Universidade do Minho
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Driving Service Excellence in a Wood-Based Panel Industry: A Data-Driven Approach to act on Supply Chain Quality

julho de 2021

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Dissertação de Mestrado
Mestrado Integrado em Engenharia e Gestão Industriaç

Trabalho efetuado sob a orientação da
Professora Doutora Maria Sameiro Carvalho

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"Mens Agitat Molem" - Virgil, Aeneida

I think I made my life about learning new things, about exploring and getting into big adventures. Five years later, I guess I realised everything I was up to during my school life. I have learned a lot, found the best people, connected with the best professors, and left my mark.

The University of Minho is my Alma Mater. It created the opportunity to go further, visit Europe, study for six months in one of the best European universities in Eindhoven. I was able to transform myself, leaving my mark in NEEGIUM and AAUM. It couldn't be done if I hadn't been here. Now, after these five years, it is time to go further and continue to impact the world.

But University and life are nothing without the people who cross my path, which made me who I am today and made me believe that it is possible to change the world. This thesis is for all of them that inspired me.

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

Conduzindo à excelência no serviço numa indústria de painéis de madeira: Abordagem orientada por dados com foco na qualidade da cadeia de abastecimento

Resumo

O crescimento das cadeias de abastecimento e das redes de manufatura aumenta a exposição ao risco de disrupções e distúrbios nas operações das empresas. Estas têm de desenvolver estratégias de gestão do risco da cadeia de abastecimento, operações mais robustas e resilientes e refinar os seus processos para permitirem uma resposta mais ágil para cumprirem os prazos acordados com os clientes.

Esta dissertação foi desenvolvida no âmbito do Mestrado Integrado em Engenharia e Gestão Industrial, em ambiente industrial, na Sonae Arauco. O objetivo é redesenhar processos para proporcionar excelência no serviço através do desnevolvimento de um novo sistema de apoio à decisão que avalie corretamente as razões de falha no serviço ao cliente. Foi seguida a metodologia *proactive data mining*, em específico, a análise exploratória de dados e tirando partido de todos dados obtidos através do sistema ERP, foi estudado e desenhado um novo sistema para garantir razões de atraso mais precisas. O projeto de melhoria de processos baseou-se na metodologia *Stage-Gate* para criar cooperação e integração num ambiente multidisciplinar. A solução proposta foi composta por estratégias de curto-prazo e de longo-prazo. A estratégia de curto-prazo foi implementada e apresentada resultados promisores nas diferentes fábricas. É constituída por um novo framework, processos refinados e um sistema dde suporte à decisão que garante mais responsabilidade e standardisação entre os diferentes gestores logísticos e respetivas fábricas. Resultou num decréscimo da área desconhecida em 35%; um aumento da variedade das razões de atraso mais precisas, em 50%; e um processo automático que é agora capaz de identificar cerca de 70% das linhas de encomenda. As razões de longo-prazo apresentam resultados teóricos baseados em simulações e definem um caminho para iniciativas futuras. Mais do que a relevância para a gestão, o objetivo foi também contribuir para a literatura através da metodologia *Stage-Gate* aplicada a projetos de melhoria de processos. Esta metodologia inovadora diminui o tempo do projeto e permite a criação de uma relação simbiótica numa equipa multidisciplinar, enquanto elimina silos funcionais. Foi considerada um sucesso na empresa e está agora em uso noutros projetos.

Palavras-Chave: Data Mining, Gestão do Risco na Cadeia de Abastecimento, Melhoria de Processos, Nível de Serviço ao Cliente, Stage-Gate

Driving service excellence in a wood-based panel industry: A data-driven approach to act on supply chain quality

Abstract

The growth of supply chains and manufacturing networks increases the exposure to the risks of disruptions and disturbances in the companies' operations. Companies need to develop supply chain risk management strategies, more robust and resilient operations and refine their processes to an agile response to the customers to meet deadlines.

This dissertation project was carried out under the scope of the Integrated Master in Industrial Engineering and Management within the industry environment of Sonae Arauco. It aims to redesign processes to drive service excellence by developing a new decision support system that correctly evaluates the reasons for failures in the customer service level. Following the proactive data mining methodology, in specific, the exploratory data analysis, and taking advantage of the current data provided by the ERP system in use, it is studied and designed a new data-driven process to provide accurate delay reasons. This process improvement project followed the innovative Stage-Gate methodology to create understanding, cooperation, and integration in a multidisciplinary environment. The proposed solution included short-term and long-term strategies. The short-term strategy was implemented and presented promising results across the different manufacturing units. It is constituted by the new framework, refined processes and a decision support system capable of creating accountability and standardisation for all the Logistics Managers and their plants'. There was a decrease in the area of unknowing related to delay reason, around 35%; an increase in the variety of the precise delay reasons, around 50%; and the automatic process is now capable of assign almost 70% of sales order items. The long-term strategies present theoretical results based on simulations and define the path for future improvement initiatives. More than the managerial relevance of this research project, it is intended to contribute to the literature related to the Stage-Gate methodology and its usage in process improvement projects. This innovative methodology decreases the time of the project and creates a symbiotic relationship in a multidisciplinary team environment while eliminating the functional silos. It was considered a success within the company and it is now in use on other projects.

Keywords: Customer Service Level, Data Mining, Process Improvement, Stage-Gate, Supply Chain Risk Management

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Acronyms

APICS American Production and Inventory Control Society.

DCs Distribution Centres.

ERP Enterprise Resource Planning.

KPI Key Performance Indicator.

LD Loading Date.

MAD Material Availability Date.

MDF Medium Density Fiberboard.

MFC Melamine Faced Chipboard.

MFMDF Melamine Faced MDF.

MRP Material Requirements Planning.

NEE North-East.

OSB Oriented Strand Board.

OTIF On Time In Full.

PB Particleboard.

SAF South Africa.

SCM Supply Chain Management.

SCOR Supply Chain Operations Reference Model.

SCRM Supply Chain Risk Management.

SKUs Stock Keeping Units.

SWE South-West.

WIP Work-in-Process.

1. Introduction

The present dissertation is developed under the umbrella of the Integrated Master in Industrial Engineering and Management at the University of Minho. This thesis is the result of a graduation project performed with Sonae Arauco's Supply Chain Department and it is focused on redesigning processes to improve the customer service level.

This research project starts with a summary of the topic that, with the literature review, describes the the problem explored throughout the next chapters. The goals of the project and the research methodology used are also provided. Finally, a overall document outline is presented.

1.1 Background

The Supply Chain Management (SCM) concept is considered by Mentzer et al. (2001) as the coordination between business functions and the tactics across them, both within a company and the businesses in the supply chain. It aims to pursue improvements in the performance of the individual company and the whole supply chain, therefore, integrating production and logistics processes (Chopra, 2016).

Over the past years, supply chains have grown both in size and extent and, in consequence, also in uncertainty and complexity. Uncertainty is the incapacity to know everything about the system and its development's conditions and the factors can be stochastic or non-stochastic (Ivanov, 2018). On the other hand, complex systems are made up by single elements which have intimate connections, counterintuitive and non-linear links: consequently, presenting self-emerging, often chaotic, behaviour (Forrester, 1997). This growth is the main responsible for global supply chains (highly coordinated flows of goods, services, information, and cash within and across national boundaries (Mentzer et al., 2001)).

The wood industry, in particular, the segment of wood-based panels production has a multitude of products due to the diversity of materials and sizes that a panel can have. In fact, the number of combinations that a single panel can have by just changing the colour and the thickness is immense. Also, there is a high number of customers in this industry, so companies must be capable of managing the flow of goods and the way they are transported.

Sonae Arauco is a world-class player in the wood-based panel manufacturing market with twenty-three commercial and production units in 9 countries in 2 continents. The dissertation took place in the SWE Region that has a complex system with four factories, two in Portugal and two in Spain and two Distribution Centres (DCs), one in Portugal and one in Spain, each of them with different characteristics, products manufactured and with interdependencies between them. Due to these settings, this industry is exposed to the possibility of disruptions in the critical supply chain processes increasing the risks they face to meet the customer needs and, consequently, lowering the service level. Nowadays, the world is changing at a considerable pace, and companies need to adapt faster than they were in the past. The fact that Sonae Arauco does not serve the end customer increases the need to meet their clients' deadlines in order to satisfy all the value chain. It is vital to manage the complexity and the uncertainty to be able to meet the expectations.

The growth of global supply chains is also responsible for the increase in supply chain breakdowns (Pettit et al., 2010). These breakdowns can be responsible for lack of accuracy in forecast, excess or lack of stock or capacity and delays (Chopra and Sodhi, 2004) and there are numerous different causes for them like uncertain lead times, uncertain demand, uncertain supply capacity (Tang, 2006). All the above affect the service level and therefore, the satisfaction of the end consumer.

One of the biggest concerns that Sonae Arauco has is the low service level evaluated by the Key Performance Indicator (KPI) On Time In Full (OTIF) when compared with the relevant competitors. Currently, the company uses a method to report the causes of failing to meet the delivery date that does not call for action. In most cases, it also overlooks the root causes making it impossible to act upon those and correct the disruptions and failures in the system. Taking that into account it is crucial to develop a new report and a new approach that enables the possibility to improve the OTIF KPI and, in consequence, improve the customer satisfaction with the service provided, allowing the company to assume a more competitive position in the sector.

1.2 Goals

The overall goal of this research project is to analyse the root causes of the defects in the supply chain of Sonae Arauco and to develop and deploy improvement initiatives to mitigate disruptions, to identify the supply chain critical factors and improve the method of reporting disruptions. Based on this, the following questions were made to serve as guidelines:

- What are the root causes that increases the risk of disruptions in the supply chain of Sonae Arauco?
- Which root causes influence the system the most?
- How can the reporting process be improved?

Throughout this project, more specific criteria needed to be met to answer the questions above:

- In depth-analysis of the current supply chain's processes;
- In-depth analysis of the current supply chain's processes: purchasing, planning, transport;
- Measure actual service level performance;
- Identify the critical factors that affect the service level;
- Identify the root causes of the low service level;
- Evaluation of improvement initiatives to increase the service level;
- Study alternatives for the improvement;
- Analyse the impact of the improvement initiatives and the alternatives when compared with the current situation.

With the steps presented above, it is expected an increase in the KPI OTIF, and, consequently in customer satisfaction.

1.3 Research Methodology

Every research project's starting point is to define the research topic. This topic should be well defined and framed into research questions and goals as presented above. As presented by Saunders et al. (2009), it is crucial to select the most suitable approach and research strategy, data collection and data analysis methods and the time horizon for the project. To help researchers on how to create an effective research methodology, Saunders et al. (2009) proposed a framework called *"research onion"*.

The researcher followed this method in order to develop his research methodology. The first onion skill to peel is the philosophies one. For this master thesis, the author chose to follow positivism, objectively and independently of social actors investigating the topics, understanding that only the observable evidence responsible for creating accurate and authentic data.

Next, the approach followed was the deductive one. This one fits best as the foundation of this research was the deduction of the possibility to improve the service level as it presented too many failures. It is also essential to know that this approach presents a comprehensive sample analysis as a requirement. In this dissertation, the research was made taken into account different factories and DCs and not only on a particular one.

The strategy used in the research was the case study. Gerring (2004) defines case study as *"an intensive study of a single unit for the purpose of understanding a larger class of a (similar) units"*. For the case study research method, the author used mixed-methods for research methods. There were made quantitative studies, structured data collection and analysis and, in parallel, qualitative studies as the researcher used diary accounts and interviews to understand the problem he intends to investigate. Data collected from different methods were analysed separately.

A literature review was carried out under the frame of Logistics and SCM, more focused on three main areas: manufacturing global supply chains, supply chain risk management and on supply chain performance, focusing on customer service level. The author chose to follow the research process of a structuring content analysis as presented by Seuring and Müller (2008).

As the low service level was a problem happening not only on specific times but continuously it was followed a longitudinal study which as the capacity to analyse change and development.

This research project was divided into different phases that were followed to answer the research questions and to achieve the overall research goals:

1. **Research Focus Proposal**
2. **Literature Review on Supply Chain Management, Global Supply Chains and Customer Service Level**

   On this phase, a theoretical background review was done using scientific and academic content such as scientific books, scientific articles, dissertations or research projects. This content was found in different sources, mostly only, such as Scopus and RepositoriumUM. The topics of the search were SCM, customer service level, supply chain risk management.
3. **Low Customer Service Level - In-Depth Analysis**

   An in-depth analysis was made to identify the root causes of the low service level. This extensive study focused on the company's historical data, the variables that influence the system and their relationship. A dashboard software, QlikView already existing in the company, was used and also the supply chain department and all social actors were interviewed and observed.

4. **Development of Improvement Initiatives**

   After analysing the system, was required to develop some potential improvement initiatives. From the pool of improvement initiatives, a payoff matrix was done to understand which ones were more effective at a lower cost. Some scenarios were explored before the deployment phase.

5. **Deployment of Improvement Initiatives**

   The COVID-19 pandemic had a significant impact on this phase. The deployment of improvement initiatives was done only on the more straightforward actions, and the more resourceful ones were deeply studied to gather theoretical improvement insights.

6. **Analysis of the Results**

   The pandemic also impacted this phase as it was required to analyse both some theoretical improvement initiatives impact and the ones which were implemented. The focus was on potential results and increase of customer service level and on the best measures to implement shortly. Furthermore, some conclusions were identified to push more effort to tackle the low service level problem.

7. **Writing Master Thesis Report**

1.4 Thesis Outline

This research project is organised into six chapters. This first chapter presents the background, research goals and research methodology used in this work.

The second chapter focuses on the literature review, providing a theoretical background on the relevant topics for this work. A brief explanation of Logistics, SCM and global supply chains is presented, focusing on supply chain risk management. Lastly, research on performance management systems related with the supply chain is displayed.

Chapter three describes the company where this project took place. A brief background on the history and products is presented. Emphasis is given to factories and DCs and the flows between them. The main processes, relevant for this study, are mapped.

After that, in chapter four, an in-depth analysis is conducted to the actual situation, including the main root causes withdrawn from such.

On the fifth chapter, the studied improvement initiatives are presented. Also, is drawn a cost vs benefit analysis to choose the best-fitted solutions. Furthermore, the results for each one of the developed initiatives are shown.

Lastly, chapter six showcases the reflection on the findings of this research project and also, some future work proposals are given to allow further developments on this topic.

2. Literature Review

This chapter aims to provide a literature review of core concepts to this research project. This overview consists of a brief introduction to SCM and Logistics and Global Manufacturing Networks and Supply Chains, highlighting Supply Chain Risk Management and methodologies. The focus is given to performance management systems and service level performance. Lastly, a summary of the literature review findings is presented given emphasis to the existent gaps and supporting the research project.

2.1 Supply Chain Management and Logistics

The first step to fully understand a topic is to dive into its history.

The term *logistics* has been used even before the current business logistics concept. It derives from the Greek word *logos* standing for reason and rational. The military science firstly introduced it due to the existence of departments that were responsible for food, arms or ammunition supply, supporting in-field teams (Islam et al., 2012).

Klaus and Müller (2012) defend that, apart from the military discipline, the term *logistics* started emerging since Smith (1776) *"Wealth of the Nations"*. Then, the development of the logistics business term is interrelated with the economist Alfred Marshall's work *"Principles of Economics"* (Marshall, 1890) and Weld (1919) insights. Ultimately, Ihde (1972) graphically showed the connection between manufacturing and transportation.

On *"Logistics at Large: Jumping the Barriers of the Logistics Function"*, (Sheffi and Klaus, 1997) present the development of logistics as an autonomous science. Firstly, *"PPP-logistics"* meaning ("placing", "pacing" and "patterning"), then *"coordination logistics"* appeared in the 1980s. The third meaning emerges in the 90s with the logistics community focus on the dynamic phenomena and the complexities to manage the flow of goods. The term *"flow systems"* begin to grab attention that ultimately led to *supply-chain* and *supply network* terms (Oliver and Webber, 1982).

Nowadays, the logistics term is defined as *"The process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to* *customer requirements. This definition includes inbound, outbound, internal, and external movements."* CSCMP (2013). It is composed of critical functions and activities, as presented in the Table 2.1 below.

Table 2.1: Key Logistics Functions and Activities, adapted from (Kasilingam, 1998)

Logistics Functions	**Activities/Decisions**
Purchasing	Vendor selection, order processing, order follow-up
Inventory Control	Order quantity, ordering frequency, inventory valuation
Facilities Location and Layout	Number and location of facilities, layout of components within a facility
Transportation	Routing and scheduling, mode and carrier selection
Intra-facility Logistics	Capacity planning, warehouse design in terms of location and space for items, order picking rules

As presented by Lummus et al. (2001) and Lambert et al. (1998), the increasing competition between companies led to the appearance of the term supply chain, in the early 1980s.

Numerous aspects, such as customer-centricity and globalisation, led to the rise of supply chain management as a vital concept to improve customer service levels, driving companies to be more competitive (Ellram, 1991).

As presented by Ballou (2007) as enterprises want to expand their operations globally, the SCM gains importance. The CSCMP (2013) defines SCM as *"the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, SCM integrates supply and demand management within and across companies."*

Based on collaboration with industry leaders, Lambert et al. (1998) defined eight key sub-processes for SCM:

1. customer relationship management;
2. customer service management;
3. demand management;
4. order fulfillment;
5. manufacturing flow management;

6. supplier relationship management;
7. product development and commercialization;
8. returns management.

Those sub-processes are intimately connected with business functions. Mentzer et al. (2001) developed a conceptual model (figure 2.2) that illustrates the supply chain as a pipeline. Emphasising the vital role of customer satisfaction to achieve profitability and competitive advantage both for the company, as an individual, and the supply chain as a whole.

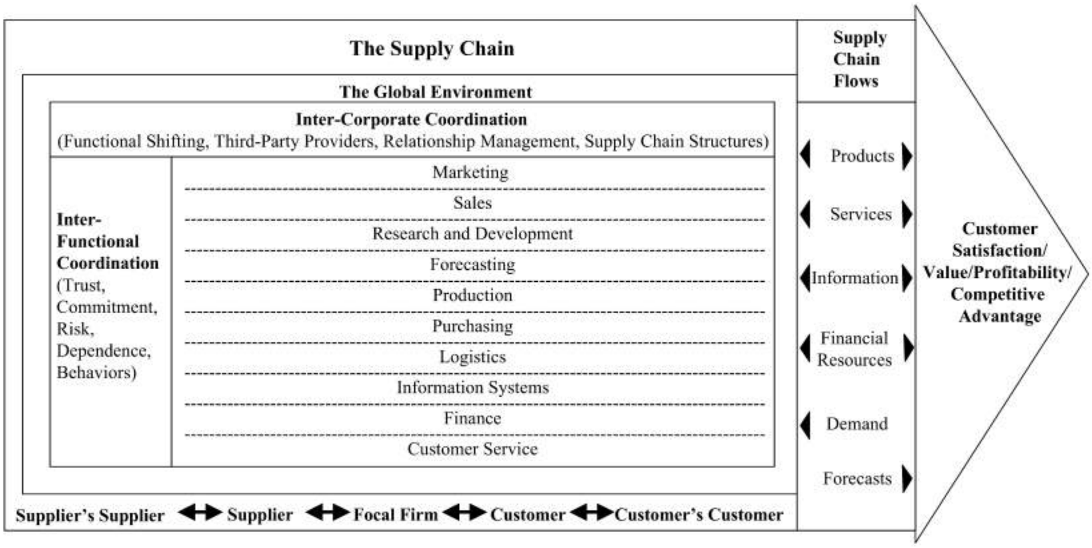


Figure 2.1: Supply Chain Management: Conceptual Model, from Mentzer et al. (2001)

For the manufacturing industry, Zijm (2019) presented an organisational framework with all the functions and their relations in a manufacturer.

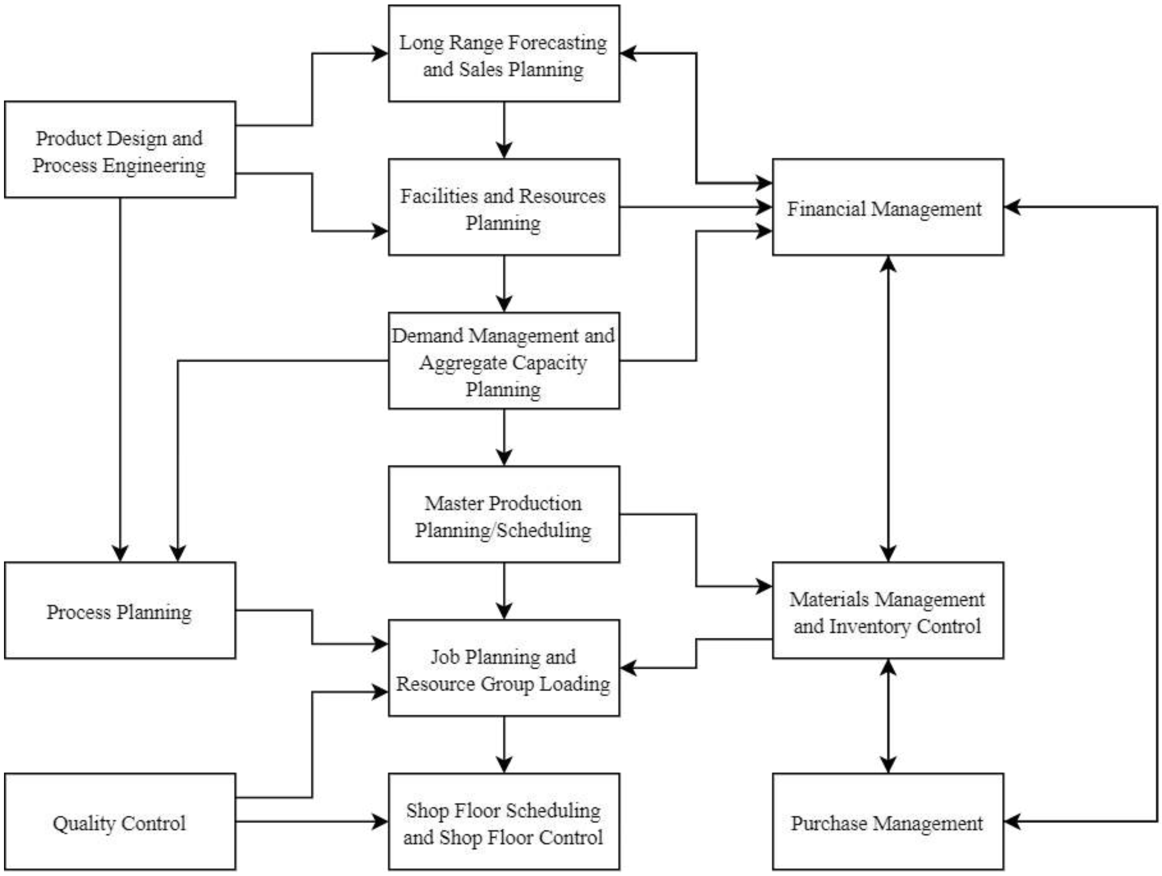


Figure 2.2: Functions and their relations in a manufacturing organization, from Zijm (2019)

2.1.1 Supply Chain Flows and Processes

It is essential to coordinate efficiently all the supply chain flows to achieve the best customer service level. As presented by Pinto (2010), the key flows in a supply chain system are flow of goods, information flows and financial flows.

