (Fisher, 2004). This framework is used to develop the supply chain strategy for Emfalu, the Company under study, as described in terms of the manufacturing focus, inventory strategy, and lead-time focus in Table 4.

Table 4: Supply Chain Strategies

	Efficient Supply Chain: Functional Products	**Responsive Supply Chain: Innovative Products**
Manufacturing Focus	Maintain a high utilization rate and continuous production to meet target stock levels	Ensure there is capacity available to produce orders in the shortest time
Inventory strategy	Generate high turns and minimize inventory costs (in both the final product and raw material stock)	Ensure the availability of raw material
Lead-time focus	Minimize lead time if it does not increment costs	Minimize lead time

4.4. Step 4: Inventory Planning

Given the supply chain strategy developed in the previous step, in this step, two production systems are proposed one for each type of product, and thus, one per strategy. This is portrayed in Table 5. Each production system has its inventory policy for raw materials and/or finished goods. This inventory policy will answer the key questions of when to order, in other words, optimal reorder point, and how much to order, in other words, optimal reorder quantity.

Table 5: Summary of strategy per product type

Product Type	# Items	Customer Segment	Supply Chain Strategy	Production System
Functional	50	B2B	Efficient	MTA
Innovative	64	B2B & B2C	Responsive	MTO

4.4.1. MTA production system proposal

A well-studied production system that embodies the characteristics of an efficient supply chain strategy is a Make-to-Stock (MTS) production system. This system involves producing products in anticipation of customer demand and keeping inventory in stock to meet that demand (Raaei et al., 2014). Nevertheless, recent studies bring up an upgraded MTS system called Make-to-Availability (MTA) (Ciechańska, 2018; Ciechanska & Szwed, 2020; Schragenheim et al., 2009). Indeed, according to ample research on the topic, the MTA strategy produces significantly better results than the MTS strategy in most cases due to lower storage costs and the costs of non-fulfillment of customer demand (Ciechanska & Szwed, 2020). Therefore, an MTA production method will be implemented for products categorized as functional.

For certain product types, guaranteeing availability while maintaining low costs is the top priority of the manufacturer. In response to this need, Schragenheim et al (2009) evaluate the Theory of Constraints (TOC) and introduce the idea of make-to-availability (MTA). MTA is a manufacturing system whose goal is to guarantee product availability to the customer, while minimizing inventory levels and lead times. Accordingly, MTA is designed for standard products or semi-customized products (Schragenheim et al., 2009). Considering the Theory of Constraints, MTA is managed by the simplified drum-buffer-rope system (S-DBR) which is a planning strategy for finite capacity (Govoni et al., 2021). In brief, the “drum” comes mainly from the market, the “buffer” protects drum, and the “rope” signals the need to release materials for new orders (Schragenheim et al., 2009). Figure 2 displays such system in which, once a production order is generated, raw material enters the system. The drum determines the system's pace, for which S-DBR considers the market to be the major drum and then the CCR, capacity constraint resource, in this case the bottleneck operation (Govoni et al., 2021). Furthermore, the rope considers the plan load, which is the work that must be accomplished in a given period to meet consumer demand (Schragenheim et al., 2009). Additionally, the supply response time is referred to as the replenishment time in Figure 2. Lastly, the result of the system will be final product inventory levels according to a specified target.

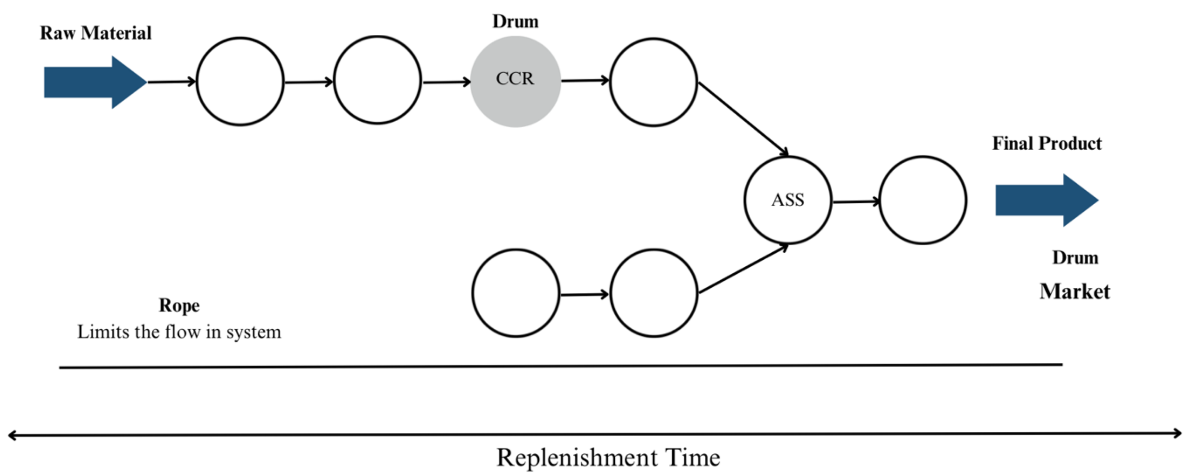

Figure 2: S-DBR and MTA system (Govoni et al., 2021)

In terms of the company under study, the CCR or bottleneck is the edge bander due to its capacity; thus, the edge bander will dictate the pace of the production system. The raw materials are the different types of lumber arriving from the supplier, and the final products are different variations of wood shelves in terms of color, texture, and size. For each of these items, the following procedure for operating a production process in a make-to-availability mode will be followed (Schragenheim et al., 2009):

Step 1: *Define the Initial Inventory Target Levels*

- That level is defined by the average replenishment time demand plus a safety buffer.

- The initial inventory level is defined based on the forecasts obtained in step 4.5. The average of the forecasted demand times the average replenishment time was calculated to have an estimate of average replenishment time demand.
- Besides, it is necessary to define a paranoia factor which is a safety margin to ensure an adequate inventory on hand to satisfy unexpected demand or supply chain interruptions. According to Cox III & Schleier (2010), multiplying the average by a factor of 1.5 is usually a good place to start. Nevertheless, the proposed buffer management system described below will reveal the time for changing the target level of each item.

Step 2: *Generate the Production Order*

- Whenever the total inventory for any item (the total of finished stock plus open production orders) is below the target level, a new production order should be generated immediately considering the manage buffer management system priorities described below.

Step 3: *Manage the buffer*

- The role of buffer management system is to provide the appropriate priorities and to signal operators when effort is required to move orders forward.
- First, the buffer status percent is calculated as follows:

$$Buffer\ status\ (\%) = \left[\frac{Target\ Inv\ Level\ -\ On\ hand\ Inv - Pipeline\ orders}{Target\ Inv\ level}\right] \times 100$$

- "Buffer status at any point in time is the ratio of missing units to the target inventory level, expressed as a percentage"(Schragenheim et al., 2009).
- In this system, inventory level per item is color coded depending on Buffer status %. Indeed, each color determines the production priority of the item.
- Namely, if the buffer status is 33% or less of the target level, it is colored green and it means that there is sufficient inventory to guarantee availability and, thus, orders of this

item should not be prioritized. If the reflected buffer status is between 33% and 66%, it is colored yellow meaning it is not urgent to produce this item. Finally, the buffer status is above 66% the item is in the red zone, implying an order to produce this item should be prioritized (Schragenheim et al., 2009).

Step 4: *Maintain the Correct Target Levels*

- A target inventory level that hovers consistently in the yellow-to-green zones is just about right.
- When the actual finished stock is in the yellow zone, it is expected enough additional stock.

MTA strategy was applied to those functional products. It is important to consider that MTA is a strategy to generate optimal final product stock. Additionally, it is necessary to consider a raw material inventory policy. For this, we will be using a computer-based inventory management system which is Material Requirements Planning (MRP). MRP is intended to determine the materials required to make a specified quantity of completed items, considering elements such as the bill of materials, lead times, and inventory levels (Stevenson, 2015). The output of the MRP is a plan of order releases, of purchased or manufactured materials, that ensures that the production schedule is met (Stevenson, 2015).

Before explaining how MRP could be implemented in the company under study, it is important to mention that this company works with two types of replenishment for products characterized in this study as functional. Most of these products are wood shelves sold to Company A, they vary in wood color, texture, and size. Hence, the distributor Emfalu has two replenishment options: ordering entire wood boards and then cutting them into wood shelves or ordering the wood shelves ready to distribute. The main difference between these two replenishment options is the lead time; entire wood boards are delivered in one to five days while wood shelves are delivered in ten to fifteen days. Therefore, two types of MRP were developed depending on the replenishment type the company wants to apply.

To better understand the application of MRP, it will be explained using a wood shelf example. In the first replenishment type, when the company under study decides to purchase entire wood boards to produce wood shelves, the MRP starts with the bill of materials (BOM). The BOM contains a list of all parts and raw materials that are needed to produce one unit of a finished product (Stevenson, 2015). In this case, to produce 1 wood shelf, 0.023 meters squared of a whole wood board are needed, plus 1.72 meters of PVC border. Each of these raw materials has its own inventory level, lead time, and minimum order size.

Then, as portrayed in Figure 3 the weekly production schedule in unit requirements is added for the next eight weeks. In this case, the weekly target level obtained in the MTA strategy will be added in step (1). Subsequently, in step (2), the planned order releases are calculated for the final product. To accomplish this, first, the weekly target level is translated to the final product, wood shelf, and gross requirements: the total expected demand for the period without regard to the amount on hand (Stevenson, 2015). Second, the projected on hand is calculated, which is the expected amount of inventory that will be available at the beginning of the period (Stevenson, 2015). This considers the initial inventory level and planned order releases. Third, net requirements are calculated, which are the actual amount needed in that period (Stevenson, 2015). In other words, gross requirements minus projected on hand: what is needed minus what it is in inventory. Fourth, planned order releases for a certain period are stipulated considering net requirements and lead time. In this case, net requirements are released the same week as requirements because it was needed to accomplish them by the end of the week. Subsequently, in steps (3) and (4), the same process is followed only that gross requirements are obtained by multiplying wood shelf planned order releases times the requirements per raw material detailed in the BOM. For instance, in week two, $68*0.023 \approx 2$ wood boards and $68*1.72=116.96$ meters of the border are needed to produce 68 shelves in that week. Moreover, planned order releases consider minimum order quantity and lead time. Indeed, if the net requirements are less than the minimum order quantity then the minimum order quantity is ordered; otherwise, the net requirements are ordered.

Now, in the second replenishment type, when the company decides to buy wood shelves ready for distribution, the same process is followed for the MRP. Only in the last step, planned order releases, the lead time of two weeks is considered.

(1)

Target Level REP0144								
Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Target Level (MTA)	**84**	**84**	**84**	**84**	**84**	**84**	**84**	**84**

MRP

(2)

wood shelf: REP0144									
Week		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements		84	84	84	84	84	84	84	84
Projected on hand	**100**	16	0	0	0	0	0	0	0
Net requirements		0	68	84	84	84	84	84	84
Planned order releases	**0**	0	68	84	84	84	84	84	84

(3)

wood board: KA708151PDU									
Week		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements		0	2	2	2	2	2	2	2
Projected on hand	**4**	4	2	0	3	1	4	2	0
Net Requirements		0	0	0	2	0	1	0	0
Planned order releases		0	0	5	0	5	0	0	0

(4)

border: 104020730									
Week		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gross Requirements		0	116.96	144.5	144.5	144.5	144.48	144.5	144.5
Projected on hand	**250**	250	133.04	288.6	144.1	299.6	155.12	10.64	166.2
Net Requirements		0	0	11.44	0	0.4	0	0	133.8
Planned order relases		0	300	0	300	0	0	300	0

Figure 3: MRP, replenishment type 1

4.4.2. MTO production system proposal

Moreover, a well-studied production system that applies the characteristics of a responsive supply chain strategy is a Make-to-Order (MTO) production system. In this system, the production process is triggered by a customer order, and the idea is to accomplish it in the promised time (Raaei et al., 2014). Hence, innovative products will be produced under an MTO system.