1. The **flow of goods** consists of all the movements, manufacturing, warehousing and picking of products until they reach the client or between factories and DCs;
2. The **information flows** are responsible for supporting all the financial and goods' flows. They are vital in connecting all the support functions of the SCM, integrating all the factories, DCs, transports and inventories. They also guarantee that the accuracy and correctness of data;
3. **Financial flows** assure the payment of products and services and are accountable for the control of costs along the chain.

The Supply Chain Council in February 1997 released in Europe the first cross-industry framework to evaluate and improve end-to-end supply chain's performance and management (Gordon, 1997). This framework is the Supply Chain Operations Reference Model (SCOR).

As presented by Huan et al. (2004) it was developed from 1997 until today. First, it comprised four distinct processes:

- Source;
- Make;
- Delivery;
- Plan.

Nowadays, in its current version SCOR 12.0, it defines six management processes as illustrated in figure 2.5.

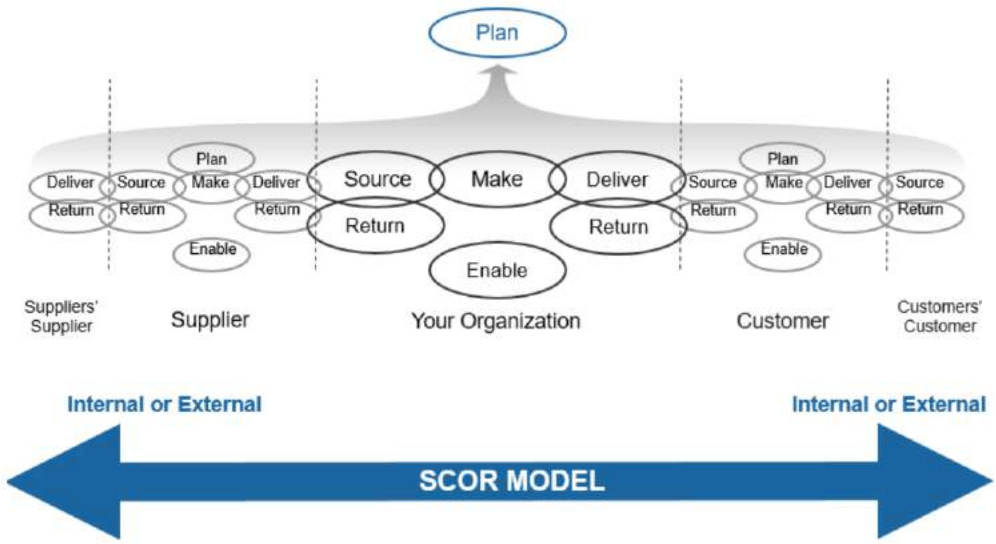


Figure 2.3: SCOR Model 12.0

SCOR encompasses customer interactions, physical goods transactions and market interactions, with no intention to focus on any specific business activity: sales, marketing, research and development or product development. It was developed to support analysis in the supply chain at three levels, as shown in the Table 2.2. Those three levels are neutral in terms of industry, and American Production and Inventory Control Society (APICS) recommends a specific fourth level in order to improve the supply chain performance. The fourth level includes industry-specific improvement tools such as Lean, Total Quality Management, Six Sigma, and others. In Table 2.2 the hierarchy between the levels is presented.

Table 2.2: SCOR Process Hierarchy, adapted from APICS (2017)

Level	**Description**	**Comments**
Level 1	Major Processes	Defines the scope, content and performance targets of the supply chain
Level 2	Process Categories	Defines the operations strategy; process capabilities are set
Level 3	Process Elements	Defines the configuration of individual processes. The ability to execute is set. Focus is on processes, inputs/outputs, skills, performance, best practices and capabilities
Level 4	Improvement Tools/Activities	Use of Lean, Total Quality Management, Six Sigma

It is essential to state that SCOR is a process reference model, describing processes and not operations. It intents to align key business functions and goals and define a process architecture to pursuit that within four vectors:

- **Performance:** Standard metrics to describe process performance and define strategic goals;
- **Processes:** Standard descriptions of management processes and processes relationships;
- **Practices:** Management practices that produce significantly better process performance;
- **People:** Standard definitions for skills required to perform supply chain processes.

After presenting the primary flows on which the SCM relies and a model that describes the processes and not the organization function that performs it, it seems imperative to dive even further into the manufacturing supply chain configuration.

The rise of several problems in SCM practice within manufacturing systems led to the appearance of three different supply chain types.

The "bullwhip effect", lack of alliances with suppliers, and the fact that companies didn't consider distribution an essential factor led to Lean Supply Chains' appearance (Wang et al., 2004). With the development of mass customization, the need for rapid response and constant change of customer requirements impelled the agile supply chain paradigm (Christopher and Towill, 2001).

Naylor et al. (1999) presented the term "leagility" to describe a hybrid solution that may be required in some cases. The hybrid solution is characterized by the "assemble to order", postponing the product differentiation until the last minute. Those different supply chains are compiled in the Table below (Table 2.3).

Table 2.3: Comparison of lean, hybrid and agile supply chains, adapted from (Wang et al., 2004)

Category	**Lean Supply Chain**	**Hybrid Supply Chain**	**Agile Supply Chain**
Purpose	Focuses on cost reduction, flexibility and incremental improvements for already available products. Employs a continuous improvement process to focus on the elimination of was or non-value added activities across the chain	Interfaces with the market to understand customer requirements, maintaining future adaptability. Tries to achieve mass customization by postponing product differentiation until final assembly and adding innovative components to the existing products	Understands customer requirements by interfacing with the market and being adaptable to future changes. Aims to produce in any volume and deliver into a wide variety of market niches simultaneously. Provides customized products at short lead times (responsiveness) by reducing cost of variety
Approach to choosing suppliers	Supplier attributes involve low cost and high quality	Supplier attributes involve low cost and high quality, along with the capability for speed and flexibility, as when required	Supplier attributes involve speed, flexibility and quality
Inventory Strategy	Generates high turns and minimizes inventory throughout the chain	Postpone product differentiation till as late as possible. Minimize functional components inventory	Deploys significant stocks of parts tide over unpredictable market requirements
Lead Time Focus	Shorten lead-time as long as it does not increase cost	Is similar to lean supply chain at component level (shorten lead-time but not at the expense of cost). At product level, to accommodate customer requirements, it follows that of an agile supply chain	Invest aggressively in ways to reduce lead times
Manufacturing focus	Maintain high average utilization rate	It is a combination of lean and agile, where the beginning part is similar to lean and the later part is similar to agile	Deploy excess buffer capacity to ensure that raw material/components are available to manufacture the product according to market requirements
Product Design Strategy	Maximize performance and minimize cost	Components follow the lean concept (cost minimization) at the beginning. Modular design helps in product differentiation towards the latter stages	Use modular design in order to postpone product differentiation for as long as possible

Rudberg and Olhager (2003) presented that the logistics scholars still miss the connecting dot between SCM and operations management, making manufacturing a "black box". They also discuss the differences between the theory behind manufacturing networks and supply chain. The summary of the differences separating both is illustrated in Table 2.4 below.

Table 2.4: Key operations strategy issues: Manufacturing networks Vs Supply Chain, adapted from (Rudberg and Olhager, 2003)

	Manufacturing Network Theory (intra-firm focus)	**Supply Chain Theory (inter-firm theory)**
Facilities		
Size	Number of sites (Number of nodes)	Number of organizations (Number of links)
Location	Corporate decision within the network	Decision based on which collaborative partners to includi in the supply chain
Specialization/Focus	Vertical and/or horizontal	Mainly Vertical
Vertical Integration		
Direction	Both forward and backward, but mainly intra-firm perspective	Both forward and backward including inter-firm manufacturing
Extent	Narrow - Only intra-firm manufacturing	Wide-focus on coordinating inter-firm relationships
Balance	External interfaces with 1st tier supplier and 1st downstream customer	Collaborative interfaces between sets of supplier and customers

From the table's analysis, we can conclude that manufacturing network theory mainly focuses on the nodes and not on the transactions between them. On the other hand, supply chain theory concentrates on the links and not on the nodes. So for a manufacture global supply chain, analysis on both would be more beneficial, integrating the two research areas.

Cheng et al. (2019) presented a graph (2.4) that illustrates the relationship when studying both supply chains and manufacturing networks.

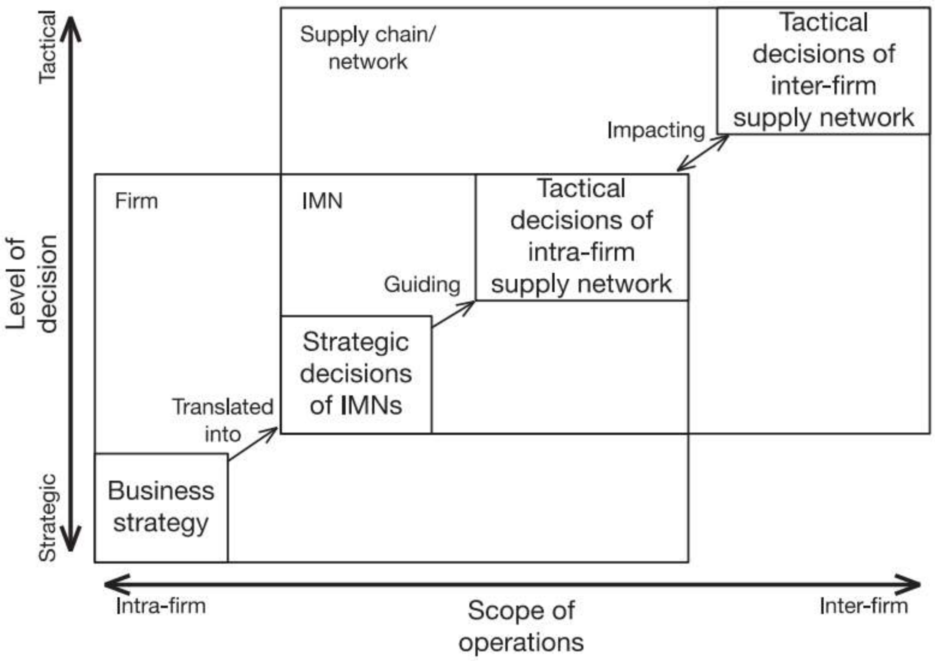


Figure 2.4: The relationship between business strategy, manufacturing networks and supply chain/network, from Cheng et al. (2019)

In fact, the business strategy focus on defining the long-term vision for the company's operations. It translates into strategic decisions related to the management of international manufacturing networks for the further development of plants at different locations and the network itself. Furthermore, these strategic decisions provide the guidelines for the tactical decisions (demand forecasting, inventory management, logistical structure and transportation mode) that impact both intra-firm and inter-firm operations.

As presented in Figure 2.4 the links are relevant in the study of the manufacturing networks. Therefore, researchers should consider the workflow between the plants and address the "intra-firm supply network" (Cheng et al., 2019).

Also, when researchers analyse supply network decisions, the focus should be on the flow between the plants and their external suppliers and consider node characteristics. It is crucial to study and discuss the relationship between business strategy, manufacturing networks, and supply chain/network interrelationship when facing newly emerging challenges and opportunities. Furthermore, any improvements companies make to manufacturing networks will impact their supply chains/networks. In addition, this information indicates that companies rethink their manufacturing networks and their supply networks with a comprehensive and holistic perspective; it also implies that the boundaries between manufacturing and supply networks are in a continuous state of flux, involving a complex reconfiguring of organizational boundaries and including the propagation of several forms of intra- and inter-firm collaboration (Coe et al., 2008)).

In conclusion, as the link between structure and capability becomes intertwined in highly networked production and supply systems, it is believed that manufacturing and supply networks cannot be managed separately. It is assumed that when one network changes, it is unlikely to happen in isolation and all the other networks are impacted too.

2.1.2 Global Manufacturing Networks

Undoubtedly, business is becoming more international than ever before. The exponential increase in foreign direct investment and international trade led to the globalisation of markets. Furthermore, it results in the adaptation and reorganisation of manufacturing systems (Cheng et al., 2015). To be competitive in this fast-paced environment, industrial companies felt pressured to scatter their plants all over the world (Canel and Khumawala, 2001).

The role of manufacturers has changed in the past, and it is continually evolving today. Miltenburg (2009) presents that manufacturing strategies are frequently seen as a response to two competitive pressures: pressure for globalisation and pressure for local responsiveness. In other words, industries changed from supplying locally and exporting to foreign markets to delivering internationally through local manufacturing. Colotla et al. (2003) presents that companies operating with a dispersed network of plants might benefit from each unit's capabilities and the advantages derived from the network.

It is essential to divide the network's benefits provided by the factory (node) and the network itself. Table 2.5 below presents a summary of the network outputs.

Table 2.5: Manufacturing Outputs provided by a Manufacturing Network, adapted from (Miltenburg, 2009)

Source	Manufacturing Output	Definition
Factory	Cost	Cost of material, labour, overhead, and other resources used to produce a product.
	Quality	Extent to which materials and activities conform to specifications and customer expectations, and how tight or difficult the specifications and expectations are.
	Delivery Time and Delivery Time Reliability	Time between order taking and delivery to the customer. How often are orders late, and when they are late how late are they?
	Performance	Product's features and the extent to which the features permit the product to do things that other product cannot do.
	Flexibility	Extent to which volumes of existing products can be increased or decreased to respond quickly to the needs of customers.
	Innovativeness	Ability to quickly introduce new products or make design changes to existing products.
Network	Accessibility	The ease of access a company has to present and future market segments, factors of production, and government agencies.
	Thriftiness	The ability of a company to achieve economies of scale and avoid duplication of activities.
	Mobility	The ease with which a company can transfer products, processes, and personnel between facilities, move facilities to new locations, and change production volumes.
	Learning	The ability of a company to learn about cultures and needs of customers, workforces, and governments, as well as process technology, product technology, and management systems, and the ease with which this knowledge is shared.

Miltenburg (2009) also explored network levers to emphasize where managers need to put their efforts to improve an existing network. Table 2.6 illustrates those levers.

Table 2.6: Network Levers: eight areas that constitute a manufacturing network , adapted from (Miltenburg, 2009)

Networking Lever	**Definition**
Facility Characteristics	Types of facilities in a network and their characteristics such as size, focus, and capabilities.
Geographic Dispersion	Where value system activities are dispersed around the world.
Vertical Integration	The extent to which a network contains facilities engaged in upstream activities involving sources of supply and downstream activities involving customers.
Organisation Structure	How facilities, departments, and personnel are organised in the network.
Coordination Mechanisms	The managerial systems and computer systems that organise data, make information available, and plan, monitor, and control activities.
Knowledge Transfer Mechanisms	The systems that transfer product knowledge and process knowledge between facilities and departments in a network.
Response Mechanisms	The systems and procedures that recognise, analyse, and act on threats and opportunities arising anywhere in a network.
Capability Building Mechanisms	The systems and procedures that create, sustain, and improve capabilities in areas such as design, production, and service.

Schmenner (1979) explored the strategies for global manufacturing networks, defining five key strategies:

1. **Product Plant Strategy:** Each production unit focuses on manufacture a comprised number of products. It decreases the complexity and takes advantage of the expertise in a particular set of areas;
2. **Market Area Plant Strategy:** Responsible for serving a particular geographical area. It enables a better service level to market requirements but requires more coordination on the corporate level;
3. **Product-Market Plant Strategy:** Combines elements of the two strategies discussed above. The decision-making process in size and sequencing is crucial to ensure better implementation of this strategy;

4. **Process Plant Strategy:** The plants are divided by processes. The manufacturing is divided into stages. While it decreases complexity on the plant level, it is vital to guarantee the network's coordination;
5. **General Purpose Strategy:** Adapts to constant change. It is expected a centralised control and the coordination of both work and workers within the factory.

Kulkarni et al. (2009) studied the differences in terms of service level and response to uncertainty between two strategies: Product Plant Strategy and Process Plant strategy and conclude that a process plant strategy will respond better to uncertainty and assure higher service level.

Cheng et al. (2016) defined that the first step for managers, when pursuing interplant's collaboration and supply chain partners, is to focus on internal integration. It needs to be the basis for inter-plant coordination and external integration. To get full benefits, it is necessary to perform a correct external integration. Otherwise, the improvements in the operating performance will no be as good as they can be. Furthermore, the inter-plant coordination catalyses external integration and influences customer or supplier integration and further improves the network of plants' operational performance.

Besides, the control over the manufacturing network should not be left only to managers, and different people at different organisation's levels should not make plant and network strategies and decisions (Colotla et al., 2003).

In fact, as proposed by Cheng et al. (2011), specific people at the company's headquarters need to ensure coordination in the network nodes and flows. They add that, on plant level, the focus should be on the design of processes and flows. On the network level, the plants' portfolio should be balanced, allowing the manufacturing network's capabilities to be enhanced in response to external and internal competitiveness (De Meyer and Vereecke, 2009).

2.2 Supply Chain Risk Management

Several researchers provided different explanations for Supply Chain Risk Management (SCRM). To have a coherent definition through this research project, it will be used Tang's: "The management of supply chain risks through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity." (Tang, 2006).

2.2.1 Supply Chain Risks

Several conceptualisations of risk exist in the literature. Harland et al. (2003) defined risk as to the probability of danger, damage, loss or any other undesired consequences. Mitchell (1995), suggests risk contains different types of losses and the risk of any particular kind of failure (loss) is the combination of the probability $(P(Loss))$ and the impact to the interested $(I(Loss))$. Therefore, for an event e: $Risk_e = P(Loss_e) \times I(Loss_e)$.

Manuj and Mentzer (2008a) described two components of risk:

- Potential losses (if the risk occurs, what losses will result and what is the significance of the consequences of the failures);
- Likelihood of those losses (the probability of the occurrence of an event that conducts to the completion of the risk

Before proceeding to the definition of methodologies to identify and mitigate risks, it is crucial to understand the concepts of risk linked with the supply chain.

Ivanov (2018) and Ivanov and Sokolov (2010) defined four critical concepts linked to risk:

- **Uncertainty:** General property of any system of a reasonable complexity degree. It can be reduced or amplified.
- **Risks:** Result from uncertainty. They can be identified, analysed, controlled and regulated.
- **Disturbance:** Disturbance (perturbation impact) is a consequence of the risk. It can happen on purpose or non-purposedly. It may disrupt the supply chain. Can be prevented and eliminated employing redundancy and flexibility reserves.
- **Disruption:** Disruption or operational deviations are the results of disturbances. It may affect strategies, processes and operations. In the case of disruptions, the supply chain needs to adapt to eliminate the effects.

Supply chain risk has also been defined as any risk to the information, material, and product flow from original suppliers to the delivery of the final product (Jüttner et al., 2003).

Manuj and Mentzer (2008b) proposed a high-level view of the supply chain and its relationship with risks.

Figure 2.5: Supply Chain High-Level View and Types of Supply Chain Risks, from Manuj and Mentzer (2008b)

Peck (2005) presented that sources and drivers of supply chain risk operate at several different levels. These are intricately connected as elements of a system and are described within four levels of analysis:

- **Level 1:** Value Stream/product or process
- **Level 2:** Assets and infrastructures dependencies;
- **Level 3:** Organisations and inter-organisational networks;
- **Level 4:** The environment.

Each level reveals considerably different perspectives, but together these levels comprise elements of a supply chain and the system within which they are embedded (Peck, 2005).

Faisal and Banwet (2006) has also suggested that risk sources are the environmental, organisational or supply chain-related variables that cannot be predicted with confidence and impact the supply chain outcome variables.

Goran (2002) presented supply chain risk as a complex phenomenon that can be segmented into sources and types of risks. Manuj and Mentzer (2008b) suggest that the sources of risk can be atomistic or holistic:

- **Atomistic:** a limited segment of the supply chain is required in order to assess risk. Proper for low-value, non-complex, and generally available components and materials.
- **Holistic:** an overall analysis of the supply chain is needed to assess risk. Suitable for high-value, complex and rare or unique components or materials.

Likewise, risks in the supply chain can be characterised as quantitative or qualitative.

- **Quantitative:** overstocking, inadequate availability of components and materials, stock-outs.
- **Qualitative:** reliability, lack of accuracy, and precision of the components and materials.

Recent literature has introduced different classifications for supply chain risks. Below, Table 2.7, summarise those classifications.