As mentioned in the supply chain strategy before, an important element of the inventory strategy for this production system is to ensure the availability of raw materials to be able to accomplish customer orders in the desired time. As a result, first, the method outlined by Beemsterboer et al., (2016) was implemented to obtain the optimal reorder point. In this study, a safety stock per item is calculated so that when the inventory level is equal to or below the safety stock, an order to the supplier is released. To calculate safety stock the formula explained in the book *Operations Management* by Stevenson (2015) for variable lead time and demand is used.

$$Safety\ Stock = z\sqrt{\overline{LT}\sigma_d^2 + \overline{d^2}\sigma_{LT}^2}$$

Where,

$\bar{d} = average\ daily\ demand\ rate$
$\overline{LT} = average\ lead\ time\ in\ days$
$\sigma_d = standard\ deviation\ of\ demand\ rate$
$\sigma_d = standard\ deviation\ of\ demand\ rate$
$\sigma_{LT} = standard\ deviation\ of\ lead\ time$
$z = standard\ normal\ deviation\ of\ service\ level$
$Service\ Level = 1 - stockout\ probability$

The forecasts obtained in part 4.5, demand planning, were used to obtain information regarding demand, d. Concerning lead time, the company provided documentation on lead time intervals promised by the supplier to deliver each item. Finally, the service level is a parameter the company under study should estipulate according to their level of risk of stockout; nevertheless, for this study, a service level of 95% was used as recommended by Beemsterboer et al. (2016).

Now that we know when to reorder, the second question is what the optimal order quantity is. The study on raw material inventory optimization for MTO enterprises by Chen et al. (2017) answers this question through the application of an optimization model. Hence, this model is applied in this study to obtain the optimal order quantity for all the innovative products. The model proposed by Chen et al. (2017), adjusted to the conditions of the company under study is as follows.

Let *Qi* represent kind *i* raw material order quantity; *Pi* denotes the unit purchasing price of raw material *i*; hi represents the unit holding cost of raw material *i*; *bi* represents the unit shortage cost of raw material *i*; Di denotes the maximum lead time demand of raw material *i*; and *SSi* represents safety stock of raw material *i* obtained in the previous step. Additionally, *mi* represents the minimum order quantity required by the supplier for raw material *i*; *ti* represents the thickness in cm of raw material *i*; and *AC* denotes the adjusted rack capacity in cm. Since wood boards, raw material, are stocked vertically in racks, rack capacity is measured as rack width times the number of racks available.

$$\min TC = \sum_{i=1}^{n} Q_i P_i + \sum_{i=1}^{n} Q_i h_i + \sum_{i=1}^{n} b_i (D_i - (Q_i + SS_i) \qquad i = 1,2, \ldots n. \tag{1}$$

s.t.

$$Q_i \geq m_i \tag{2}$$

$$t_i(Q_i + SS_i) \leq AC \tag{3}$$

$$Q_i \in \mathbb{Z} \tag{4}$$

Formula (1) is the objective function that aims to minimize total cost. Total cost is the sum of purchasing cost, holding cost, and stockout cost. Constraint (2) means that the quantity ordered of raw material *i* should be greater or equal to the minimum order quantity required by the supplier. Constraint (3) means that the space occupied by the safety stock plus the optimal order quantity of raw material *i* should be less than or equal to the total rack adjusted space capacity. Finally, constraint (4) ensures that all order quantities are integers. This optimization problem was solved using Excel's Solver GRG Nonlinear method. Accordingly, the company under study will have a table like Appendix 10, that will help in the decision-making of inventory replenishment for raw materials of all innovative products.

4.5. Step 5: Balancing and decisions

4.5.1. MTO-MTA hybrid model

Now that we have described how each production system is going to work, in this step, we propose how to join both production systems in a single hybrid production plan. According to Raaei et al. (2014), "capacity coordination might be the most challenging issue to have arisen in the eld of hybrid production planning since the performance of such systems is directly influenced by the way the capacity is coordinated." Hence, our proposal includes policies and algorithms that will aid in capacity coordination.

To start with this hybrid production plan, it was first studied the current capacity coordination software the company uses for order scheduling. The current sales/operations interface can be described as follows: when sales representatives receive an order, the operations department is contacted to inquire about the time in which an order can be met. Given the limited response time and lack of any linked decision support tool, production possibilities are advised by operations in an intuitive way. Once sales representatives receive the estimated time frame and the client accepts it, sales representatives usually load the order details in a Google Appsheet. Operations receives the order list in Google Sheets. There are no ways sales can track order status, just by contacting operations directly.

Henceforward, first, the following policies are proposed to improve the current order scheduling process and ensure that it follows S&OP principles and the established supply chain strategies:

- All orders (both MTA and MTO) should be uploaded through the Google Appsheet, to ensure that information is transparent between sales and operations.
- The Google Sheets containing the information of all orders will be shared with the sales department, including an order status (pending, in progress, done). The production coordinator will be responsible for adding order status, through the Appsheet.

- If any DC has idle time, an MTA production order will be released to ensure high utilization of machinery.
- There should be at least one MTA order per day to ensure the weekly target level is met.
- The proposed algorithms should be followed to ensure optimal capacity coordination (more on this in the following step).

Secondly, two order scheduling algorithms are proposed to aid in two key decision-making questions: (1) select the distribution center (DC) to produce MTO orders, considering the company has two distribution centers; and (2) when to introduce an MTA order to the order schedule. The idea of creating simple algorithms to aid in decision-making came from the study by Danilczuk et al. (2022). In this study, the authors propose a job scheduling algorithm for a hybrid production process and obtain optimal capacity coordination. As a result, the same strategy is applied to the company under study obtaining the algorithms depicted in Figure 4.