Table 2.7: Risks Types in the Literature

Authors	Risk Types
Harland et al. (2003)	Strategic, operations, supply, customer, asset impairment, competitive, reputation, financial, fiscal, regulatory and legal risks
Jüttner et al. (2003)	Environmental Risk; Network-related Risk; Organisational Risk
Chopra and Sodhi (2004)	Disruptions, delays, systems, forecast, intellectual property, procurement, receivables, inventory and capacity risks
Cristopher and Rutherford (2004)	**External to the network:** environmental risk; **External to the firm but internal to the supply chain network:** demand and supply risks; **Internal to the firm:** process and control risks
Tang (2006)	**Operational Risks:** uncertain customer demand, uncertain supply and uncertain cost; **Disruption risks:** earthquakes, floods, hurricanes, terrorist attacks, economics crises
Trkman and Mccormack (2009)	**Endogenous risks:** market and technology turbulence; **Exogenous risks:** discrete events (terrorist attacks, contagious diseases) and continuous risks (inflation rate, consumer price index changes)
Olson and Wu (2010)	**Internal Risks:** available capacity, internal operation, information system risks; **External risks:** nature, political system, competitor and market risks
Ravindran et al. (2010)	**Value-at-Risk (VaR):** labour strike, terrorist attack, natural disaster; **Miss-the-Target (MtT):** late delivery, missing quality requirements
Tang and Musa (2011)	Material flow, financial flow and information flow risks
Samvedi et al. (2013)	Supply, demand, process and environmental risks

Ho et al. (2015) classified the risks above in five major categories: macro, demand, manufacturing, supply and infrastructural.

Those risks can be framed into two categories with the significant effects they produce in the supply chain. On the one hand, we have the operational risks related to the bullwhip effect, which are recurrent. On the other hand, the disruption risks linked to the ripple effect, which are exceptional.

In the last years, many advances were made in studying and mitigating the first type of risks (Chopra and Sodhi, 2004). Nowadays, the focus is on disruption risks, as they present a new challenge for companies due to the structural damages they cause (Ivanov, 2018).

Ivanov and Dolgui (2019) concluded that to deal with the ripple effect, supply chains need to be planned to be robust, stable and resilient enough to maintain their essential characteristics; guarantee execution; be able to adapt their behaviour to respond to disturbances; recovers for the planned performance.

To deal with the risks presented above, the supply chains need three characteristics: resilience, flexibility and robustness.

Ponomarov and Holcomb (2009) defined supply chain resilience as *"The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function."*.

Cristopher and Rutherford (2004) proposed four key characteristics of resilient supply chains:

- risk management central to supply chain strategy;
- a culture of risk and quality awareness;
- responsive and capable of sustained response to a sudden and significant shift in input;
- supply chain acceleration and deceleration.

Duclos et al. (2003) defined six components of supply chain flexibility based on their findings in the existing literature:

- **Operations System Flexibility:** ability to develop operations to respond to emerging customer trends at each node of the supply chain;
- **Market Flexibility:** ability to perform mass customisation and forge close relationships with customers, including adapting current products and creating new;
- **Logistics Flexibility:** ability to cost-effectively procure and fulfil products as the sources of supply and customers vary;
- **Supply Flexibility:** ability to reconfigure the supply chain, adjusting the supply to customer demand;
- **Organisational Flexibility:** ability to arrange workforce skills to the necessities of the supply chain to meet customer service requirements;

- **Information System Flexibility:** ability to align the information system architectures and systems with the changing information needs of the organisation to follow varying customer demand.

Vlajic et al. (2012) defined supply chain robustness as "the degree to which a supply chain shows an acceptable performance in (each of) its Key Performance Indicators (KPIs) during and after an unexpected event that caused disturbances in one or more logistics processes".

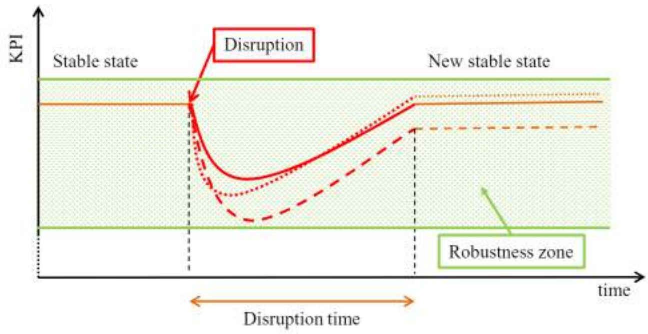


Figure 2.6: Supply Chain's Robustness, from Monostori (2016)

There are some KPIs for quantifying supply chain risk that can be categorised into operational and disruption risks regarding bullwhip and ripple effects, respectively.

For the operational risks, Towill and Disney (2002) proposed the use of inventory variance ratio.

$$InvVarR = \frac{\sigma^2_{\text{inventory}} / \mu_{\text{inventory}}}{\sigma^2_{\text{demand}} / \mu_{\text{demand}}} \tag{2.1}$$

The order rate variance ratio operates similarly.

$$OrdVarR = \frac{\sigma^2_{\text{order}} / \mu_{\text{order}}}{\sigma^2_{\text{demand}} / \mu_{\text{demand}}} \tag{2.2}$$

where variances (σ) are calculated according to 2.3

$$\sigma_{\text{demand}}^2 = \frac{\sum\left(x_{\text{demand}} - \mu_{\text{demand}}\right)^2}{(n-1)} ; \sigma_{\text{orders}}^2 = \frac{\sum\left(x_{\text{orders}} - \mu_{\text{orders}}\right)^2}{(n-1)} \tag{2.3}$$

where x is the demand or orders in a period, σ is the demand standard deviation or orders, and n is the number of periods.

Ivanov (2018) suggested the use of ripple effect performance impact (PI).

$$PI = \frac{\text{Sales}_{\text{plan}}}{\text{Sales}_{\text{disruption}}} \tag{2.4}$$

It represents the correlation between the KPI planned in a disruption-free node and the real KPI in the case of disruption. Ideally, PI = 1. If P < 1, the supply chain have operated in a non-optimal-manner. If P > 1, the disruption diminishes supply chain performance.

Ivanov et al. (2019) suggests that additional KPIs for disruption risks can be applied for specific analysis, such as Value-at-Risk and Conditional Value-at-Risk.

2.2.2 Methodologies for Supply Chain Risk Management

Zsidisin and Ritchie (2009) defend that efficient risk management can provide value to many stakeholders of a firm. The compliance with appropriate methods can help to reduce or avoid crises. Risk management consists of identifying operational risks and promoting mitigation plans for maintaining operational performance.

Supply chain risk management should be looked upon an operational point of view, but it is also beneficial to consider supply chain risk management from a strategic management perspective.

Rice and Caniato (2003) report that many companies have developed several risk assessment programmes that are designed to:

1. Identify different types of risks;
2. Estimate the likelihood of each type of major disruption occurring;

3. Assess potential loss due to a major disruption;
4. Identify strategies to reduce risk.

Since the beginning of the XXI century, companies are increasingly recognising the value of risk assessment programs. They are using different techniques from formal quantitative models to informal qualitative plans to assess supply chain risks.

Some of the enablers for better supply chain risk management include: Lean, Six Sigma and Agile philosophies and Radio Frequency Identification (RFID). Those methodologies grant better visibility, velocity and more effective process control (Dani, 2009).

Ho et al. (2015) focused on a literature review to define which methods were used the most. From their review, it is possible to understand that the quantitative methods have a more significant impact than the qualitative ones. The qualitative methods are mostly used for risk identification and categorisation, risk management philosophy, and to construct SCRM ideas. Furthermore, in scientific literature, quantitative methods have further application. The more relevant ones are:

- **Analytical Methods**
  - **Mathematical Programming:** Unconstrained and constrained mathematical programming; Linear programming; Nonlinear programming; Integer nonlinear programming; Stochastic linear programming; Stochastic integer linear programming; Max-mix linear programming; Mixed integer linear programming; Multi-objective mixed integer linear programming;
  - Newsvendor Model;
  - Simulation;
  - Fuzzy Set Theory;
  - Analytic Hierarchy Process;
  - Game Theory;
- **Empirical Methods**
  - Multiple Regression Model;
  - Analytic hierarchy process;
  - Survey;
  - Cluster analysis;
  - Factor analysis.

A comprehensive variety of qualitative and quantitative-based conceptual frameworks have been proposed to deal with more than one process of SCRM (Ho et al., 2015). The majority of these studies focused on only two SCRM processes, such as risk identification and assessment, risk identification and mitigation or risk assessment and mitigation.

Kern et al. (2012) observed that better risk identification supports the following risk assessment and this, consequently, leads to better risk mitigation.

Ho et al. (2015) suggests a significant correlation between these three SCRM processes, and that more attention should be given to three instead of two processes.

Bandaly et al. (2012) and Kern et al. (2012) developed a conceptual framework for the risk identification, assessment and mitigation processes. Their framework's five key components are:

- risk identification;
- risk assessment;
- risk consequences;
- risk management response;
- risk performance outcomes.

Tang (2006) summarised the strategic and tactical plans for managing supply chain risks, as illustrated in Table 2.8.

Table 2.8: Strategic and Tactical Plans for managing supply chain risks, from Tang (2006)

	Supply Management	**Demand Management**	**Product Management**	**Information Management**
Strategic Plans	Supply network design	Product rollovers and product pricing	Product variety	Supply chain visibility
Tactical Plans	Supplier selection, supplier order allocation and supply contracts	Shift demand across time, markets, and products	Postponement and process sequencing	Information sharing, vendor managed inventory, and collaborative planning, forecasting and replenishment

Supply chain risk strategies can be defined as being reactive or proactive. Being reactive is a default behaviour when a risk materialises.

In a proactive strategy, potential risks are identified at the supply chain design stage, their likelihood and impact are assessed, and they are classified in terms of importance. The focus of this exercise is to target the identified risks in order to avoid them. This may not be possible in all cases, and consequently, there is a need to develop and implement contingency plans to minimise the impact if and when the risk occurs (Zsidisin and Ritchie, 2009).

Although the method of proactively managing the risks looks to be fairly familiar to most of the risk management/mitigation strategies, it is not explicitly mentioned in the SCRM strategies.

One of the main conditions for a robust, proactive risk management process is to get unbiased estimates of the probability of the occurrence of any particular disruption and accurately measure the potential impact. To have an effective risk management process, it must obtain accurate estimates of any particular disruption probability. Reliable estimates are obtained by risk prediction techniques.

Data mining is a process that has the ability to use appropriate data to uncover roots of risk exposure that may otherwise remain hidden or overlooked before the risk occurs. Haimowitz and Keyes (2002) suggest that proactive data miners will understand the risk for enterprise improvement through competitive advantage or innovation in processes, services or products.

There are two dimensions of risks: frequency and severity. According to Haimowitz and Keyes (2002), data mining commonly refers to high frequency, low severity scenarios. It can help in making more frequent risks less severe and more severe risks less frequent.

The role of data mining is to analyse historical data, to improve prediction capability. Dani (2009) suggests these analytical approaches:

1. Estimation of the parameters of past performance: Means, Standard Deviations, Correlations, and Associations for hypothesis testing;
2. Classification: Segmentation, or Clustering of data units to facilitate modelling process;
3. Construction of a functional relationship: or model between responses and explanatory variables.

Data mining is essential at both strategic and operational levels. On the strategic level, its goal is to model and predict the critical event. On the other hand, it aims to gather and understand the relevant data to discover patterns to provide business intelligence on the operational level.

Linoff and Berry (2011) proposed some specific tools used:

- **Estimation:** Tools useful for exploratory data analysis. Useful in analysing the data to identify the most relevant sets of data to concentrate. Statistical tools as: Pareto Analysis, and graphical analysis;
- **Clustering/Segmentation:** Logically group observations based on their characteristics' similarity. Preceding the modelling phase: K-means and Distance matrices;
- **Classification/Discrimination:** The process of attributing observations to a predetermined number of classes. The groups' distance is measured concerning specific variable(s) required for prediction such as chi-squared automatic induction, regression analysis, discriminant analysis, and rule induction;
- **Prediction:** Formal mathematical models are built to predict the occurrence of the event. Techniques used are: Linear/nonlinear regression, Classification and Regression trees, Multiple adapted regression splines, artificial neural nets, genetic algorithms, time-series regression models and stochastic models;

Data mining tasks can be divided into two categories: descriptive or predictive data mining. The first focuses on obtaining insight into the data by uncovering patterns before predicting. On the other hand, the second involves using attributes to predict unknown future values of the dependent variables. It transforms data into actionable decisions.

Dani (2009) proposed a "predictive-proactive" SCRM methodology, as shown in figure 2.7.

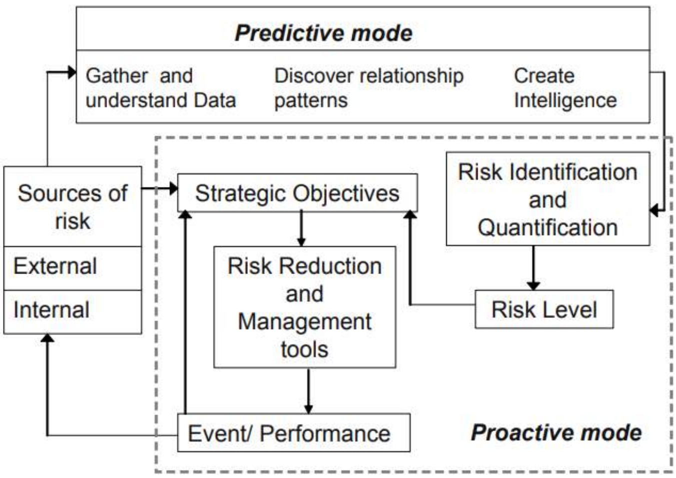


Figure 2.7: "Predictive-Proactive" SCRM framework (Dani, 2009)

2.3 Supply Chain Performance

Measuring performance can be one of the most complex tasks in an improvement project. System's qualitative analysis can be challenging to use significantly and may not provide the desired information. On the other hand, a quantitative analysis can be done if the system has already data. However, the numerical method used may not describe the system's behaviour effectively. Beamon (1999) describes that more than issues of context, scope issues can make it more arduous to develop the correct measurement method.

Beamon (1999) defends that a supply chain performance measurement system that only considers a single performance measure is commonly ineffective. Due to that fact, Beamon (1999) developed a new framework for performance measurement, involving the critical elements for the strategic goals: resources, output and flexibility. The performance measurement system must contain at least one individual measure from each of the three identified types. Furthermore, the individual measures chosen from each type must coincide with the organization's strategic goals. This measurement system can then allow the study of the interactions among the measures or ensure a minimum level of performance in different areas (Beamon, 1999).

In Table 2.9, the goals of the performance measure types are presented:

Table 2.9: Performance Measurement Types, from Beamon (1999)

Performance Measure Type	Goal	Purpose
Resources	High level of efficiency	Efficient resource management is critical to profitability
Output	High level of customer service	Without acceptable output, customers will turn to other supply chains
Flexibility	Ability to respond to a changing environment	In an uncertain environment, supply chains must be able to respond to change

Resources are often measured in terms of the minimum requirements or a composite efficiency measure, and directly related to the system's output and flexibility performance. Output performance measures must correspond to the organisation's strategic goals and correspond to the customers' goals and values since strategic goals generally address meeting customer requirements. Beamon (1999) defined the following examples of supply chain performance measures:

- **Resource**:
  - Total cost - Total cost of resources used.
  - Distribution costs - Total cost of distribution, including transportation and handling costs
  - Manufacturing cost - Total cost of manufacturing, including labor, maintenance, and re-work costs.
  - Inventory: Inventory Investment; Inventory Obsolescence; Work-In-Process; Finished Goods; - Costs associated with each type of inventories;
  - Return-On-Investment - The return on investment is generally given by the ratio of net profit to total assets.
- **Output**:
  - Sales - Total revenue.
  - Profit - Total revenue less expenses.
  - Fill rate - Proportion of orders filled immediately: Target fill rate achievement; Average item fill rate.
  - On-time deliveries - Measures item, order, or product delivery performance: Product lateness; Average lateness of orders; Average earliness of orders; Percent on-time deliveries;
  - Backorder/stockout. Measures item, order, or product availability performance: Stockout probability; Number of backorders ; Number of stockouts; Average backorder level;
  - Customer response time - Amount of time between an order and its corresponding delivery.
  - Manufacturing lead time - Total amount of time required to produce a particular item or batch.
  - Shipping errors - Number of incorrect shipments made.
  - Customer complaints - Number of customer complaints registered.

Flexibility, which is rarely used in supply chain analysis, can measure a system's ability to accommodate volume and schedule fluctuations from suppliers, manufacturers, and customers. The two most agreed upon dimensions for measuring the flexibility of any type are range and response (Gerwin (1993), Upton

(1994)). The range dimension measures the variety of available alternatives for the system adaptation to continue to operate. The response dimension measures the easiness with which the adaptation can be carried out in terms of the reaction time (or cost) needed to respond to the change that occurred. Thus, the range is related to the system effectiveness, and the response is related to the system efficiency.

In today's competitive age, it is proven that many companies have not succeeded in maximising their supply chain's potential because they have often failed to develop the performance measures and metrics needed to fully integrate their supply chain to maximise effectiveness and efficiency (Gunasekaran and Ngai, 2004). The following are pointed out as the main problems in performance measurement by Gunasekaran et al. (2005) and Gunasekaran and Kobu (2007):

- Having a large number of metrics, making it difficult to identify the critical ones;
- Incompleteness and inconsistencies in performance measurement and metrics;
- Failing to represent a set of financial and non-financial measures in a balanced framework;
- Failing to connect the strategy and the measurement;
- Being too much inward looking.

Mccormack et al. (2008) compare the traditional and innovative performance measurement, clearly putting forward the importance of long term value orientation, as given in Table .

Table 2.10: Comparison between Traditional and Innovative Performance Management Systems, from Mccormack et al. (2008)

Traditional Performance Management System	**Innovative Performance Management System**
Based on cost/efficiency	Based on value
Trade-off between performances	Compatibility of performances
Profit oriented	Client oriented
Short-term orientation	Long-term orientation
Individual metrics prevail	Team metrics prevail
Functional metrics prevail	Transversal metrics prevail
Comparison with the standard	Monitoring of improvement
Aimed at evaluation	Aimed at evaluation and involvement

Beamon (1999) presents that previous work in performance measurement has generally focused on:

- Developing new performance measures for specific applications;
- Benchmarking, as in Camp (1989);
- Categorizing existing performance measures, as in Neely et al. (1995).

Beamon's research discusses the importance of a supply chain system ability to respond effectively to a changing environment and to achieve simultaneously a high level of efficiency, a high level of customer service.

With markets getting more competitive than ever, companies feel pressured to achieve higher service levels. Jeffery et al. (2008) defend that supply chain management empowers organisations to reduce costs and improve the customer service level. However, they also refer that additional pressures in other areas such as product variety make it more challenging to achieve the desired service level.

Even though managers know that the service level is crucial to companies' competitive advantage, it is still complicated to quantify it using a scientific approach (Ettl et al., 2000).

The selection of a range of appropriate performance measures for a particular company ought to be made in light of its strategic intentions, which will have been formed to suit the competitive environment in which it operates and the nature of business. For example, suppose technical leadership and product innovation are the critical sources of a manufacturing company's competitive advantage. In that case, it should measure its performance in this area relative to its competitors. Nevertheless, suppose a service company decides to differentiate itself in the marketplace based on the quality of service, then, amongst other things. In that case, it should be monitoring and controlling the desired level of quality (Ahmad and Dhafr, 2002).

Performance areas must be operationalised, that is, made measurable, in the form of performance indicators for the company to monitor performance and goal realisation.

Corbett (1998) considered that the KPIs within the manufacturing strategy are cost, quality, flexibility, delivery, and inventory. Ahmad and Benson introduced the assessment and analysis of manufacturing performance covering quality, delivery reliability, cost and delivery lead time.

Ahmad and Dhafr (2002) highlighted that measured KPIs are generally split into six sections:

- Safety and Environment;
- Flexibility;
- Innovation;
- Performance;

- Quality;
- Dependability.

Furthermore, they focus on the KPI of dependability. This KPI consist of:

- Customer Complaints;
- On-Time-In-Full Delivery to Customers;
- On-Time-In-Full Delivery from Suppliers;
- Overall Equipment Effectiveness.

Focusing on the customer service level:

- **On-Time-In-Full Delivery to Customers**;

The purpose of this KPI is to measure the delivery of the product on time and in full with no defects in the product, packaging, transport arrangement or supporting documentation.

APICS (2017) defines it as "A delivery scoring system in which a target delivery goal (usually expressed as a percentage) is set, and the deliverer tries to meet that delivery goal fully and by the delivery date.

It will measure the ability to adhere to the first agreed demand date for each order and whether there were any problems with the materials shipped. Ahmad and Benson (1999) add that supporting such a measure needs a rigorous recording system either by the plant or the distribution company if these aspects are out-sourced. The goal in this KPI will be to achieve a value >99%.

2.4 Reflection Upon Literature Review's Findings

The literature review previously presented resulted from the analysis of several books, articles and scientific publications. From there, it was identified as necessary for the manufacturing firms to build up robust and efficient supply chains and networks. That will allow the companies to be at the forefront of their sector and have a leading position and competitive advantage. More than ever, companies need to create solid and trustworthy cooperation networks with suppliers and customer to reduce non-value operations.

The main flows and processes in the supply chain were studied to create a stable basis of knowledge for the analysis' phase in this dissertation. More than that, it was reviewed the global manufacturing networks due to this topic relevance for the case study created and the configuration found in the company where this project took place.

As a solid background was created, it was required to perform a more in-depth literature review on more precise topics.

On the one hand, it was crucial to identify the most common supply chain risks analysed in the literature and their relationship with the key supply chain's processes, as well as the critical characteristics that create a resilient, flexible and robust supply chain.

On the other hand, from the supply chain risk management perspective in global supply chains, it is fundamental for the companies to create their strategies around three critical areas: risk identification, risk assessment and risk mitigation. Those allow a quicker and more effective response, both proactively and reactively, to subtle disruptions that are becoming more frequent.

Furthermore, the main proactive and reactive strategies and the qualitative and quantitative methodologies for risk identification and assessment were also highlighted, focusing on data mining.

This literature review is the starting point and the backbone content of this research project to create knowledge for achieving all the goals proposed in chapter 1, specifically the improvement of the reporting process in the supply chain risks and delivery failures, and, in consequence, for the customer service level improvement.