For algorithm (2), two criteria are applied. The first criterion is that the MTA order should be introduced before the MTO order for which the aggregated time is greater than 8 hours. This criterion is because for MTA orders it is wanted to maximize production efficiency (Fisher, 2004). Therefore, considering that the shift starts at 8 am and at 4 pm, 8 hours later, both DC are at maximum capacity of machinery and workers, it would be optimal to produce MTA orders at this time frame. Moreover, the second criterion is that the introduced MTA order should not compromise MTO orders delivery dates. MTO orders should preferably be delivered on time to the customer.

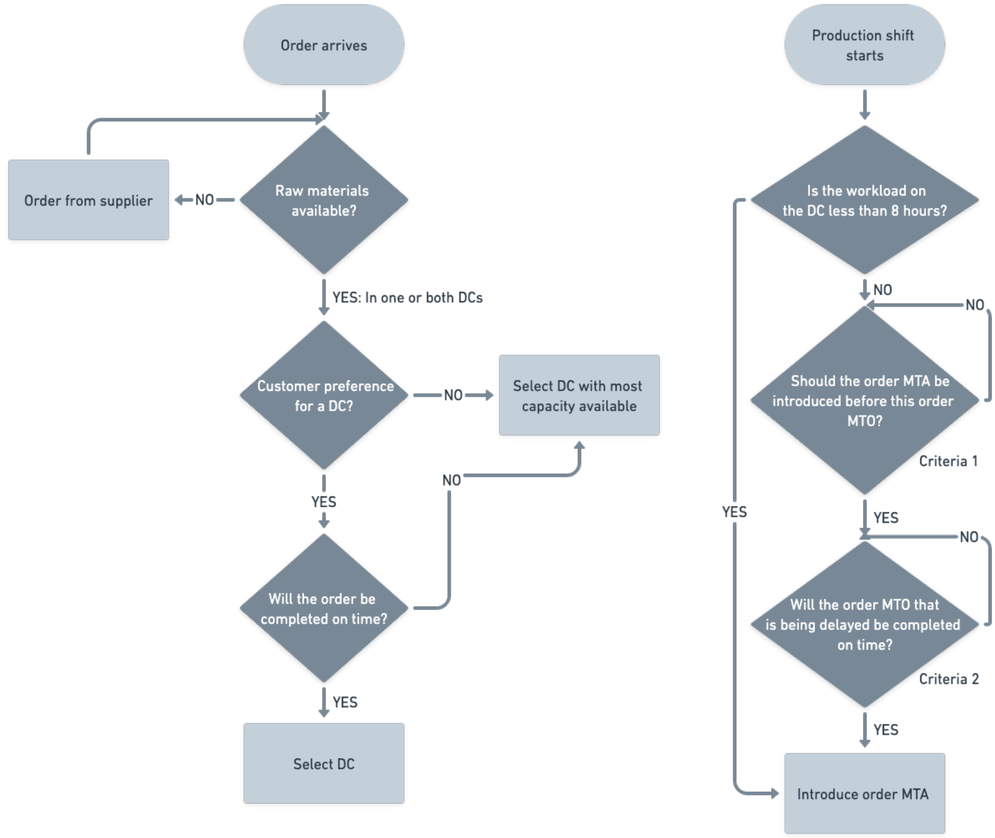

Figure 4: Algorithms for decisions (1) and (2), respectively

4.5.2. Application

The proposed solution for the company under study is to have a centralized site where capacity is coordinated, and order data is displayed. To do this, an App to upload order data was developed using Google Appsheet. Besides, it was connected to a Google Sheets to store data. Users can download the app or use it through the web by using mail. Each mail user will have permissions limited to restrict who edits the data and avoid any conflicts as shown in Appendix 11. Indeed, the only way to input the data is through the App. Also, the Google Sheets will be shared with both departments, sales and production, to visualize order information and to view a dashboard with important summarized data.

The dashboard includes three different bar graphs illustrating different information regarding the company's workload in hours. The first bar graph shows the total workload in hours for each DC, including delayed, in progress and pending orders. The second graph depicts the planned workload in hours per order status (delayed, in progress, pending and done). Finally, the third graph shows the planned workload in hours per type of order, MTA or MTO. This information will aid in the decision-making process for capacity coordination with the algorithms.

The process will begin with the sales representatives entering an order with its requirements through the App; the processing time per order will be calculated automatically. Then the manufacturing department will receive this information in the Google Sheets and proceed to apply the proposed algorithms in Figure 4. Finally, the production coordinator in each DC will move orders from the default, pending, to the actual status.

4.6. Step 6: Maturity Model Re-evaluation

Considering that the company under study, Emfalu, implements the proposal outlined in this study, the company could reach an overall integrated level of S&OP according to the maturity model by Wagner et al. (2014). Indeed, Emfalu could reach level 4, integrated for all dimensions, except for information technology, upon implementation. The information technology dimension could reach up to level 2, reactive because the next level requires the implementation of an ERP, which is out of reach for this research. These levels are highlighted in orange in Appendix 3.

Process Effectiveness: After applying the proposed methodology, Emfalu will have a formalized planning process that aligns supply and demand. Indeed, through the implementation of the hybrid production system, capacity coordination will improve and, thus, service level to both customer segments will improve. Besides, the proposed plan ensures sales and operations have routinely scheduled meetings for planning purposes. As a result, Emfalu advances from level 2, reactive, to level 4, integrated, in this dimension.

Process Efficiency: Currently employees will receive the information they need to make decisions. Just to mention some, those decisions include replenishment, stock level, order scheduling, and capacity. Besides, now the planning effort fits the organization's requirements as they manage two types of products, that are sold to two customer segments so now they have two supply chain strategies and production systems that meet the desired service level of both segments. Hence, Emfalu advances from level 2, reactive, to level 4, integrated, in this dimension.

People and Organization: This proposal will bring knowledge about S&OP to the company. Besides, there is now a dedicated S&OP process owner that has a lot of commitment and executive support to implement this proposal. Moreover, if the proposal is implemented planning will be more agile and enable fast response to unexpected changes. Hence, Emfalu advances from level 2, reactive, to level 4, integrated, in this dimension.

Information Technology: What the company will receive from this proposal is a set of systems that provides workflow and planning support. All optimized plans were obtained from research. Besides, these systems will increase data transparency between departments. Therefore, Emfalu advances from level 1, rudimentary, to level 2, reactive, in this dimension.

5. Conclusions

This study analyzes the proposal of Sales and Operations Management (S&OP) in an Ecuadorian medium-sized enterprise called Emfalu. First, the research evaluates the level at which the company under study is, based on an S&OP maturity model proposed by Wagner et al. (2014). The company was found to be in a reactive level of S&OP; however, if the proposal of the present study is implemented, it could reach an integrated level. In other words, the company could advance from level two to level four, out of five levels. It is also worth mentioning that, although the company works with more than 700 items, only 114 are the ones that represent 80% of the profit. Hence, focusing on strategically producing these few items to meet customer demand, creates a significant and positive impact on the profitability of the company. With regards to forecasting, the best model for all product families was Winters due to its lower forecast error, MAPE and mainly because the demand for product families is seasonal.

Considering Emfalu works with two customer segments, B2B and B2C, that have different product types, demand patterns, and customer expectations, it was necessary to analyze and propose two different production strategies. One is a make-to-availability system for those products which comply with the characteristics of a functional good, which means they have a predictable demand and are mostly standard. For them, inventory target levels were calculated based on forecasts and a paranoia factor to increase the availability of the final good when the customer orders it. Besides, for raw material replenishment, MRP was applied to know when to order and how much. On the other hand, for those products following innovative characteristics, variable demand and required customization, a make-to-order production system was applied. For this system, it was necessary to guarantee the availability of raw materials. As a result, a raw material inventory policy was proposed responding to questions about when to order and how much to order.

Finally, it was necessary to combine these two production systems in a single plan, which lead to an MTA-MTO hybrid production system. For this, sales representatives will need to enter data from each order through an App. The data will be stored in Google Sheets that will be shared with the sales and production department. Besides, order data will be analyzed and reported using a dashboard that will help production make capacity coordination decisions.

5.1. Future Research

Measuring capacity: As mentioned in the supply planning step, capacity information was obtained directly from the company. Therefore, for future research, it will be suggested to perform time studies or other methods to measure production capacity. This would ensure capacity information is analyzed thoroughly and thus, better S&OP.

Assigning strategic inventory per DC: For the inventory planning stage, all inventory policies and calculations consider overall stock decisions for either raw material or finished goods depending on the production system. Nevertheless, the company has two DC so for future research it would be beneficial to study product rotation, customer preferences, and historical orders to be able to allocate stock strategically in each distribution center.

6. Discussion

The limitations encounter for this study rely upon the S&OP maturity model by Wagner et al. (2014) that was applied. Indeed, it came to our attention that this renowned maturity model evaluates mostly at the administrative level without considering regular activities performed by employees. As a result, it was difficult to acknowledge small changes in everyday processes. Besides, it is difficult to decide which level an organization is in without a quantifiable method. Finally, in the supply planning step, it was obtained information about production capacity directly from the company. Hence, there was no way of knowing if this information was accurate or not, and results on MTA target levels and capacity coordination could be impacted by this information.

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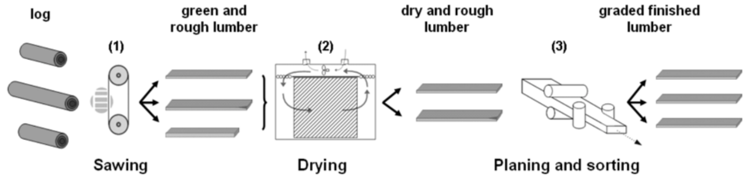
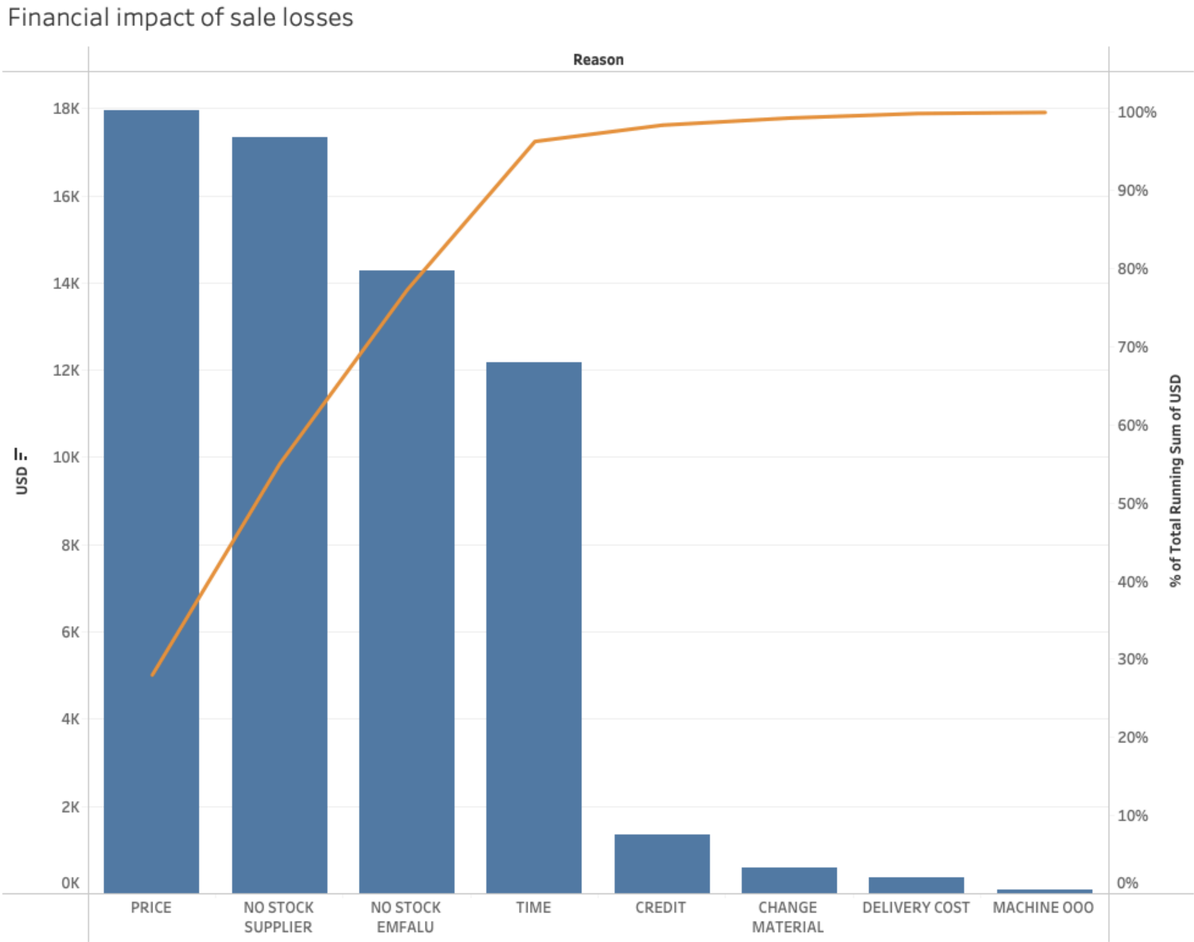
ANEXOS