Due to that, it ends with the study of the performance management systems allowing the definition of the more reliable approach to protect and improve the customer service level, following the guidelines defined by Schmitt (2011): *"The best protection can be achieved through a balance of proactive and reactive measures. Proactive measures (inventory reserves) cover the front-end of a disruption and provide immediate protection until reactive measures can be implemented. Reactive measures (back-up capabilities) protect the supply chain until the disruptions end and prevent long (or permanent) interruptions to customer service."*

Moreover, from the literature reviewed, it was possible to find a gap. The majority of the studies focus on the analysis and improvement phases. On the other hand, few research projects (like Sehgal et al. (2006)) focus on identifying and analysing the supply chain risks and reengineering processes and teams within the company to allow a more accessible, data-driven and informed risk mitigation phase.

3. Company Presentation

This chapter intends to provide an overview of the company where this research project took place. Initially, there is a summary describing the group, Sonae Indústria, emphasizing the expansion and restructuring processes. It is also presented the joint-venture between the group and Inversiones Arauco Internacional, Sonae Arauco, focusing on the business areas, brands and products. Finally, the supply chain of Sonae Arauco is defined, highlighting the supply chain department, SWE Region's plants, DCs and the flows between them. It also focus on the processes that will be the main part of this research project: the delay reasons report method.

3.1 Sonae Indústria

Sonae (Sociedade Nacional de Estratificados) was founded in 18th August 1959. Back then the industrial activity started with the production of high-pressure decorative laminates, branded as Laminite. Sonae Indústria diversified the product offer with particleboards and melamine surfaced boards and invested in additional capacity throughout the '70s and '80s. In the '90s and at the beginning of the '00s, Sonae Indústria has undergone an expansion process in Iberia, Canada, Germany, France, South Africa and Brazil with plants and commercial activity in those countries. At this time, Sonae Indústria adds Movelpartes, components for the furniture industry, to the portfolio, assuming a position of a company who manages different businesses for products to be used in furniture, interior design and construction industries. At the beginning of the '10 decade, Sonae Indústria has undergone a restructuring process due to the economic context, discontinuing, selling and closing several industries, concentrating the production in the most efficient plants. It is also the time when Innovus brand is launched, offering new decorative solutions. In 2016, a strategic partnership was completed with Inversiones Arauco Internacional involving the existing European and South African wood-based panels plants and operations, leaving out Tafisa Canada (the largest particleboard and melamine production plant in North America) and the laminates and components businesses. In 2018 Sonae Industria launched a new brand for its laminates and compacts business, SURFORMA.

3.2 Sonae Arauco

Created in 2017 as a joint-venture between Sonae Indústria and Inversiones Arauco Internacional, Sonae Arauco is one of the world's biggest player in the wood-based panel industry.

Inversiones Arauco Internacional, a Chilean company, founded in 1970, looking for producing and managing renewable forestry resources, now spread to over 75 countries. It is known as an international benchmark in terms of industrial plants, production standards, efficiency and forestry, present throughout the entire forestry value chain, planting, managing and harvesting.

The strategic alliance between these two important players in the wood sector consist of all the wood-based panelling, impregnated paper and chemical plants in Europe and South-Africa, specifically, 23 commercial and industrial units, in 9 countries and 2 continents, with around 3000 employees around the world.

Sonae Arauco's products are divided into two brands: Innovus for decorative products (created in 2011 with a new collection in 2019) and Core and Technical for raw boards (launched in 2020).

(a) Particleboard (b) Medium Density Fiberboard (c) Oriented Strand Board

Figure 3.1: Core and Technical Products - Raw Boards

The raw boards are Medium Density Fiberboard (MDF), Particleboard (PB) and Oriented Strand Board (OSB). For decorative products, with a vast range of colours and patterns, are Melamine Faced Chipboard (MFC) and Melamine Faced MDF (MFMDF), respectively PB and MDF coated with a melamine sheet, conferring to the raw board different finishings and presents an MDF coloured, which consists on an MDF raw board coloured. Sonae Arauco has more than 200 decors and 15 different finishes in these panels. In addition to these panels, the company also produces Wood Veneer (WV) consisting of a raw board coated with a thin wood sheet.

(a) Melamine Faced Chipboard (b) Melamine Faced MDF (c) MDF Coloured

Figure 3.2: Innovus Products - Melamine Faced Boards and MDF Coloured

3.3 Sonae Arauco's Supply Chain

As presented above Sonae Arauco is a multinational company with commercial units, production units and DCs in different countries. Those are internally divided into three regions: SWE, North-East (NEE) and South Africa (SAF). The main actors in the company's supply chain are suppliers, plants, distribution centres and customers. All of them work in cooperation as they are responsible for the production of different products, distribution of different Stock Keeping Units (SKUs) for a different customer segment and work in separate for each region. Even if a product is not produced in the SWE factories, if the client is from this geographical area, it will be fulfilled from an SWE unit. For the transportation, Sonae Arauco works in partnership with transport companies.

The focus of this research will be the SWE Region, with four production units, two in Portugal, Mangualde and Oliveira do Hospital and two in Spain, Linares and Valladolid and two DCs, one in Portugal, Souselas and one in Spain, Madrid.

The four SWE region plants are responsible for the production and direct fulfilment of customers. The relevance, purpose and amount of m^3 purchased by the customer defines the segment:

- **Trade** - Dealers of Sonae Arauco's products. They are the interface between our products and small and medium-sized enterprises on the furniture and construction business. They are subdivided into Innovus Premium Dealer, Innovus Standard Dealer and Standard Dealer due to the quantities purchased and relevance in the market. Sonae Arauco has more than ten trade customers in Portugal and more than twenty-five in Spain.
- **Industry** - Big companies on the furniture, doors and construction markets that buy Sonae Arauco's products directly due to the quantities of m^3 purchased and regularity of orders. They can be

segmented into Global Key Accounts, Key Accounts and Standard Accounts. It involves more than one hundred industry customers distributed between Portugal and Spain.

These manufacturing units are responsible for the production of different products so interaction between plants is possible and occurs regularly due to the product's allocation:

- **Mangualde** - Responsible for the production of MDF and Wood Veneer faced boards;
- **Oliveira do Hospital** - Some SKUs of PB, MFC and MFMDF;
- **Linares** - Other SKUs of PB, MFC and MFMDF;
- **Valladolid** - Manufacture MDF, MFC and MFMDF.

In 2019 Sonae Arauco strategically developed the two DCs, previously mentioned, one in Madrid and other in Souselas to improve the customer service level for the Trade market. DC Madrid works with SKUs with more sales in Spain. On the other hand, the Souselas one distributes boards in Portugal based on the 7-day delivery boards in the catalogue.

The number of boards manufactured and distributed is different from plant to plant, not only in terms of products but also in quantity. In figure 3.3 below, it is possible to see the quantities produced per product by each plant in six months from September 2019 to February 2020. This period was selected due to Covid-19 constraints on getting correct data from March 2020 until September 2020, and Souselas DC only started working on September 2019.

Figure 3.3 illustrates the variety of products distributed in the different plants and each factory's capacity and shows the imbalance between the plants and distribution centres as there are various differences between the manufacturing units in both size and resources.

It was chosen a six-month period because there is a slight variation between the quantities distributed per month due to the contracts of m3 that need to be produced by Sonae Arauco every month. The company uses a system of quotas to control the production and needs to ensure specific amounts of some products every month.

The following section will explain how plants have interdependencies between them and how the process-plant and product-plant strategies, currently implemented, affect the production and impact the distribution.

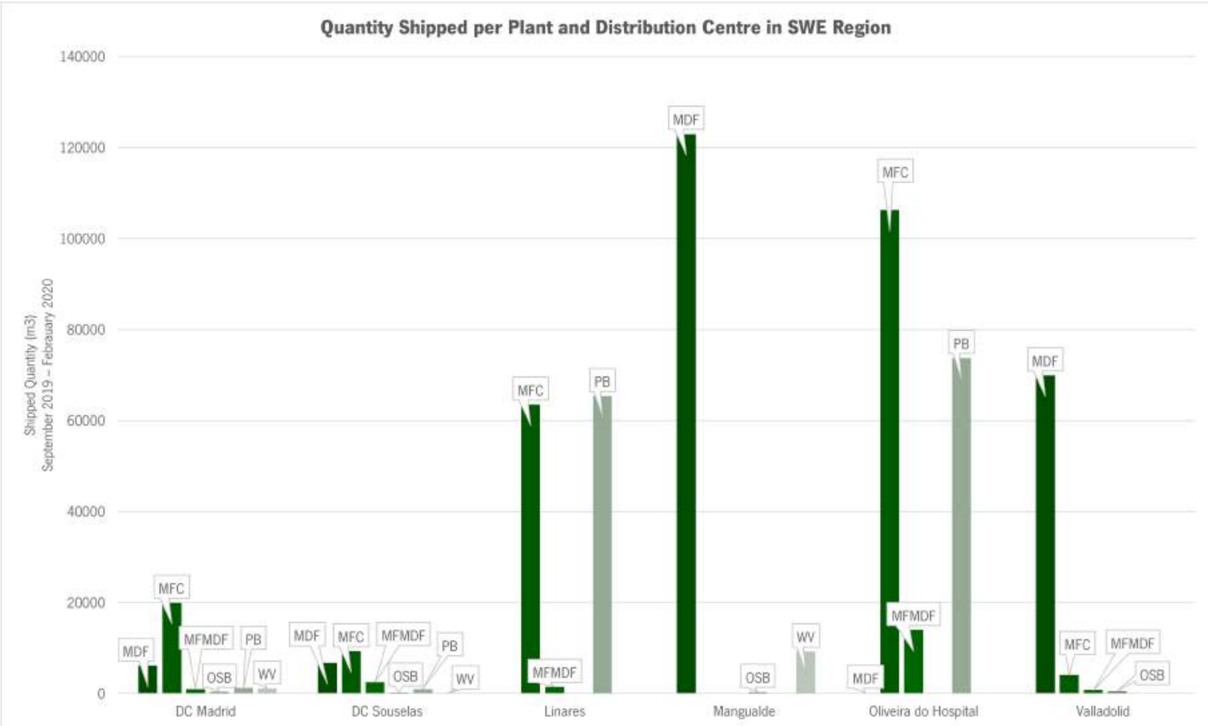


Figure 3.3: Number of m^3 shipped per plant and distribution centre per six months

3.4 Definition of Sonae Arauco's Processes

This section presents some important vectors in the analysis made throughout this research project. The supply chain department structure, supply chain flows, processes and operations are now defined as they are the basis for the study presented in this dissertation. The focus is drawn to the planning method, and the delay reasons report.

3.4.1 Flows Mapping Between Logistics Platforms

Before proceeding for the full analysis of the delay reasons report, it is essential to understand the interdependence between factories and distribution centres.

As presented in the section above the flow of goods is based on the product's plant allocation, customer segment and geographical area. Figure 3.4 illustrates an overview of the different production plants, DCs and all the distribution network in the SWE Region.

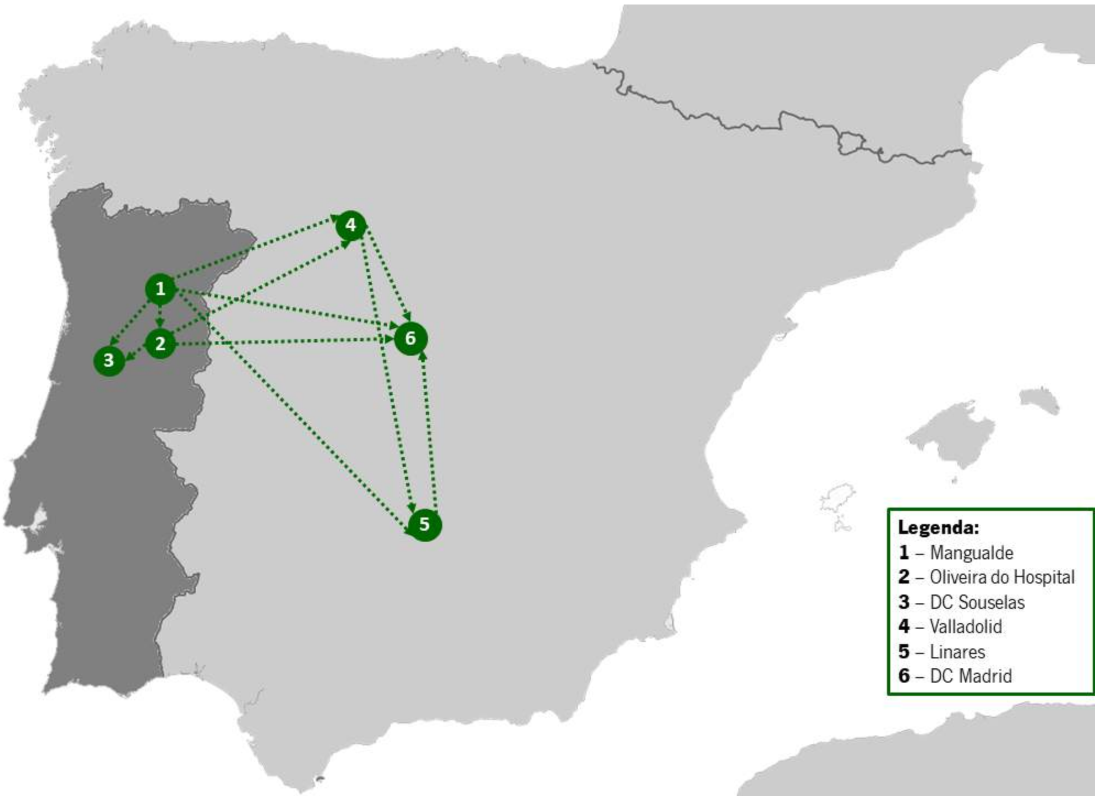


Figure 3.4: Sonae Arauco's Plants and Distribution Centres

Analysing the flows presented above together with the product's plant allocation, it comes clear the necessity of interrelationship needed in order to fulfil the customer. Mangualde plant (1) works closely with Oliveira do Hospital (2), Valladolid (4) and Linares (5) and both DCs. Valladolid (4) receives material from Oliveira do Hospital (2) and Linares (5). The DC Souselas (3) only operates with Mangualde (1), and Oliveira do Hospital (2). Differently operates the DC Madrid (6), which receives boards from all the plants. All plants fulfil the customer (Trade or Industry) directly, only the two DCs serve uniquely to Trade based on the rules presented above. Figure 3.5 summarise the flows between plants, DCs and customers.

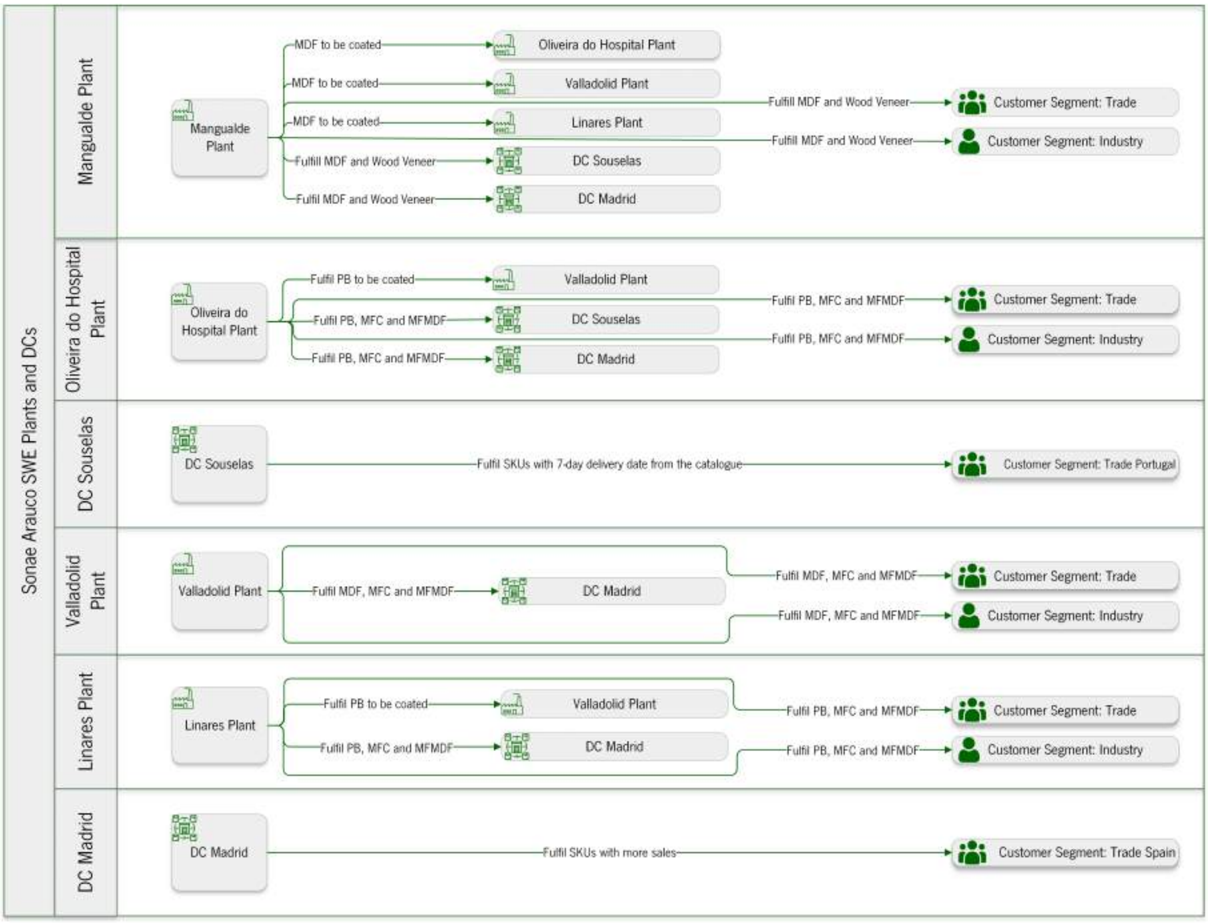


Figure 3.5: Sonae Arauco's SWE Plants Interrelationship

3.4.2 Supply Chain Department and Planning Method

Sonae Arauco SWE Supply Chain department is responsible for all the planning, warehouse, distribution and transports. It is divided into two teams: planning team and the transports team.

- **Planning team** - Responsible for planning and scheduling. It is divided into two teams, a central one in Maia and an in-factory team in the plants. Distributed into master planners (Maia) and schedulers (in-plant);
- **Transports teams** - Responsible for route planning, transports assignment and the planning of loads. Also divided into a central team in Maia and an in-factory team in the plants. Transport planners (Maia) and warehouse managers (in-plant).

In Figure 3.6 is presented a more detailed view of the organisation chart for the SWE Supply Chain Department.

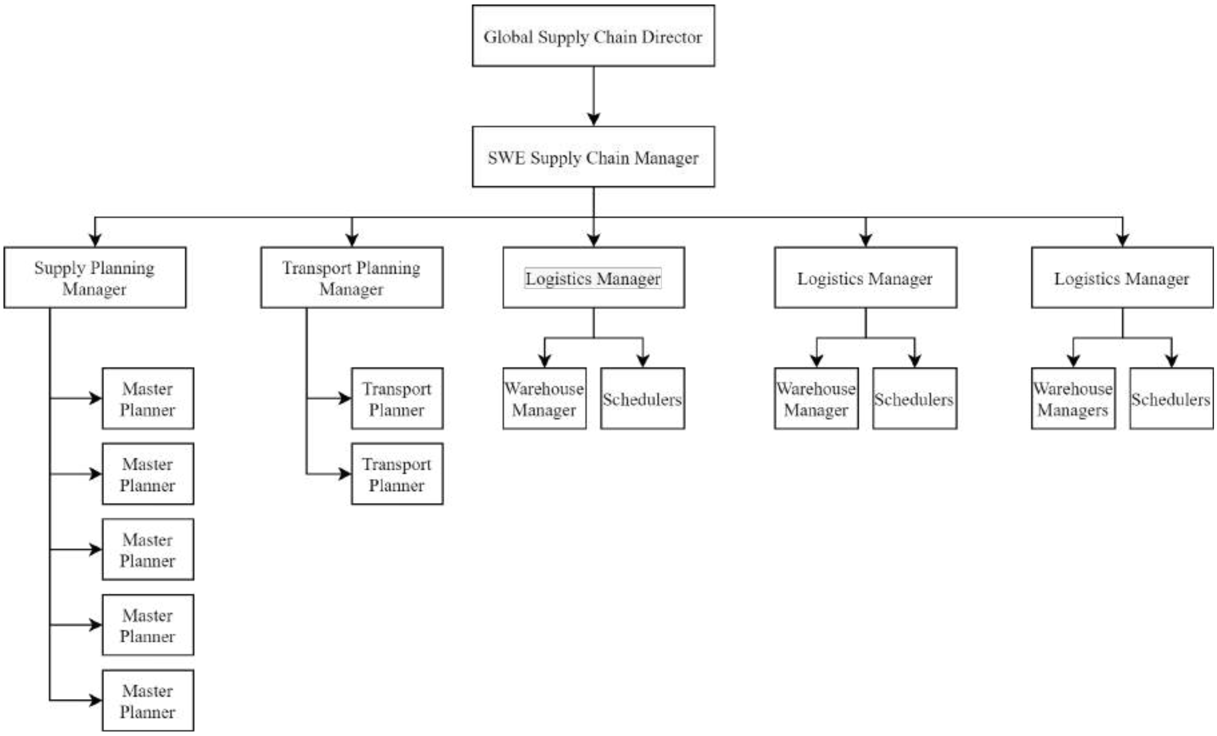


Figure 3.6: Sonae Arauco's SWE Supply Chain Department

The teams are coordinated by the SWE Supply Chain Manager. Each plant has a supervisor for the schedulers and warehouse managers that are the Logistics Managers, and the central team have the Supply Planning Manager and the Transport Manager both are responsible for each area planners.

As the primary goal of this research project is to find which root causes influence the poor service level of the SWE Region the most and how the reporting process of those causes can be improved it is essential to do an end-to-end analysis of the supply chain, presenting the planning method used by Sonae Arauco (figure 3.7) and the relationships between all the actors.