Appendix 1: Production in a lumber supply chain



Appendix 2: Financial impact of sale losses



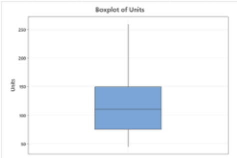
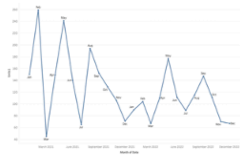
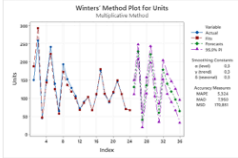
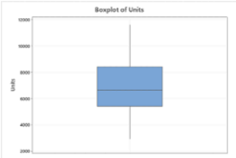
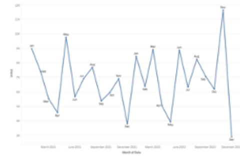
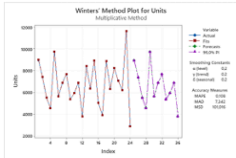
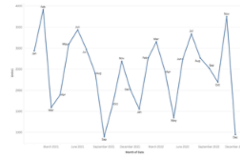
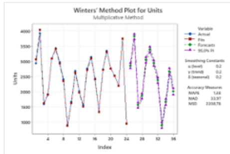
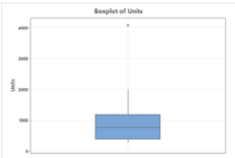
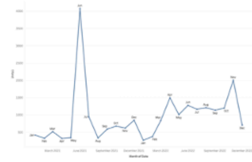
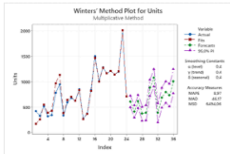
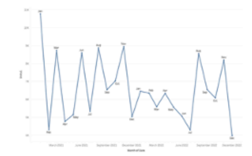
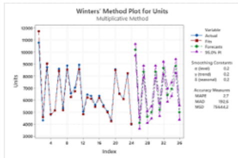
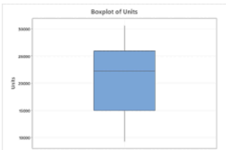
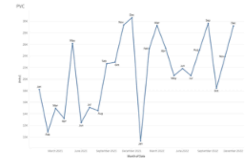
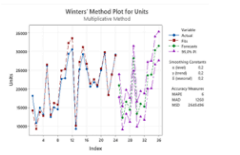
Appendix 3: S&OP Maturity Model

	Level 0: Undeveloped	Level 1: Rudimentary	Level 2: Reactive	Level 3: Consistent	Level 4: Integrated	Level 5: Proactive
Process Effectiveness	-No formalized planning process - No scheduling of review meetings - No consideration of capacities - No promotions and price changes planned - No risk management in place - No product life cycles and new product introductions planned - No efforts made to align supply and demand-side plans	- Slightly formalized planning process - Meetings not routinely scheduled - Not all SKUs/product families considered in planning process - Issues like promotions, price changes, capacities, risk management, new products, and life cycles planned but not considered in S&OP - Little attempts to develop a consensus supply and demand plan jointly and/or to consider information from others - Existence of multiple supply and demand plans	- **Moderately formalized planning processes and typically routinely scheduled meetings** - **Most SKUs/product families considered in planning process** - **Issues like promotions, price changes, capacities, risk management, new products, and life cycles insufficiently planned and considered** - **Demand-side provides a synchronized consensus demand plan so that supply-side organizations can generate a more or less aligned supply plan** - No alignment with financial plans	- Level 2 plus: - Very formalized planning processes - Routinely scheduled meetings - All SKUs/product families considered in planning process - Issues like promotions, price changes, capacities, risk management, new products, and life cycles internally sufficiently planned and considered - Demand- and supply-side organizations (without finance) jointly generate an aligned set of plans - **Financial targets/plans primarily drive decisions, instead of being discussed and aligned together**	- Level 3 plus: - Internally completely formalized planning processes Routinely scheduled and event-driven meetings - Issues like promotions, price changes, capacities, risk management, new products, and life cycles internally, but not externally sufficiently planned and considered - Demand- and supply- side organizations generate together with finance an aligned S&OP plan - No interactions with supply chain partners	- Level 4 plus: - Planning process is formalized throughout the supply chain - Event-driven meetings - Issues like promotions, price changes, capacities, risk management, new products, and life cycles internally and externally entirely planned and considered - All relevant information is internally and externally shared to improve supply chain visibility - External supply chain partners participate in alignment process to ensure plan feasibility and cross-company profit maximizing decision making
Process Efficiency	- All planning is done manually - Information only partially available - Many redundancies - Frequent re-planning necessary - No planning meetings - No plan alignment - Planning efficiency and effectiveness not measured - No KPIs in place to measure planning performance - No performance tracking efforts made	- **Due to decentralized information storage, many redundancies in information preparation** - High degree of friction losses in cross-departmental information flows - Meeting attendees not authorized to make decisions - Poor plan alignment makes frequent re-planning inevitable - Basic KPIs defined but only sporadically managed - **KPIs not aligned across departments, with business strategies, and bonus schemes**	- Partially centralized information storage reduces redundant work in information preparation - **Moderate friction losses in cross-departmental information flows** - **Due to rudimentary plan alignment, frequent re- planning required** - **Meeting attendees typically authorized to make decisions** - **Basic KPIs defined and regularly managed** - Most KPIs harmonized across departments and partially aligned with bonus schemes - **Some efforts of tracking performance**	- Level 2 plus: - Relevant information is automatically shared and prepared Very little friction losses in cross-departmental information flows - Meetings are formalized and executed that way (e.g., authorized attendees) - Due to appropriate plan alignment, less frequent re-planning necessary - Planning effort fits partially to the organization's requirements - Structured mechanism for S&OP performance evaluation - Regular reporting and tracking of performance	- Level 3 plus: - People receive only information they actually need - No friction losses in cross-departmental information flows - Meetings typically exception-focused and event-driven - Due to sufficient plan alignment, re-planning becomes very rare - Planning effort perfectly fits to the organization's requirements - Full alignment of KPIs across departments, with business strategy and bonus schemes - Internal S&OP benchmarks irregularly performed	- Level 4 plus: - External participants are integrated via systems such as EDI to avoid redundant data entry - S&OP meetings take place event-driven only and on a virtual basis to avoid numerous journeys - Supply chain partners participate in alignment process to avoid rescheduling due to, for example, capacity restrictions of suppliers - KPIs also consider performance of supply chain partners and are aligned with payment modes Internal and external S&OP benchmarks regularly performed
People & Organization	- No assignment of roles and responsibilities with regard to planning tasks and activities - No planning organization established - Employees do not understand the necessity of, and requirements for, S&OP - Insufficient planning know-how - No management commitment	- Deficiencies in planning organization (no clear role descriptions, organization not aligned with business) - People are not held accountable for their plans and performance - Little skills, aptitude, and attitude of employees toward S&OP - Insufficient commitment and executive sponsorship	- **Roles and responsibilities clearly defined** - **No dedicated S&OP owner** - **People partially held accountable for their plans and performance** - **Insufficient knowledge to perform advanced S&OP activities** - **Moderate commitment and executive sponsorship**	- Level 2 plus: - New planning organization with dedicated S&OP process owner established - S&OP responsibilities clearly specified in job descriptions, people know and stick to them - Sufficient knowledge to perform advanced S&OP activities - Great commitment and executive sponsorship	- Level 3 plus: - Planning organization entirely aligned with the business - Planning is agile and enables fast response to unexpected changes - Sufficient knowledge to perform additional planning related activities, such as risk management - Excellent commitment and executive sponsorship	- Level 4 plus: - New organizational structure with dedicated S&OP process owner who coordinates planning efforts for the entire supply chain - Employees and top management highly committed and strive for continuous improvement - Top management of all partnering companies sponsor and participate in S&OP
Information Technology	- No planning systems - Heterogeneous spreadsheets existent and in use - Master data not (accurately) defined - No harmonization of master data throughout the organization	- **Isolated demand and supply planning systems with a very limited scope of functionalities implemented** - No integration of demand and operations planning software - **Planning systems do not have access to all relevant planning data** - **Inconsistent master data definitions** - **Master data not harmonized throughout the organization**	- Demand planning software and multi-facility production planning systems with more advanced functionalities such as statistical analyses to generate (sequentially) optimized plans employed - **Information from other systems need to be manually entered or uploaded (no interfaces)** - Planning systems have access to most relevant planning data - Most master data consistently defined but not entirely harmonized throughout the organization	- Level 2 plus: Multi-facility APS system in place - S&OP workbench and software that provides workflow support - All planning modules and tools are linked via interfaces to the underlying ERP-system and have access to all planning data - Plan adjustments are automatically incorporated in all modules - Master data consistently defined and harmonized throughout the organization	- Level 3 plus: - Systems continuously keep track of plans and trigger automatically alerts in case of unexpected deviations - Software suggests resolution alternatives if required - Simultaneous/real-time feasibility analyses supported - One 'single truly integrated system' in place - Master data proactively managed internally but not externally	- Level 4 plus: - Software supports CPFR, TPM and other visibility tools to integrate supply chain partners in IT infrastructure - IT systems are completely aligned throughout the supply chain - All relevant data (including capacities of third-party manufacturers, etc.) is available - Master data consistently defined and harmonized throughout the supply chain