From the figure above, it is possible to comprehend that the planning method is segmented in three zones:

- **Frozen Period** - In this period, client requests cannot be changed or cancelled. Only the planning team can make changes if there is some urgent matter.
- **Slushy Zone** - In this zone, it is possible to change customer orders. Quantity changes are possible until 10% more, and for changes in the confirmation date, a replanning is required.
- **Liquid Zone** - In this zone, it is possible to change the customer requests. Only when there are changes in quantity or confirmation date, a replanning is required. Any other type of modifications is possible.

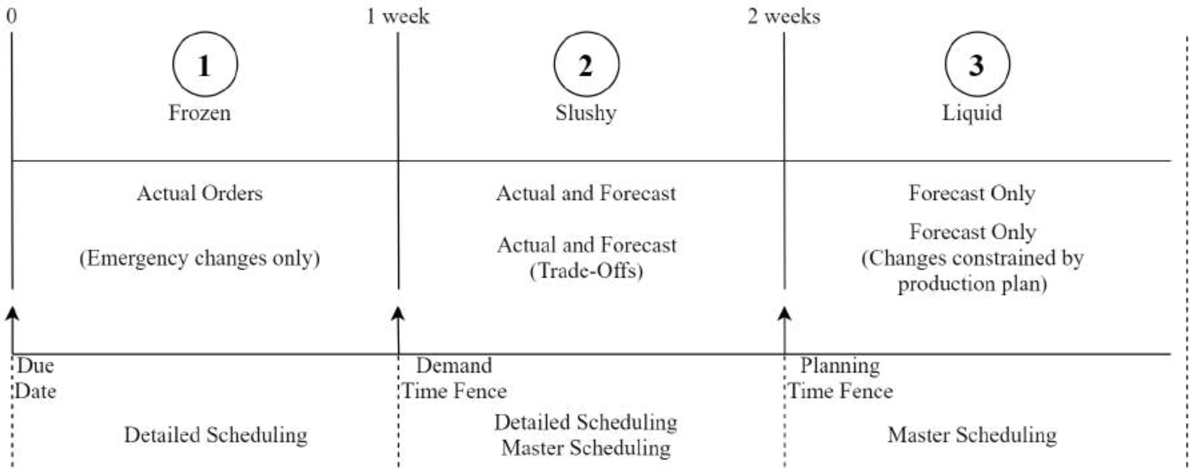


Figure 3.7: Sonae Arauco's SWE Planning Method

It is also understandable from the graph that master planners and schedulers have a different role in this planning method:

- **Master Planners** - Accountable for the distribution of the production plan, stock management, confirmation and planning of customer requests, alignment between planning and Sales & Operations Planning. They are the contact between the sales team and the production team and responsible for finding the best solution for clients from the alternatives available. They have responsibility for planning in the liquid zone.
- **Schedulers** - Responsible for the scheduling of the production plan, sequencing the order items. They need to control the shop-floor obedience to the plan, and they need to replan if there are some gaps. They are accountable for the scheduling in the frozen period. Schedulers share the slushy zone with the master planners.

3.4.3 Customer Service Level and Delay Reasons Report

The previous section gives a brief presentation of the supply chain team and the planning method. Those two are critical for the understanding of how the KPI OTIF is used in Sonae Arauco and how the report of delay reasons is made. OTIF is calculated per order item based on the confirmation date given to the customer. Firstly, it is needed to understand the process for the sales order confirmation.

The sales team use the Enterprise Resource Planning (ERP) software SAP to create a sales order. The master planner responsible for the plant where this product will be allocated receives the order in his SAP board. The order is then confirmed automatically, based on the heuristics used by SAP, the confirmation typology of the product (7 days, 14 days, 21 days, 28 days) or validated by the master planner. When this process finishes, the sales team receives the first confirmation date and inform the customer on how long, each order item will take.

When the product delivery date does not meet the requirements for the OTIF, some delay reasons are automatically set. If the conditions for these automatic delay reasons are not met the system consider the reason as *"not assigned"*. In order to comprehend the process to declare the delay reasons from which the supply chain team is accountable, two more key elements need to be explained:

- **Material Availability Date (MAD)** - The MAD is the date from when the product is available after production. It is established that the MAD happens four days before the confirmation date given to the client. Two days for movements in the warehouse and two days for transport.
- **Loading Date (LD)** - The LD is the required date to guarantee a secure loading and transport from Sonae Arauco until the customer. The system requires that this date happens two days before the confirmation date.

The bird-view of the sales order item confirmation process and the automatic delay reasons assignment process owned by the supply chain is presented below (Figure 3.8).

In a more detailed view, the process consists of the following steps:

- **Sales Team** - The Sales Team is responsible for the acquisition of new sales orders. When they receive a sales order request, they check in SAP if the order can be validated and the first condition they review is if the company is blocked for credit. If the company have enough credit, the sales requisition is validated and ready for planning. When there is a block, the credit team is contacted. It is also the sales team that is accountable for the end of the process, confirming with the client that the order was received.
- **Credit Team** - Responsible for informing the client that they are financially blocked. They are the only ones that can unblock a sales order to allow the readiness for planning. When the conditions are not met, regarding credit, it is also assigned a delay reason regarding it, but that will not be studied in this research project because is out of scope.

- **Supply Chain Team** -The Supply Chain Team, as explained above, is divided in a central and an in-plant team. The central team is accountable for validating that the sales requisition is ready for planning and to plan that order. They are also the ones responsible for checking if the conditions for the perfect order are met. Those conditions should be analysed both in time and quantity and presented above. If they are not met, a delay reason is assigned.
- **In-Plant Supply Chain Team** - Accountable for the schedule of a planned sales order and control its correct manufacture. They are also responsible for the in-depth analysis of delay reasons, that will be studied further in the next chapter.

The detailed process regarding supply chain owned delay reasons will be studied in detail in chapter 4. This analysis will consist of the automatically set delay reasons, from which the central team is responsible, both in terms of planning and transport. The process of detailing those reasons, made by the Plants Logistics Managers, will also be in the analysis's scope.

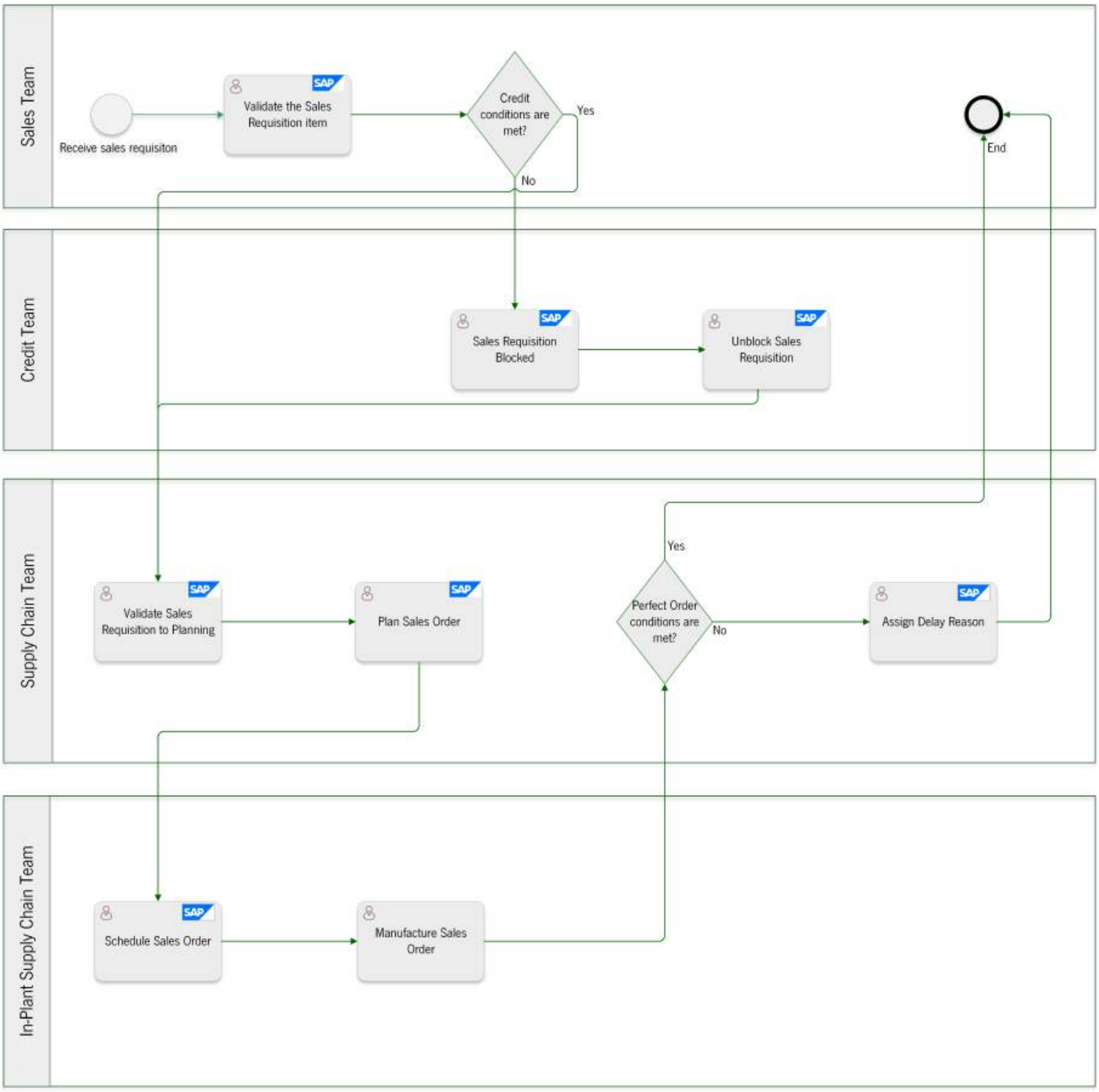


Figure 3.8: Sonae Arauco's SWE Order to Delivery Process Overview

4. Case Description and Critical Analysis

To define short and long-term strategies, it is essential to describe the actual situation of the company regarding the customer service level. Through this section, a diagnostic and operations' analysis is drawn to identify the root causes. Subsequently, it is presented a summary of the key improvement initiatives proposals. It is important to refer that DC Souselas is not analysed. It is considered a warehouse for both Mangualde and Oliveira do Hospital Plants, and it is evaluated as a part of it. For confidentiality reasons, all values have a correction factor, imposed by the company.

4.1 Poor Customer Service Level

Before proceeding to the complete analysis of the reasons behind the low customer service level, it is essential to define the KPI OTIF according to the company. Sonae Arauco calculates the OTIF by the first confirmation date given to the customer with two requirements:

- **Calculated through each order item separately** - Each order is composed of different articles. The OTIF takes into account each item per se.
- **Independent validations of quantity and date** - In order to understand the status of the service level, Sonae Arauco evaluates the OTIF with those parameters as independent variables. The date tolerance is in the interval [-4;0] days, and the quantity delivered tolerance in the interval $\pm 5\%$.

If the conditions presented above are not met the system will consider the OTIF equal to 0%.

The full detailed evaluations can be found in the table 4.1 below.

Table 4.1: KPI OTIF Possible Evaluations

Evaluation	In Full	Not In Full
On Time	OTIF = 100%	OTIF = 0%
Not on Time Early	OTIF = 0%	OTIF = 0%
Not on Time Late	OTIF = 0%	OTIF = 0%

Nowadays, a reporting process is implemented in the company, where only the KPI OTIF is monitored monthly, including only the delay reasons automatically established by the SAP system or manually set when the reason is already known beforehand. Afterwards, a process to review the delay reasons is already established at Sonae Arauco. The SAP already assign an automatic delay reason. Then, Logistics Managers are responsible for analysing all data concerning order lines with OTIF equal to 0% and filtering them. From that review process, they should provide a more precise cause from a list (table 4.2) that is already defined. If they need a new delay reason, they can also add that to their monthly service level report.

Table 4.2: Delay Reasons - Code and Definitions

Delay Reason	**Definition**	**Main Reason**	**Owner**	**Automatic**
AP	**Delay of Planning/Production**	**AP**	**Supply Chain**	**Yes**
FM	Lack of Raw Materials	AP	Supply Chain	No
IP	Lack of Impregnated Paper	AP	Supply Chain	No
LL	Lack of Laminates	AP	Supply Chain	No
QL	Quality Problem	AP	Supply Chain	No
RP	Lack of Dry Paper	AP	Supply Chain	No
SP	Downtime Production	AP	Supply Chain	No
X6	Goods not Supplied - Warehouse	AP	Supply Chain	No
X7	Goods not Provided - Production	AP	Supply Chain	No
XK	Availability	AP	Supply Chain	No
XL	Customer Requested Delivery Date not Realistic, Because Make-to-Order	AP	Supply Chain	No
ES	Stock Strategy	AP	Supply Chain	No
TR	**Transportation**	**TR**	**Supply Chain**	**Yes**
CG	Composition of Load	TR	Supply Chain	No
CN	Waits Order of Load	TR	Supply Chain	No
EC	Partial Delivery	TR	Supply Chain	No
X1	Not Loaded - Loading Capacity	TR	Supply Chain	No
X4	Same Day Loading and Delivery	TR	Supply Chain	No

XH	Load Features (weight, size,...)	TR	Supply Chain	No
XI	Transport not Organised	TR	Supply Chain	No
XJ	Customer Requested Delivery Date on Transport Day	TR	Supply Chain	No
XM	Tour not Filled	TR	Supply Chain	No
RA	Complete Delivery AP	TR	Supply Chain	No
AD	Antecipation Delivery	AD	Supply Chain	No
CE	Pick Up by the Customer	CE	Sales	Yes
IC	Customer Request	IC	Sales	Yes
CR	Lack of Credit	CR	Credit	Yes
AA	Delay on pricing Approval			No
XR	Commercial Priority		Supply Chain	No
XX	Order Entry Error			No

However, the review process is not standardised between all the plants, and the report is not always complete or fully developed. As the primary goal of the Supply Chain department is the improvement of the customer service level, the KPI OTIF is the adequate one to use as it measures the service both in date and quantity. Nevertheless, the report method without proper monitoring will not deploy improvement actions to increase the OTIF and customer satisfaction.

Sonae Arauco uses the web-based platform QlikView that allows the company to create specific dashboards related to critical business areas defined by the enterprise (Appendix A.1). This platform is the primary tool to perform analysis in this research project. The main dashboard used is the *"Service"* one (A.2)where it is possible to review all data regarding customer service level and personalise filters to follow the analysis pursued.

Figure 4.1 illustrates the OTIF behaviour at the SWE region between September 2019 and February 2020.

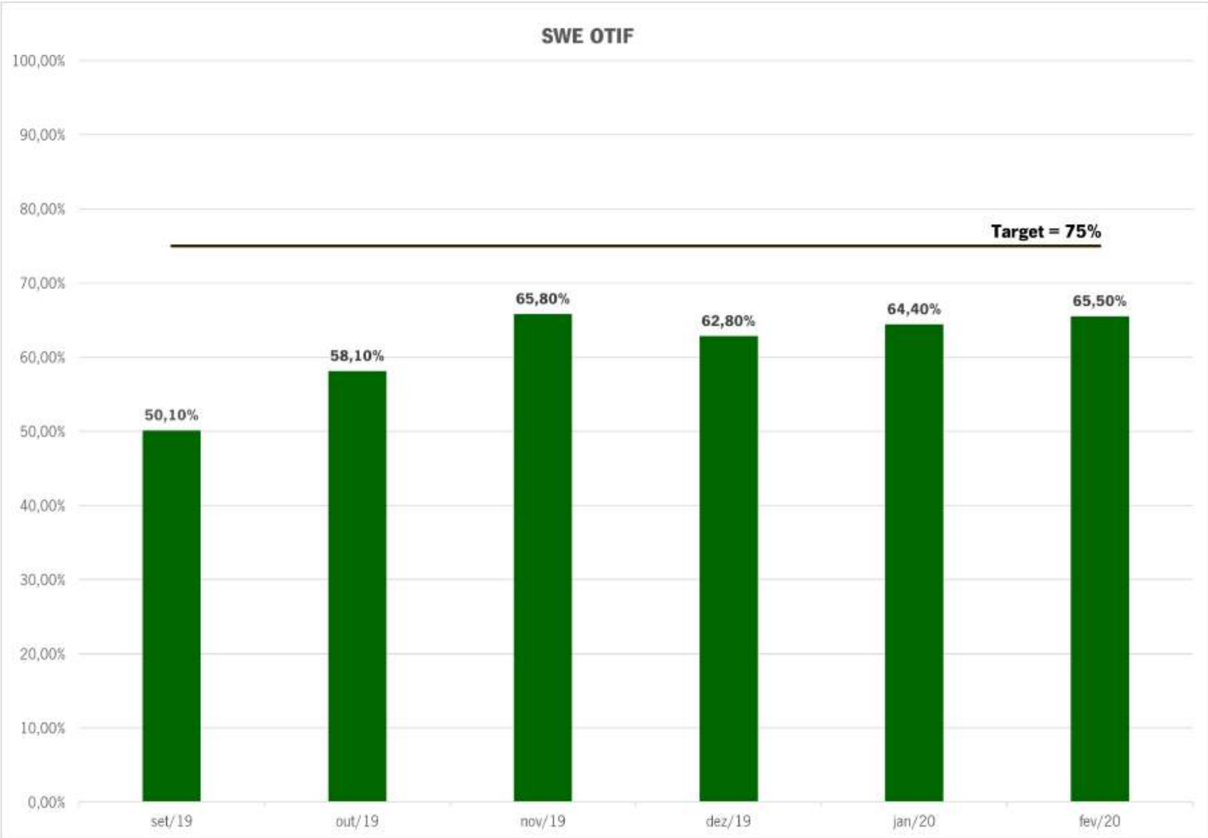


Figure 4.1: Sonae Arauco's SWE OTIF evolution, from September 2019 to February 2020

For the period in analysis, it is possible to conclude that the average OTIF in SWE Region is **61,12%**, quite below the target defined. The average value per plant can be found in Appendix B.1. To better understand the low customer service level it is required to do an in-depth analysis regarding the delay reasons, for the six months above, taking into account the average number of order items with OTIF equal to 0% per day. From the Pareto graphic presented below (Figure 4.2), it is possible to identify a considerable unawareness concerning the root causes of the low service level, enhancing the importance of eliminating this black box. As this black box is the one that affects the most the capacity to deploy improvement projects in the company, the goal of this dissertation is to reduce this area of unknowing.

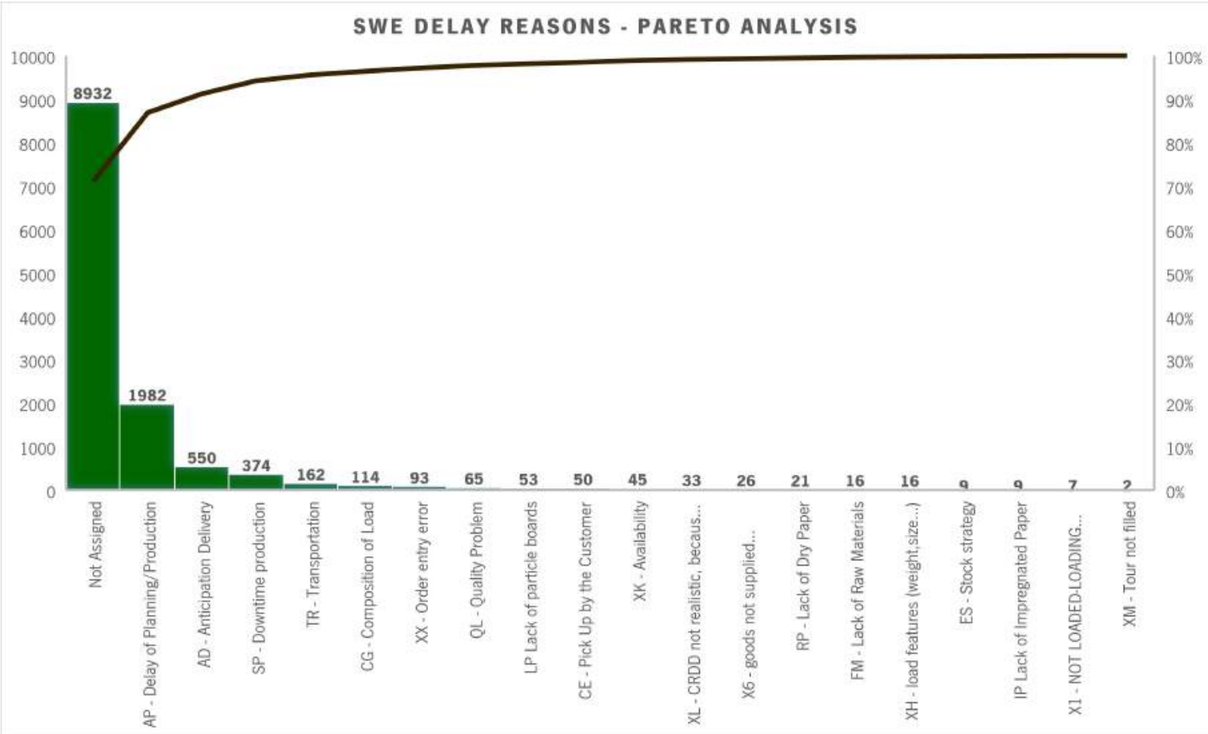


Figure 4.2: Sonae Arauco's SWE Delay Reasons, from September 2019 to February 2020

We can identify that **71%** of the delay reasons, for the period in analysis, are *"Not Assigned"*. That corresponds to the immense area of unknowing that is discussed in the previous paragraph. More than that, only **15.7%** are delay reasons automatically set for the planning team (*AP - Delay of Planning and Production*) and **1.3%** are automatically set for the transport team (*TR - Transportation*). Those numbers illustrate the ineffectiveness of the system and process used. A detailed view of those numbers will be presented next and help us set the in-depth analysis's scope.