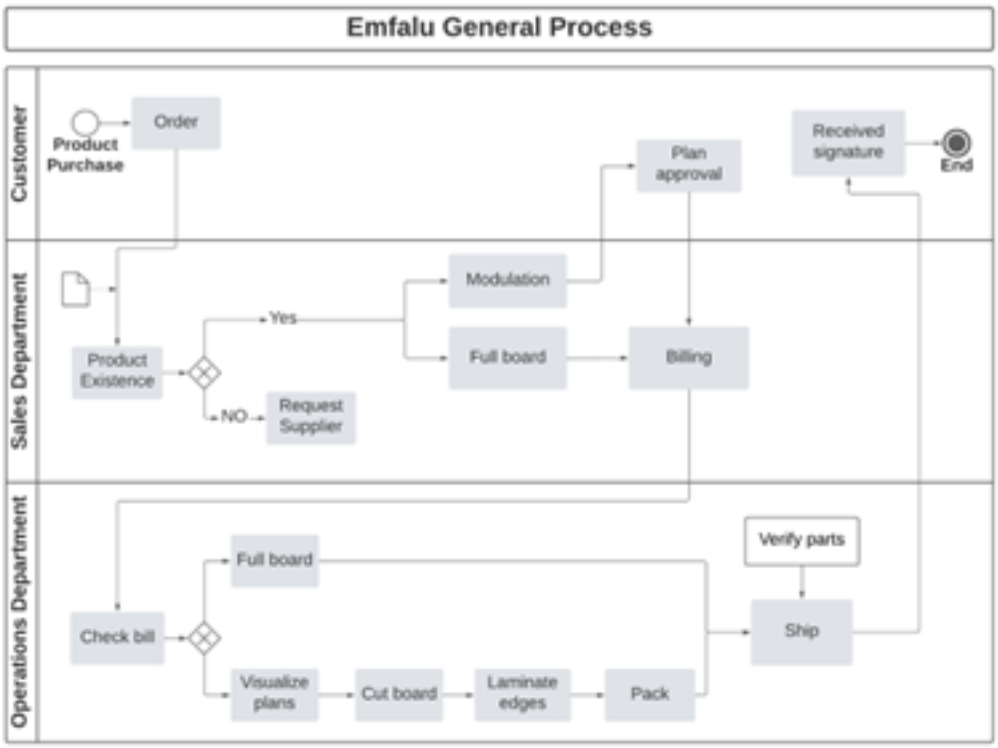
Appendix 4: Forecasting models and their features

Time Series Methods	Main Features
Moving Average	-It has no trend, it is stationary (Nahmias, 2007). -No trend or seasonality (Chopra and Meindl, 2013). -Random variations (Stevenson,2015).
Simple Exponential Smoothing	-Stationarity (Nahmias, 2007). -No observable trend or seasonality (Chopra and Meindl, 2013). -When the data varies around a mean and maintains gradual changes (Stevenson,2015).
Double Exponential Smoothing (Holt)	-Linear trend (Nahmias, 2007). -Trend, but not seasonality (Chopra and Meindl, 2013). -Linear or non-linear trend (Stevenson,2015).
Triple Exponential Smoothing (Holt-Winters)	-Seasonal with or without trend (Nahmias, 2007). -Trend and seasonal factor (Chopra and Meindl, 2013).
Box Jenkins	-ARMA: Stationary (Chopra and Meindl, 2013). -ARIMA: Non-stationary (Chopra and Meindl, 2013).

Appendix 5: Summary figures for forecasted models

Product Family	Outliers	Mann-Kendall Test (Units vs Month)	Forecast Model Selected	MAPE
MDF				5.324
MDP A				0.108
MDP B				1.38
MDP C				8.97
Plywood				2.7
PVC				6

Appendix 6: General Process of the company



Appendix 7: Supply planning procurement information

	SUPPLY PLANNING PROCUREMENT
Supplier Products	The supplier/manufacturer has a range of products that are classified based on: the type of wood, thickness of the board, color, and texture.

Supplier lead times	There are two principal specifications in which lead times will differ. It is necessary to consider suppliers' stock. If the supplier has the products in stock, the lead time will range between 1-5 days. On the other hand, if the supplier must produce, the lead time will vary between 10-15 days once the procurement order is placed.
Raw material inventory capacity	The diverse kinds of lumber are the company's raw materials. It will depend on the thickness, which ranges from 3mm to 36mm, regarding capacity. As a result, the company can store 330 boards DC 1 and about 1,200 boards in DC 2.
Holding costs	Storage Costs: This includes the costs associated with renting a space and any utilities needed to keep the inventory in good condition. Lease DC 1: $2500 Lease DC 2: $2700
Transportation costs	Included in cost of raw material.
Restrictions on order size	The minimum quantity of the order size is 5 boards.

Appendix 8: Production planning information

SUPPLY PLANNING PRODUCTION PLANNING	
Current available production capacity	There is a total of three cutting machines and two for the edge boards. In DC 1, two cutting machines and one edge bander. In DC 2, there is just one of each. The capacity is cutting 18 boards per machine and laminating 11 meters per minute (edges come in meters) approximately.

Appendix 9: Distribution planning information

SUPPLY PLANNING DISTRIBUTION PLANNING	
Capacity	One truck available: 4.5 tons
Holding costs	Gas and maintenance: $$
Shipping	*B2C segment:* Distribution is free if the order reaches a minimum of $500, otherwise, the distribution cost is calculated based on the location of delivery. Besides, the customer can also decide to pick up the product from the DC. *B2B segment*: Distribution is always handled by Emfalu, and the cost is included in the price of the product sold.

Appendix 10: MTO raw material inventory system

ID	Stock level	Safety Stock	Min Order Q	Status	Q
REP0165	119	28	30	Correct Level	30
REP0169	354	25	20	Correct Level	20
REP0172	75	29	24	Correct Level	24
REP0178	137	10	34	Correct Level	34
REP0180	120	8	16	Correct Level	22
REP0044	0	22	16	Order	52
REP0176	245	14	36	Correct Level	36

Appendix 11: Application permissions

Members	Allow data to edit	By
Sales Department	• Number of bill: unique number to find any specifications. • The name of the client. • In which DC was made the transaction. • Number of boards sold. • The meters of edge. • Transportation either by truck, or the customer picks up the order.	Form

	• Any observations.	
Production Department	• Decide what type of order it is. • Decide in which DC the order will be produce (based on the type of order and the algorithms). • Delivery date and time based on approximate dates given by the system. • Any observations.	Form
Production Coordinator	• Decide the status of each order: Standby Order, Order in Process, Delay, Completed • Any observations.	Form
Calculated Data	• Based on production times, the number of boards, and meters of edge, the time in the system will be automatically calculated in hours. • Based on the number of boards and meters, the system can determine an approximate delivery date.	Google Sheets