In the next section, an analysis regarding the as-is reporting process will be made focusing on the reason codes and the actual follow-up from the logistics managers to this method.

4.2 Critical Analysis and Causes' Identification

Taking the problem presented above as the starting point, it revealed essential to analyse company processes' actual operation. The focus is on the reporting process to identify the main factors that influence the OTIF the most. It is also crucial to concentrate on the items that failed delivery in the confirmed date following criteria defined with Sonae Arauco to focus the development and deployment of improvement initiatives. It is also important to refer that the COVID-19 pandemic plays a considerable role in this section as it is the main responsible for the choices made.

4.2.1 As-Is Reporting Process

Previously, it was mentioned that the reporting process for delay reasons shows many flaws and areas of unknowing. With that in mind, it is necessary to understand and evaluate the percentage of order items that do not present any delay reason, even though the KPI OTIF is equal to 0%. This data will enable us to evaluate the current model's effectiveness and begin to draw considerations regarding it.

Table 4.3: Effectiveness of the As-Is Reporting Process

	Average Number of Sales Order Items per Month								
	Shipped Monthly	With OTIF=0%		Without Delay Reason		With Automatic Delay Reason		With Precise Delay Reason	
Plants	Number	Number	%	Number	%	Number	%	Number	%
Mangualde	1159	518	45%	452	75%	98	19%	33	6%
Oliveira do Hospital	1327	386	29%	255	66%	93	24%	38	10%
Valladolid	699	217	31%	140	64%	47	22%	30	14%
Linares	1060	610	58%	317	52%	143	23%	125	20%
DC Madrid	1198	458	38%	452	99%	0	0%	6	1%
SWE Region	5442	2189	40%	1551	71%	381	17%	231	11%

Before proceeding to the table analysis, it is essential to explain some criteria that are followed:

- We consider only the delay reasons that the supply chain owns for the number of items with automatic delay reasons assigned and precise delay reasons. The percentage of items with delay reasons (automatic or precise) is calculated from that total.
- There is a gap of 5% due to other delay reasons that are owned by different departments.
- The percentage of items without delay reason is calculated taken into account the total number of shipments.

From the table analysis, we can understand that the percentage of sales order items without delay reasons is, on average, 71% for the SWE Region, with the significant values in DC Madrid and Mangualde's Plant. It is also noted that both automatic or precise delay reasons are not above 25%. In fact, when it comes to precise delay reasons, only Linares achieves 20%, all the others are below 15%. It also illustrates that, for the SWE Region, neither automatic nor precise delay reasons are above 20%.

To conclude, those numbers demonstrate the low service level, as we have, on average, 40% of order items with OTIF equal to 0%. It shows the model's inability to perform the delay reasons report, making it impossible to promote initiatives to develop the service provided.

After investigating the number of order items without a delay reason defined, and understanding this model's inefficiency, it is important to dive deeper into the detailed process to assign a delay reason to a specific order item.

This analysis aims to find where this reporting process and model used are failing and set the scope for improvement initiatives and more in-depth analysis, if required.

The first step is to understand the conceptual model behind the process of assigning delay reasons.

As shown in figure 4.3, we can understand that there is a layer for the automatic delay reasons and that the SAP manages it. This first layer is divided by department which is accountable for different delay reasons, shown in table 4.2.

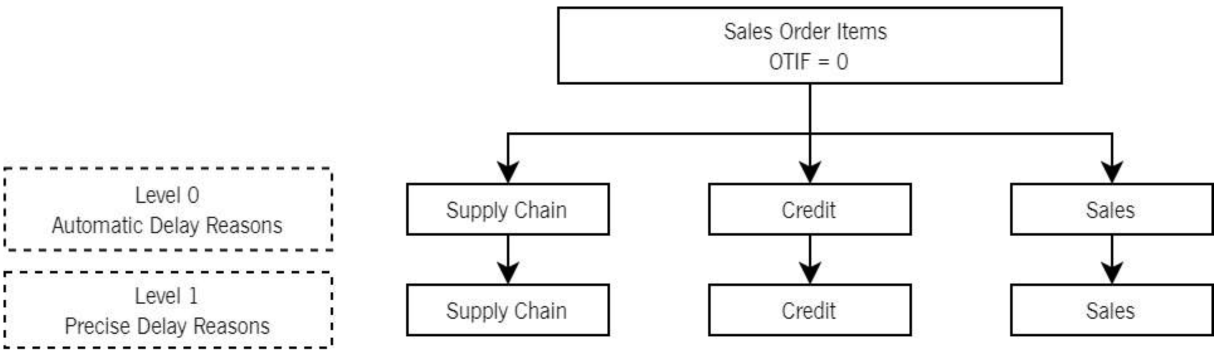


Figure 4.3: Delay Reason Process - Conceptual Model

In the second layer, we find more precise delay reasons, still divided into departments, but not into functional teams that are truly responsible for those reasons. That is leading to a lack of knowledge regarding the failures, as presented above.

It is now necessary to dive into the understanding and analysis of the current process to assign delay reasons within the supply chain team. It is relevant to remember that the supply chain team is divided into two teams centrally (planning and transports) and an in-plant team coordinated by Logistics Managers.

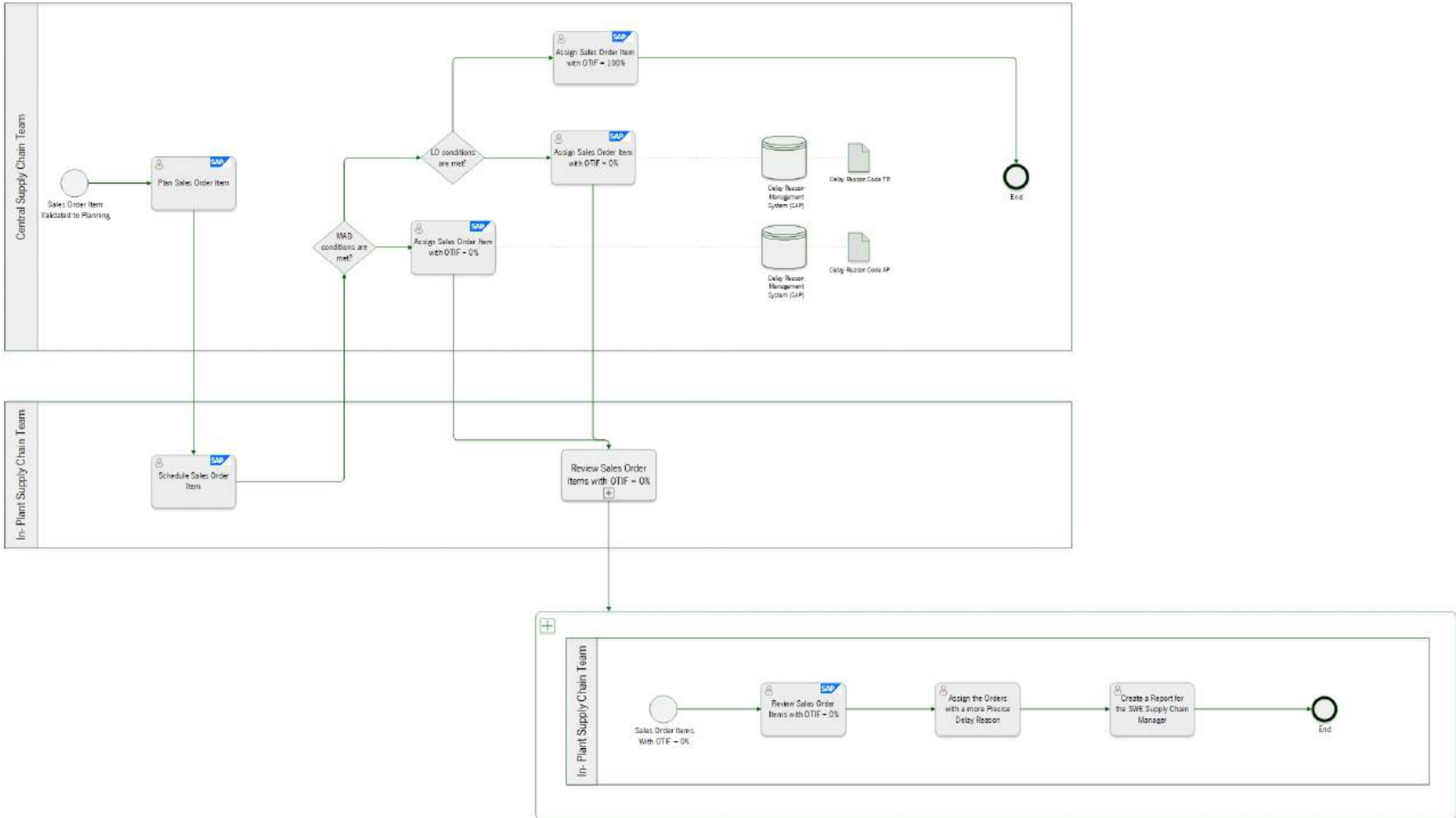


Figure 4.4: Supply Chain Delay Reason Assignment - Process

The process for the delay reason assignment is detailed in Figure 4.4. The current supply chain team delay reason assignment process comprised two different phases: an automatic phase and a review process once a month.

The supply chain team receives the information that a sales order item is ready for planning and adds it to the planning board. The in-plant team schedules the sales order item. As soon as the MAD is achieved, the SAP has a procedure that evaluates if the products are ready. If they are not ready, the SAP assigns an AP delay reason automatically. On the LD, The ERP runs another procedure and verifies if the boards already left the warehouse and are being delivered to the customer.

After that, and once a month, the Logistics Manager is responsible for a Review Process. They look at all the sales order items with OTIF equal to 0%, assign a precise delay reason, and create a report to present to the SWE Supply Chain Manager.

It comes clear that the automatic process is not capable of assigning an automatic delay reason for all the orders with OTIF equal to 0%. Furthermore, the review process does not happen in the same Management System (SAP) as the automatic process. Also, there is no obligation to follow the codes (Table 4.2), which creates inconsistency between the plants. In the Appendix B.2, an example of the review report is presented.

The flaws in the Assignment Process (that comprises both the Reporting and Review process) are responsible for the significant number of "Not Assigned" Delay Reasons in 71% of the sales order items with OTIF equal to 0%.

The Assignment Process needs to be redefined to ensure that the delay reasons are set and, the Logistics Managers are accountable for the Review Process, and it is standardised in all the SWE Region.

4.2.2 In-Depth Analysis by Plant

The previous section detailed the current model and the reporting and review processes and their results in the SWE Region. This part will focus on the plants' in-depth analysis and their influence as nodes in this manufacturing network.

The platform Qlikview is crucial here to retrieve the data used in the analysis. Due to the COVID-19 pandemic, one of the requirements is to frame the analysis within certain parameters to limit the action's scope. For that, we follow the principles that are already established in other areas of the company for their analysis:

- Customer Segment
- Product Tipology

The criteria above allow a more oriented analysis to development initiatives due to the company's manufacturing strategy. With that, it is possible to frame the critical areas to improve.

As previously referred, the Souselas DC is considered a warehouse for the Portuguese plants and integrates them in this analysis.

In the next subsections, the plants' study will be presented using the criteria defined with the company.

4.2.2.1 Customer Segment Analysis

The first specific analysis presented is the analysis per customer segment.

As the primary goal is customer service, it is crucial to start with this study. For this analysis, we use the two customer segment groups defined previously: Industrial clients and Trade clients.

In the first segment, we consider the three subgroups: Global Key Account, Key Account and Standard Account.

Below, the results of this analysis are presented.

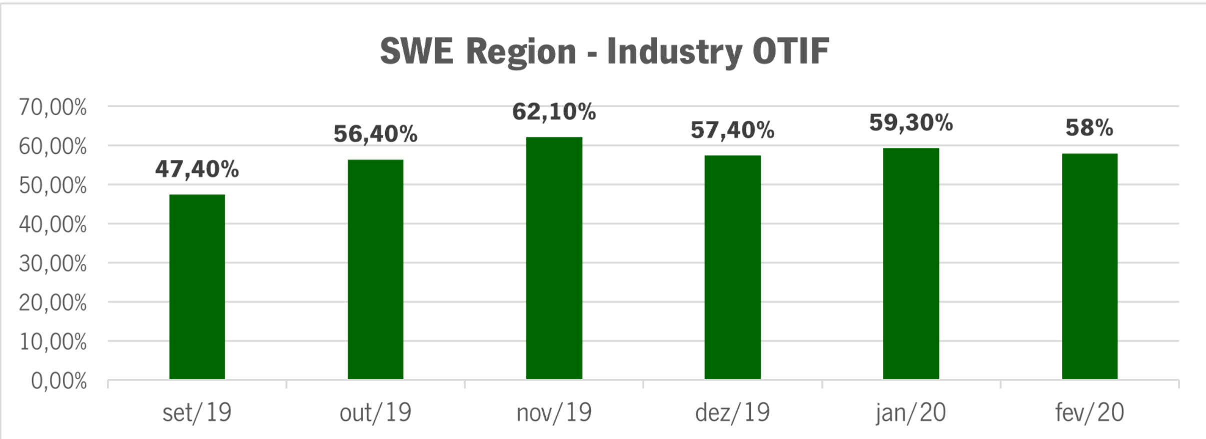
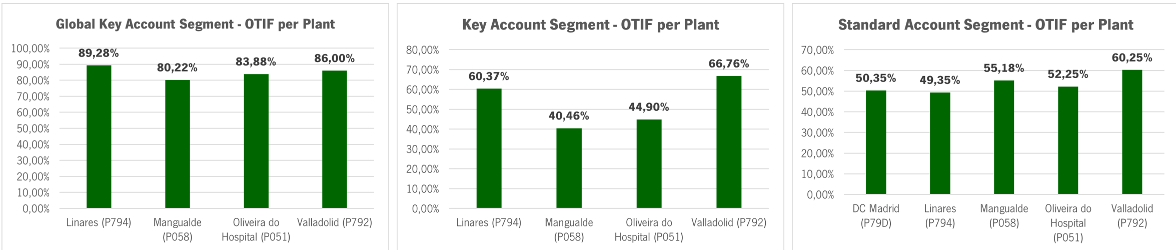


Figure 4.5: Sonae Arauco's SWE OTIF evolution - Industry, from September 2019 to February 2020

From Figure 4.5 we can understand that the average value never exceeds 60% unless in November 2019. Those values present that the company have more than 40% of items that are not perfect orders.

We are referring industry clients, that are the direct consumer of our products. Failing to meet in 40% have a direct impact on their operations, making it urgent to improve our overall service.



(a) Global Key Account (b) Key Account (c) Standard Account

Figure 4.6: SWE Average OTIF per Industry Customer Segment, from September 2019 to February 2020

On Figure 4.7, we have an overview of the OTIF per plant per segment. We can see that the values follow the company's customer importance, the best service for Global Key Accounts, then Key Accounts and after Standard Accounts.

In the Global Key Account, we perform, on average, 85%. The Standard Account have the worst service, on average, 53,5%. The targets are 90% for Global Key Account, 75% for Key Account and 70% for Standard Account.

When it comes to plants, the plant with the lower service is Mangualde, in all the segments, unless in the Standard Account. Nevertheless, on the Standard Account, it also performs poorly.

It is essential to state that we should not have values for DC Madrid in this segment. We have those values due to products with fewer sales that we needed to sell directly to industry clients to free space in the distribution centre for other SKUs.

Next, we proceed with the same analysis for the Trade segment.

Figure 4.7 illustrates the evolution of the OTIF in the Trade segment for the period in the analysis. We can draw two conclusions.

The overall OTIF is increasing due to the new DCs, one started working in July and other in September. The other is that it is substantially better than the service we offer to Industry type clients, on about 7.9 pp, especially from November until February.

When we go to the detailed analysis, in Figure 4.8, it is possible to perceive that Oliveira do Hospital performs considerably above the other plants in the first two segments: Innovus Premium Dealer and Innovus Standard Dealer. That happens due to the connection between the plant and Souselas DC.

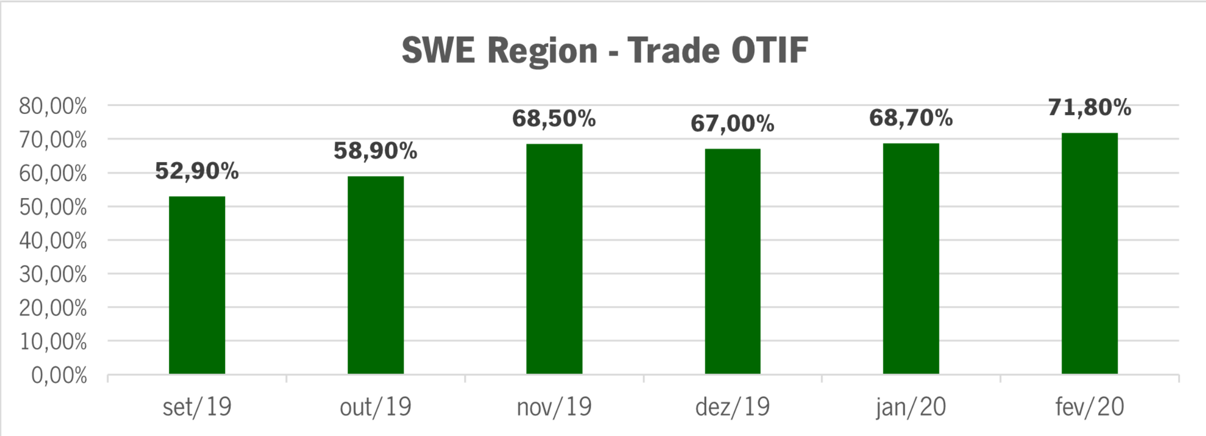
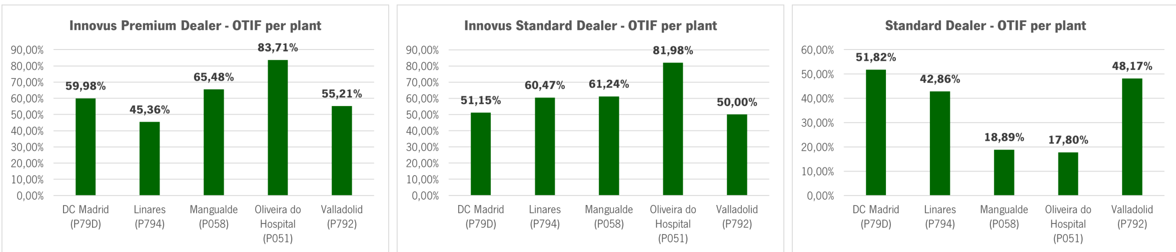


Figure 4.7: Sonae Arauco's SWE OTIF evolution - Trade, from September 2019 to February 2020



(a) Innovus Premium Dealer (b) Innovus Standard Dealer (c) Standard Dealer

Figure 4.8: SWE Average OTIF per Trade Customer Segment, from September 2019 to February 2020

Linares and Valladolid, the Spanish plants, do not have a good service level, because they get to fulfil more industry type clients, as DC Madrid serves the trade clients in Spain.

We can come to the same conclusion as in the Industry segment, the service we provide our customers need to improve.

To summarize this analysis, we present two tables comparing both segments in terms of the number of lines with OTIF equal to 0%. The graphics used in the creation of these summary tables are displayed in the Appendix B.3.

Table 4.4: SWE Average Number of Sales Order Items with OTIF = 0% per Plant per Customer Segment, from September 2019 to February 2020

	Average Number of Sales Order Items per Month				
	With OTIF = 0%	**Industry**		**Trade**	
Plants	Number	Number	%	Number	%
Mangualde	518	290	13%	228	10%
Oliveira do Hospital	386	176	8%	210	10%
Valladolid	217	195	9%	22	1%
Linares	610	543	25%	67	3%
DC Madrid	458	2	0%	456	21%
SWE Region	2189	1206	55%	983	45%

From the table's analysis, we can understand that both Linares and Mangualde are responsible for performing the worst to industry clients.

With the trade segment, the worst performer is DC Madrid, because it absorbs trade sales in Spain.

Besides that, we can conclude that the service performs poorly in both segments, and they are balanced in terms of order items with OTIF equal to 0%.

Afterwards, it is required to dive deeply in the analysis. Below, it is presented the table with the detailed segments inside each large group.

Table 4.5: SWE Average Number of Sales Order Items with OTIF = 0% per Plant per Specific Customer Segment, from September 2019 to February 2020

	Average Number of Sales Order Items per Month											
	Industry						Trade					
	Global Key Account		Key Account		Standard Account		Innovus Premium Dealer		Innovus Standard Dealer		Standard Dealer	
Plants	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Mangualde	31	1.42%	51	2.33%	208	9.50%	15	0.69%	94	4.29%	119	5.44%
Oliveira do Hospital	17	0.78%	17	0.78%	142	6.49%	8	0.37%	78	3.56%	124	5.66%
Valladolid	32	1.46%	20	0.91%	143	6.53%	2	0.09%	10	0.46%	10	0.46%
Linares	4	0.18%	70	3.20%	469	21.43%	8	0.37%	21	0.96%	38	1.74%
DC Madrid	0	0%	0	0%	2	0.09%	140	6.40%	118	5.39%	198	9.05%

SWE Region	84	3.84%	158	7.22%	963	43.99%	173	7.90%	322	14.71%	489	22.34%

When we look at the table, we can comprehend that it is on the more critical customers that we have a better service level and in the standard clients, we are having more significant problems.

With 43.99% in standard accounts and 22.34% in standard dealers, it is vital to increase those values.

We can draw other conclusions:

- Mangualde and Linares are the first ones where we should look at when developing improvement initiatives;
- Linares have the majority of problems with standard accounts, performing well with the other segments (also has a higher number of lines, making that plant responsible for most of the problems with that segment).

4.2.2.2 Product Typology Analysis

In order to perform the most suitable implementation plan, it is not only necessary to look for the failures that happen per customer segment. This second analysis is also essential for that.

As explained previously, Sonae Arauco's manufacturing network and supply chain are configured considering different products and processes in the various infrastructures. With that allocation of resources, it is vital to analyse how each factor impacts the system and which products are delivered with the worst service.

This study started with a macro view of the OTIF in those two more significant groups of products: Raw Boards and Melamine-faced Boards. Then, we look inside those groups: PB and MDF for Raw Boards and MFC and MFMDF for Melamine-faced Boards.

Below, the summary of the research is presented.

Figure 4.9 illustrate the evolution of OTIF in the SWE Region per month in terms of raw boards. As the raw boards are both raw material and the final product, it is possible to understand that it presents an OTIF above the average. Combined in these six months, the average OTIF is 64%.

The Figure 4.10 displays the difference between the OTIF per plant, in these six months, per raw board typology, PB and MDF.

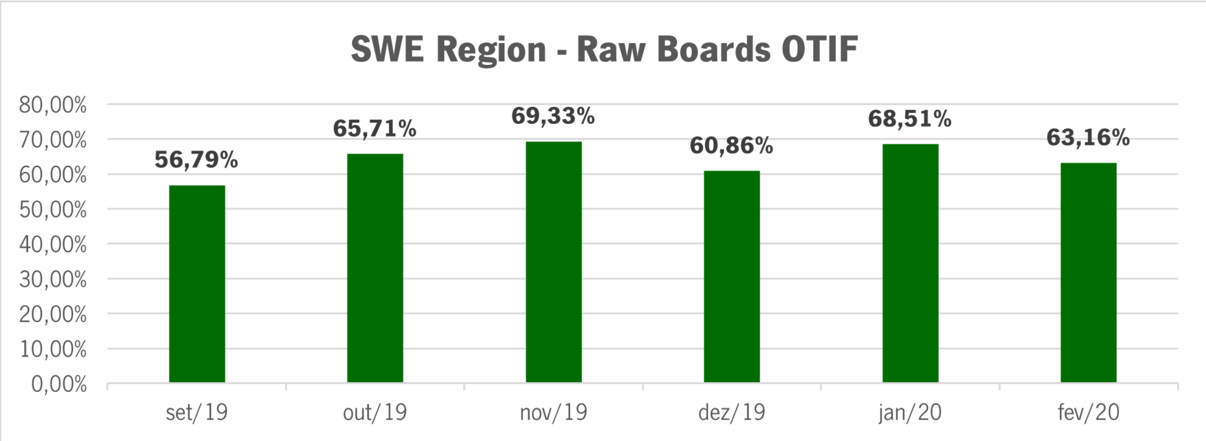
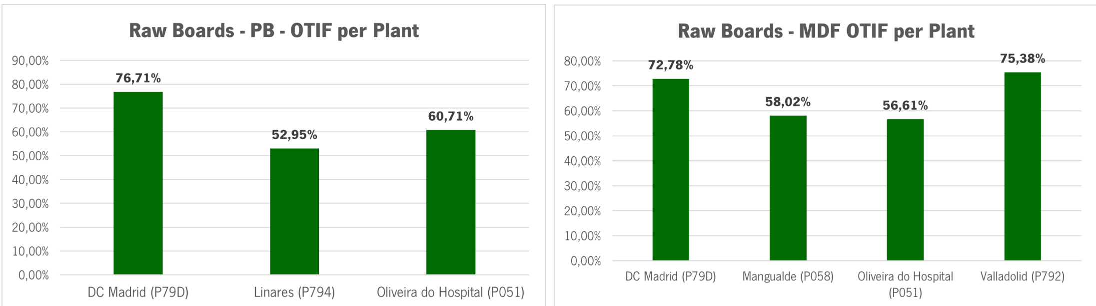


Figure 4.9: Sonae Arauco's SWE OTIF evolution - Raw Boards, from September 2019 to February 2020

Before proceeding to analyse the values presented above, it is necessary to recall the product's plant allocation. Valladolid does not fulfil PB Boards, only use them to be coated and Mangualde only has MDF production lines. When it comes to MDF, Linares only use it to produce MFMDF. Even though Oliveira do Hospital appears in the second graphic, it is only due to specific orders that need to be fulfilled from there. When we analyse the number of lines, we will understand that.



(a) Particleboard (b) Medium Density Fiberboard

Figure 4.10: SWE Average OTIF per Product Tipology - Raw Boards, from September 2019 to February 2020

Looking at the graphics, in Figure 4.10 it is possible to draw some conclusions:

- Linares present the worst service in terms of PB with only 52.95%;
- Mangualde also has the worst service level for the MDF (Oliveira do Hospital number of lines is not that significant);
- It confirms the conclusions from the previous section that those two plants have the worst results in the OTIF;
- DC Madrid has the best performance on both products, due to only serve products with more sales.

Next, we proceed with the same analysis for the Melamine Faced Boards typology.

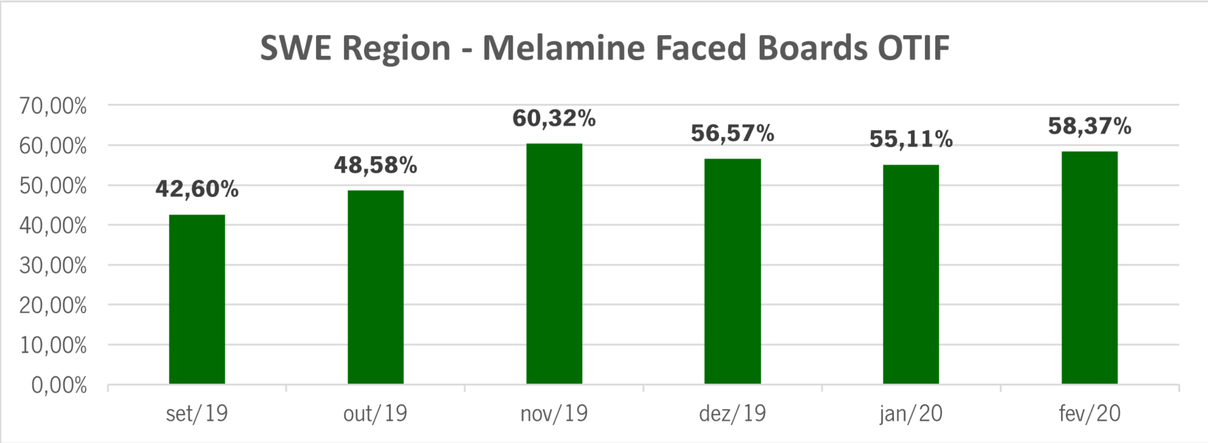
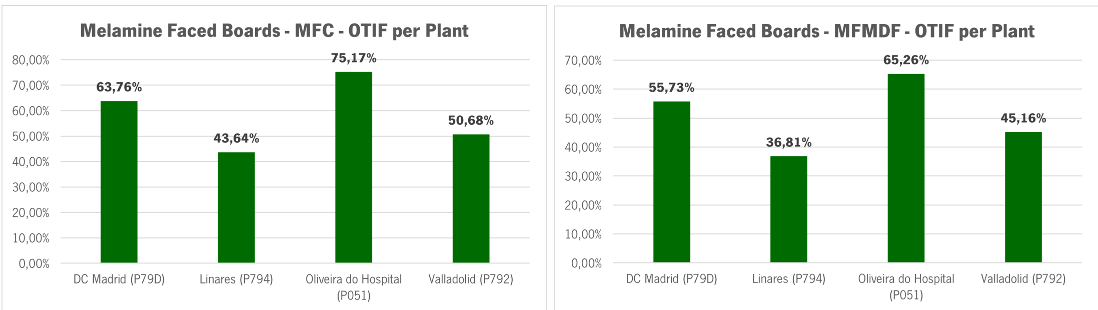


Figure 4.11: Sonae Arauco's SWE OTIF evolution - Melamine Faced Boards, from September 2019 to February 2020

Figure 4.11 illustrates the OTIF evolution for the Melamine Faced Boards in the SWE Region.

As Melamine Faced Boards are composed of a raw board and a melamine sheet, it is understandable that a worse service is presented as discussed next.

The differences between plants make some units dependent on others. A delay in the production of raw boards will affect the production of the Melamine Faced boards. So it is expected a lower service for this type of products.



(a) Melamine Faced Chipboard (b) Melamine Faced MDF

Figure 4.12: SWE Average OTIF per Product Tipology - Melamine Faced Boards, from September 2019 to February 2020

When we go to the detailed analysis, in Figure 4.12, it is possible to perceive that Oliveira do Hospital performs considerably better than the other plants in both products.

It is possible to get similar conclusions, as the previous analysis. Linares is again the plant with the worst service level. Mangualde is not presented here due to only manufacture MDF. It is one more time showed the influence of those two plants on the service provided.

The MFMDF typology presents a lower OTIF due to the lower service also in the MDF raw board. Plants are Mangualde dependent on this product, which makes this plant's failures affect the others.

To summarize this analysis, we present two tables comparing both products' typology in terms of the number of lines with OTIF equal to 0%.

Table 4.6: SWE Average Number of Sales Order Items with OTIF = 0% per Plant per Product Tipology - Raw Boards, from September 2019 to February 2020

	Average Number of Sales Order Items per Month				
	With OTIF = 0%	**Raw Boards**		**Melamine Faced Boards**	
Plants	Number	Number	%	Number	%
Mangualde	388	388	20%	228	0%
Oliveira do Hospital	392	98	5%	210	15%
Valladolid	189	119	6%	22	4%
Linares	578	118	6%	67	24%
DC Madrid	388	75	4%	456	16%
SWE Region	1934	797	41%	1137	59%

From the table's analysis, it is possible to understand that the Melamine Faced Boards represent 18% more failures. Also, Mangualde is the most responsible for the poor service in raw boards.

Those two conclusions help us to identify two major problems:

- There is a problem for the service in melamine faced boards. As raw boards have, in most cases, adequate service levels, the situation should be with the other components;
- Mangualde only produces raw boards and is responsible for 20% of failures. This plant is crucial for the low service level.

To understand the first conclusion, it is required to dive deeply in the analysis. Table 4.7 shows the performance of the detailed typologies inside each large group.

Table 4.7: SWE Average Number of Sales Order Items with OTIF = 0% per Plant per Product Tipology - Raw Boards compared to Melamine Faced Boards, from September 2019 to February 2020

	Average Number of Sales Order Items per Month							
	Raw Boards				Melamine Faced Boards			
	PB		MDF		MFC		MFMDF	
Plants	Number	%	Number	%	Number	%	Number	%
Mangualde	0	0%	388	20.06%	0	0%	0	0%
Oliveira do Hospital	95	4.91%	3	0.16%	227	11.74%	67	3.46%
Valladolid	0	0%	118	6.10%	60	3.10%	10	0.52%
Linares	118	6.10%	0	0%	441	22.80%	18	0.93%
DC Madrid	13	0.67%	62	3.21%	294	15.20%	20	1.03%
SWE Region	226	11.69%	571	29.52%	1022	52.84%	115	5.95%

In the analysis above we identified that most problems happen with melamine faced boards.
In table 4.7, it is highlighted the detailed numbers regarding the product typology. With that detail, it is possible to realise that MFC is the product that impacts the poor service, the most, with 52.84%. However, PB, the raw board for the MFC does not significantly impact the service level, which helps us identify a problem with planning/purchasing the other materials or producing MFC.
It is also important to confirm that Mangualde, with the MDF production, considerably influences the service provided, responsible for 20% of the failures.

4.3 Summary and Diagnosis

The current Reporting Process presents 71% of *"Not Assigned"* delay reasons, which corresponds to an immense area of unknowing. With the detailed process analysis, it was possible to highlight its complexity and the lack of standardisation between all plants. It was also possible to understand the current delay reason codes were not defined coherently and precisely described. Consequently, it was necessary to frame an in-depth analysis of the production units to find which plants impact more the failures.
With 45% and 58%, Mangualde and Linares, respectively, with higher percentages with sales order items with OTIF equal to 0%, with a total of 518 and 610 items per month, on average. Furthermore, none of the plants achieved more than 25% when studying the sales order items with automatic delay reasons, and only Linares achieved 20% when focusing on precise delay reasons.
To sum up, the process could not detect the reasons for the delays and were unreliable to develop and implement improvement initiatives from this current model.

This diagnostic defines that the first step to improving the service level is to create a new model for the delay reasons process.

Secondly, it was necessary to analyse in-depth the plants to define a roadmap for implementing the new process.

All the plants were studied following two parameters, customer segment and product typology. From that analysis, it was possible to conclude that Mangualde and Linares should be the first ones to test the new model. It also helped us to find a specific product with low service levels. MFC is responsible for 52.84% of the sales order items with OTIF = 0%, even with PB only having 11.69%.

To conclude, in Figure 4.13, it is illustrated a diagram, for short-term and long-term strategies, summarising the improvement initiatives' proposals to improve the knowledge regarding failures and, consequently, the customer service level. These initiatives will be discussed next, in Chapter 5.

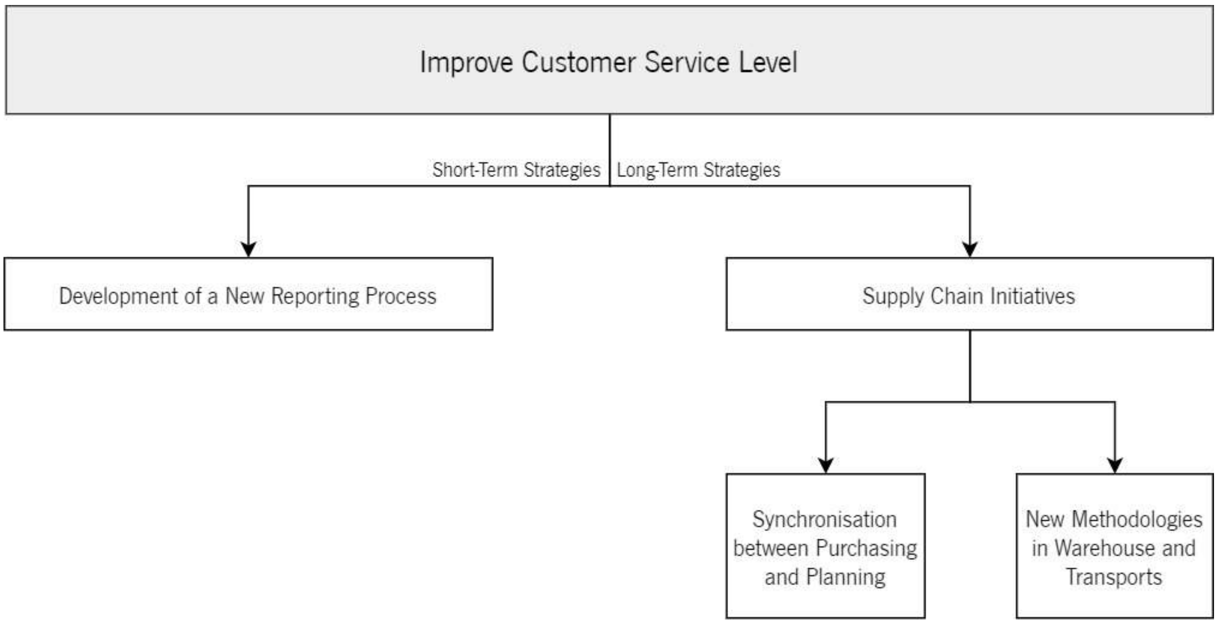


Figure 4.13: Improvement Initiatives Proposals - Summary

5. Improvement Proposals and Results

According to the diagnosis presented in the previous section, this chapter suggests a compilation of improvement proposals, segmented into two strategy's branches: short-term and long-term. Short-term strategies comprise a new reporting process with new Delay Reasons, an extensive automation level, and standardise between plants. Furthermore, the implementation strategy is also presented. A stage-gate-based approach was used to develop a new model for the proposed decision support system. Concerning the long-term strategies, those include synchronisation between purchasing and planning and studying new approaches to the warehouse and transports focusing on warehouse location systems and time-windows for truck loading.

In conclusion, the analysis of the results will be exposed, being developed in Chapter 6.

5.1 Short-Term Strategies

This section describes the approach used in developing and deploying the new Reporting Process and the implementation strategy behind it. This Reporting Process was implemented, and its results were monitored.

5.1.1 Development of a New Reporting Process

The diagnosis presented in Chapter 4 highlights the significant area of unknowing that the current report and delay reason assignment processes cannot uncover and the low service level. Those created the necessity to develop a new model that would correct the current flaws.

The following scenario was defined:

- **As-Is Scenario:** The current reporting process cannot provide a realistic view of the Delay Reasons. Moreover, it relays a lot on people, and it is not standardised between plants. There are 71% of delays that do not have any justification by the model used. It is impossible to propose improvement initiatives due to the unknowing of the failures.

From the conclusions provided by the analysis, a completely new model needed to be developed. The purpose was to create a new framework that would align strategic areas with operational goals. It should identify all the reasons for failure and be more automated. Furthermore, it was intended to set a path for a completely automated process that could propose a reason beforehand and, in the future to predict it. Therefore:

- A new conceptual model should be framed based on clustering strategical business functions;
- New business processes need to be established;
- New Delay Reasons and codes were set and defined;
- Standardisation between plants and accountability must be assured.

Following these baselines, the following scenario was suggested:

- **To-Be Scenario:** A new framework and decision support system that allows identifying the failures aligned with the business functions and that calls to action. It is proposed to change all the Delay Reasons and their codification, create accountability within departments and create a standardised process between plants to register and act upon the failures identified. The overall goal is to create awareness and understanding of the current flaws and set the track to improvement proposals and a better service level.

After the validation of the two scenarios by Sonae Arauco, it was structured the approach to create and validate the new method. Firstly, the project team was composed by the author of this research project and:

- **Supply Chain Team**
  - Global Supply Chain Director;
  - SWE Supply Chain Director;
  - Supply Planning Manager;
  - Transport Planning Manager;
- **Sales Team**;
- **Controlling Team**;
- **IT Team**:
  - Enterprise IT Architects for Supply Chain, Sales, Industrial and Analytics;
  - Development
  - Delivery

As this project required different teams' expertise, a stage-gate-based approach was used to frame validation points where the team would gather and evaluate the outputs achieved in each phase, and if the criteria defined were met. The following gates were specified:

- **Gate 0 - Project and Scenarios Definition**
  - **Purpose:** Definition of the project scope, project team and the as-is and to-be scenarios;
  - **Gate Criteria:** Project Directive, Starting Point and Goal of the Project;
  - **Output:** Project Scope; Project Team and responsibilities assigned; Scenarios;
  - **Deciding Body:** Project Sponsor - Global Supply Chain Director;
- **Gate 1 - Creation of a new conceptual hierarchy model**
  - **Purpose:** Approve a new model for the clustering of Delay Reasons that combine both strategic and operational levels and guarantee accountability;
  - **Gate Criteria:** Strategic and operational levels are combined; Responsibilities are defined; Clear view of the process intervenients;
  - **Output:** A strategic and operational hierarchy model that is designed to ensure accountability for the service failures;
  - **Deciding Body:** Project Team (except IT Team);
- **Gate 2 - Determination of new Delay Reasons and codification**
  - **Purpose:** Decide on the new Delay Reasons and codification and their definitions;
  - **Gate Criteria:** Delay Reasons simple codification; Uniformity of the Delay Reasons definition between plants;
  - **Output:** A new list of Delay Reasons and their codification and a glossary with the definition of each reason;
  - **Deciding Body:** Project Team
- **Gate 3 - Design of a new process and automation**
  - **Purpose:** Verify the design of the new process and if the conditions for automation are met;
  - **Gate Criteria:** Uncover all Delay Reasons; Automation and simplicity in the usage of the ERP system;
  - **Output:** A new process that ensures the uncovering of all Delay Reasons; an automated process in the ERP system used;
  - **Deciding Body:** IT Team

- **Gate 4 - Implementation of a Pilot Test in one plant**
  - **Purpose:** Test and Validate that all the previous developed methodology is functional;
  - **Gate Criteria:** Decision of the trial plant; The plant's order items with OTIF=0% have, at least, the automatic delay reason;
  - **Output:** The monthly report of the test plant with the Delay Reasons;
  - **Deciding Body:** Project team, Master Planner responsible for the pilot plant and in-plant supply chain team; Master Planners responsible for the other plants and in-plants supply chain teams;
- **Gate 5 - Validation of the Pilot Test and propagation of the new methodology to the different plants**
  - **Purpose:** Verify the consistency of the results in all the plants and if the standardisation is assured;
  - **Gate Criteria:** Decision on the implementation strategy between the other plants and the timeline; The plants' order items with OTIF=0% have, at least, the automatic delay reason;
  - **Output:** The monthly report of the plants with the Delay Reasons;
  - **Deciding Body:** Project team, Master Planners responsible for the plants and in-plants supply chain teams;
- **Gate 6 - Result's Analysis**
  - **Purpose:** Verify if the process is more capable than the existent one;
  - **Gate Criteria:** To-Be Scenario is implemented and is generating high-grade results;
  - **Output:** Comparison between the As-Is and To-Be Scenarios;
  - **Deciding Body:** Project team;

Focusing on the detailed work in-between the different gates, the first part, before Gate 0, was already explained previously in this chapter.

To ensure the delivery of a new conceptual hierarchy model with the clustering of business functions and respective Delay Reasons, the definition of the order-to-delivery process's actors is essential.

This clustering's starting point was to establish four critical teams that were already studied in the analysis phase: Credit, Sales, Supply Chain and Logistics. The segmentation between Supply Chain and Logistics was made due to the different responsibilities these business functions have in the company. Supply Chain comprises the planning and the production of goods, and Logistics include the warehouse and transport.

With this first layer set, it was necessary to subdivide the two significant clusters: Supply Chain and Logistics, as they were the key actors in the order-to-delivery process. As mentioned before, the operational areas inside each group are planning and production and warehouse and transport, respectively.

To pursue accountability between each team, it was required to specify the first level of Delay Reasons that would be crucial to ensure the responsibility for failing to meet the perfect order and give a high-level view of which operational and strategic functions should deploy improvement initiatives. Combining these three layers is one of the main differences from the previous model, which failed to give insight on the operational level. Moreover, it was essential to specify the reasons inside each large group in a fourth layer that were the root causes for the failures. At this level, these reasons should be connected with even a more detailed area like purchasing, quality or the ones already defined.

There was an on-going project from the industry and production department focused on retrieving data directly from the shop floor. As it was still in an early development phase throughout this research project, the last layer was introduced to connect the shop floor information with the overall model explained above but not explored deeply. That will turn possible to predict a sales order item with OTIF equal to 0% as soon as certain unexpected failures happen through the manufacturing process and will help the reporting process as it will provide valuable real-time insights. In Chapter 6, an overview of how this future research should be conducted will be explored.

The detailed view of this hierarchy model is presented in Figure 5.1.

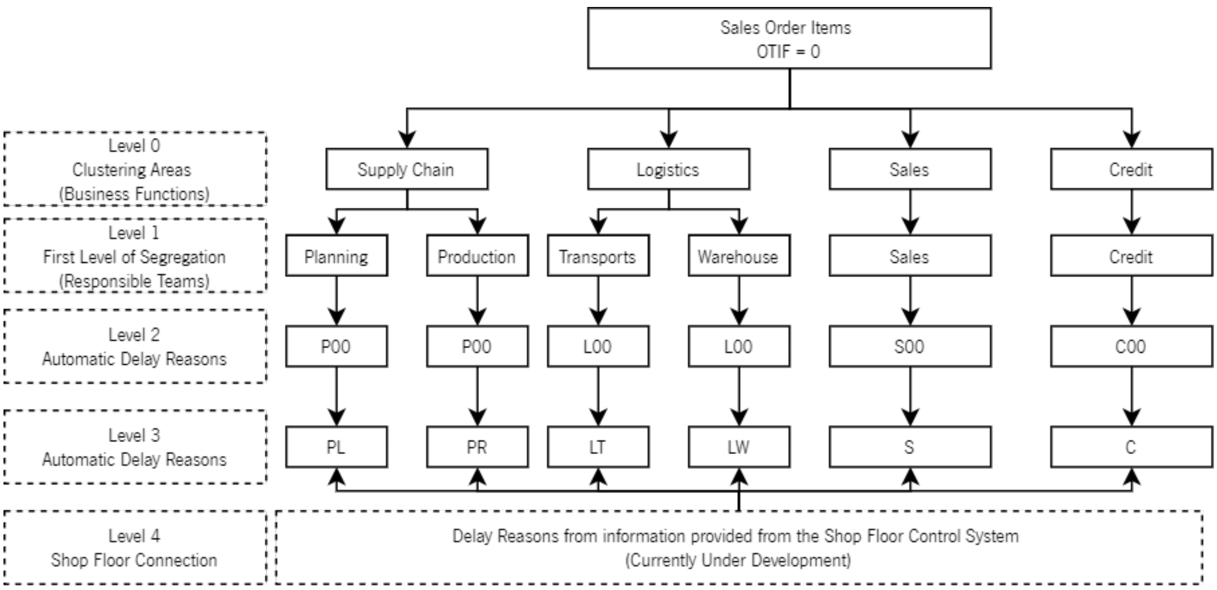


Figure 5.1: Proposed Reporting Process Conceptual Model

At Gate 1, this model was validated by the project team as it followed all the criteria. When compared to the previous model, an important factor is that this one clearly states the responsible for each area of failures and creates the accountability between the strategic and operational level to develop and deploy improvement initiatives that will positively impact the customer service level.

As soon as the model was validated, it was necessary to redefine the Delay Reasons and the new codification. One of the main problems diagnosed in chapter 4 was the Delay Reasons codes that exist. The codes presented no coherence and shared and standardised terminology. Also, there was no glossary/definition provided to assure that all the reports follow the same idea. When talking to logistics managers, it was understandable that they have different views of the same reasons. That created total inconsistent and disconnected reports between plants, turning the SWE Supply Chain Manager's decisions unreliable.

The main objective pursued in the redefinition of the Delay Reasons was to focus on the clusters defined in the previous phase. The current reasons were analysed and adapted to the problems and risks concerning the different operational functions. It was also necessary to look into relevant specific areas that could be related to these new reasons. Additionally, it was fundamental to create new terminology that followed two principles:

- it is possible to extend to new reasons inside the same group;
- it is understandable which business function is responsible for that failure reason.

This way, it is possible to understand, just by looking at the reason code, which teams perform better or worst and which ones are responsible for promoting new improvement projects.

To follow all the baselines presented, the new terminology *(AAOO)* was created with the project team and consist of:

- **AA -** The first two letters are related to the strategic and operational areas. The first represents the first letter of the function in the second layer of the model (Figure 5.1), and the second letter, the operational team in the third layer;
- **OO -** The two numbers are sequencing, enabling creating new reasons inside each group if needed.

In the next table, it is presented the reasons and their codes.

Table 5.1: New Delay Reasons and Codification

Code	Delay Reason
P00	**P00 - Planning/Production (PL/PR)**
PL0	PL0 - Lack of Raw Materials: Chemicals
PL1	PL1 - Lack of Raw Materials: Wood
PL2	PL2 - Lack of Raw Materials: Paper or Sheets
PL3	PL3 - Lack of SFG: Impregnated Paper
PL4	PL4 - Lack of SFG: Master Board
PL5	PL5 - Master Data Issues
PL6	PL6 - Wrong Manual Replanning
PL7	PL7 - Customer Service Request-Commercial Priority
PL8	PL8 - Quality Issues in Production
PR1	PR1 - Lack of personal in Production
PR2	PR2 - Technical Issues in Production
PR3	PR3 - Excess Production
L00	**L00 - Transports/Warehosue (LT/LW)**
LT0	LT0 - Truck not arrived or delayed
LT1	LT1 - Dimensions/Weight planned incorrectly
LT2	LT2 - Wrong vehicle type / defect truck
LT3	LT3 - Lack of Truck capacity
LT4	LT4 - Safety / PSA Issues
LT5	LT5 - Driver shift break
LT6	LT6 - Truck not full
LT7	LT7 - Complete delivery
LT8	LT8 - Wrong Delivery Date
LT9	LT9 - Planned time different from the executed
LW0	LW0 - Customs Declaration Issues
LW1	LW1 - Lack of Equipment
LW2	LW2 - Lack of Personal
LW3	LW3 - Delay in manual packaging

LW4	LW4 - Layout/Capacity Issue
LW5	LW5 - Quality Release Delay
LW6	LW6 - Loading delay
LW7	LW7 - Stock damaged
LW8	LW8 - Stock not found
LW9	LW9 - Stock quantity ≠ allocated
LW10	LW10 - Density value difference
LW11	LW11 - Packaging weight difference

After the project team validated the new codes, it was required to create a definition for all the Delay Reasons. On top of that, these definitions should create a systematic and shared view of the root causes of failures. With that, it would be possible to fulfil one of the main requirements of this research project. For the glossary, the author worked directly with each plant's logistics managers and reviewed all their inputs to give form to the definitions presented below.

- **P00 - Planning/Production (PL/PR):** Automatic Delay Reason, if there is no delay reason assigned on the Material Availability Date and the stock is not available;
- **PL0 - Lack of Raw Materials: Chemicals:** Assigned if the boards are not produced due to lack of chemicals;
- **PL1 - Lack of Raw Materials: Wood:** Assigned if the boards are not produced due to lack of wood;
- **PL2 - Lack of Raw Materials: Paper or Sheets:** Assigned if the boards are not produced due to lack of paper or sheets;
- **PL3 - Lack of SFG: Impregnated Paper:** Assigned if the boards are not produced due to lack of impregnated paper;
- **PL4 - Lack of SFG: Master Board:** Assigned if the boards are not produced due to lack of master board;
- **PL5 - Master Data Issues:** Assigned if there are any problem in the technical data that affect the production;

- **PL6 - Wrong Manual Replanning:** Assigned if the master planner or the scheduler make a mistake in the manual replanning;
- **PL7 - Customer Service Request-Commercial Priority:** Assigned if there is a request from the commercial team to perform an early or late delivery;
- **PL8 - Quality Issues in Production:** Assigned if the boards produced are not conforming with the quality requirements;
- **PR1 - Lack of personal in Production:** Assigned if the boards are not produced due to lack of personal in production;
- **PR2 - Technical Issues in Production:** Assigned if the boards are not produced due to technical problems in the production lines;
- **PR3 - Excess Production:** Assigned if the boards are not produced due to lack of in-plant capacity;
- **L00 - Transports/Warehouse (LT/LW):**Automatic Delay Reason, if there is no delay reason assigned on the end of the LD;
- **LT0 - Truck not arrived or delayed**: Assigned if the boards are not delivered on the confirmed date due to the truck's delays;
- **LT1 - Dimensions/Weight planned incorrectly:** Assigned if the boards are not delivered on the confirmed date due to incorrect cargo planning in dimensions or weight;
- **LT2 - Wrong vehicle type / defect truck:** Assigned if the boards are not delivered on the confirmed date due to problems in the truck or incorrect selection of the truck;
- **LT3 - Lack of Truck capacity:** Assigned if the boards are not delivered on the confirmed date due to the truck's lack of capacity;
- **LT4 - Safety / PSA Issues:** Assigned if the boards are not delivered on the confirmed date due to safety problems in the transportation;
- **LT5 - Driver shift break:** Assigned if the boards are not delivered on the confirmed date due to truck's delays caused by the driver shift break;
- **LT6 - Truck not full:** Assigned if the boards are not delivered on the confirmed date due to the truck's cargo being too low to perform a designated route;
- **LT7 - Complete delivery:** Assigned if the boards are not delivered on the confirmed date due to the truck's incapacity to perform a full delivery;

- **LT8 - Wrong Delivery Date:** Assigned if the boards are not delivered on the confirmed date due to incorrect planning of delivery date by the transports team;
- **LT9 - Planned time different from the executed:** Assigned if the boards are not delivered on the confirmed differences between the planning and the execution;
- **LW0 - Customs Declaration Issues:** Assigned if the boards are not delivered on the confirmed date due to problems with the customs declarations;
- **LW1 - Lack of Equipment:** Assigned if the boards are not delivered on the confirmed date due to warehouse lack of equipment (example: forklifts are not enough);
- **LW2 - Lack of Personal:** Assigned if the boards are not delivered on the confirmed date due to lack of personal in the warehouse;
- **LW3 - Delay in manual packaging:** Assigned if the boards are not delivered on the confirmed date due to warehouse incapacity to perform the manual packaging on time;
- **LW4 - Layout/Capacity Issue:** Assigned if the boards are not delivered on the confirmed date due to problems in the picking in the warehouse caused by the layout or by exceeding the capacity;
- **LW5 - Quality Release Delay:** Assigned if the boards are not delivered on the confirmed date due to delays in the quality team analysis;
- **LW6 - Loading delay:** Assigned if the boards are not delivered on the confirmed date due to loading delays;
- **LW7 - Stock damaged:** Assigned if the boards are not delivered on the confirmed date due to the existence of damages in the stock boards;
- **LW8 - Stock not found:** Assigned if the boards are not delivered on the confirmed date due to the incapacity to find stock boards in the warehouse;
- **LW9 - Stock quantity □ allocated:** Assigned if the boards are not delivered on the confirmed date due to the differences between the stock quantity and the allocated quantity. The in-plant team reserved an incorrect quantity of stock;
- **LW10 - Density value difference:** Assigned if the boards are not delivered on the confirmed date due to differences in the density values;
- **LW11 - Packaging weight difference:** Assigned if the boards are not delivered on the confirmed date due to problems in the packaging weight;

At Gate 2, the project team meet and discuss the Delay Reasons and definitions. As the work involved all the parties, deliverables were validated, and, therefore, it was approved to start designing a new process. These first three phases were fundamental to creating the new methodology's foundations and fulfilling the most critical requirements, specifically, the strategic and operational alignment, accountability and shared view and standardisation between plants.

Consequently, it was necessary to start phase four. This stage will transform the methodology and framework into a decision support system. It will define a new process and develop the interface to make all the conceptual models an actionable solution. Although the new processes were developed for the different business functions, the focus will be on the ones related to the supply chain and logistics areas in this research project.

In contrast to the processes presented in Chapter 4, these new ones should specify responsibilities and correctly automate the assignment of the first level of Delay Reasons. Looking at the diagnostic, it comes clear that the automatic process was not achieving the results, with 71% of the sales order items with no delay reason assigned. More than that, the number of steps and transactions to assign a non-automatic delay reason was also immense, creating an obstacle for the logistics managers responsible for reviewing of failures. Also, there was no process related to the replanning of sales order items and the delay reason assignment.

New rules were defined as the starting point to design a new process (Figure 5.2) that solves all the problems presented:

- Sales and Credits reasons have priority over the others;
- If there is no delay reason assigned on the **MAD** and the stock is not available, an automatic **P00** is assigned;
- If there is no delay reason assigned at the end of the **LD**, an automatic **L00** is assigned;
- It is only possible to overwrite the delay reason to a precise delay reason within that group;
- If there is any inconsistency in the delay reason automatically assigned, the SWE Supply Chain Manager or the author of this dissertation should be contacted;
- In the case of replanning a sales order item, the master planner responsible must assign a specific reason.

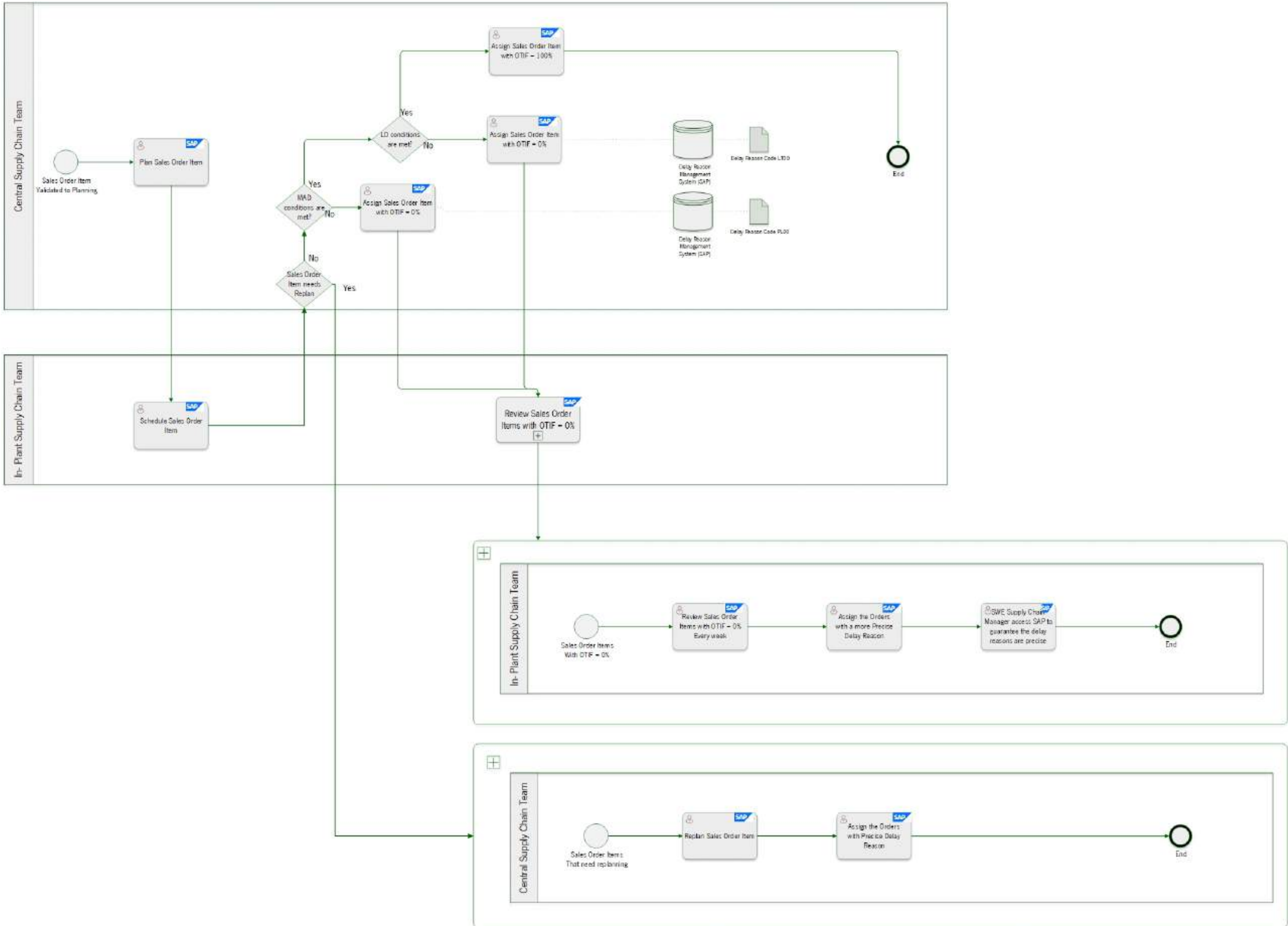


Figure 5.2: Supply Chain Delay Reason Assignment - New Process

The next step was to define responsibility roles:

- The SWE Supply Chain Manager and the author of this dissertation can see and update any delay reason and transfer Delay Reasons to other groups if a valid justification is presented;
- Plant logistics managers can access both Planning/Production or Logistics areas;
- Master Planners can only access Planning/Production reasons;
- Transport planners can only access Logistics reasons;
- The sales team can only access sales reasons;
- The credit team can only access credit reasons;
- The IT Team can access the configuration of the rules inside the SAP environment.

After validating these baselines and responsibilities, the IT Team developed a new SAP transaction that would allow the Delay Reasons automatic assignment and a simple reviewing process. It is now possible to assign, review and gather all the information regarding the delivery failures in only one system. Hence it is the crucial part of this decision support system. More than having the alignment of operations and strategy will provide practical and reliable information to act upon it. Below, the interface and the way of using this new system is shown:

Figure 5.3: New Cockpit for Delay Reasons - SAP System - First Page

The first page is composed of an overview of the different groups of Delay Reasons. Each group is only accessible by people inside that specific team. The total access is only possible for the SWE Supply Chain Manager and the author of this dissertation, as previously explained.

Inside the cockpit, it is allowed to define specific filters to the sales order items with OTIF equal to 0%. The delay reason and the tolerances are automatically set based on the section and the tolerances defined by the company.

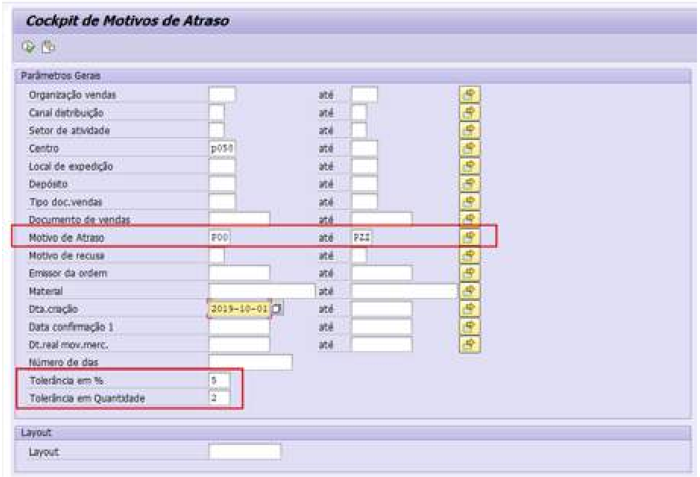


Figure 5.4: New Cockpit for Delay Reasons - SAP System - Parameters and Filters

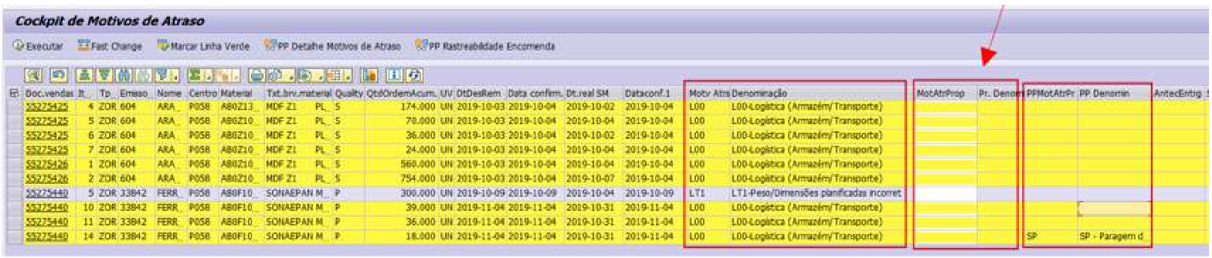


Figure 5.5: New Cockpit for Delay Reasons - SAP System - Delay Reasons Assignment Page

Figure 5.5 illustrates the cockpit with the list of Delay Reasons. In yellow, the lines that need to be specified are highlighted. In grey, there are the items that already have a precise delay reason. For certain plants, the system will provide a delay reason proposal that comes from the production area. This topic will be explored in future research in Chapter 6.

On Gate 3, the IT Team and the author of this study gathered and reviewed all the phase outcomes. As the outputs met the specific criteria defined, it was required to go for the next stage and do a pilot test in a plant.

In the next section, the implementation strategy is described, and the results for the trial are presented.

5.1.2 Implementation Strategy

Before proceeding to the implementation strategy, it is essential to look at the analysis' phase results. Chapter four concluded that both Mangualde and Linares were the worst-performing plants, making them the best candidates for the pilot test. The overall goal is to, after having a process that defines the root causes, teams can deploy improvement initiatives to increase the customer service level.

To develop the strategy for the implementation of this new decision support system, a prioritisation matrix was used, divided into the following quadrants:

- **Low-Hanging Fruits:** Provide value and do not take much effort to execute. Even though they are potentially less significant than more challenging initiatives, they are easy to implement and quickly bring value;
- **Big Bets:** Looming initiatives that are crucial to the organisation but require a significant effort.
- **Maybes:** Initiatives that always get delayed for the others with high priority. The approach should be to explore them and create value to transfer them to the low-hanging fruits quadrant;
- **Not Worth the Effort:** If these projects are approved, they may force the company to a substantial effort that would not create significant value. The opportunity-value of these when comparing to low-hanging fruits can be significant.

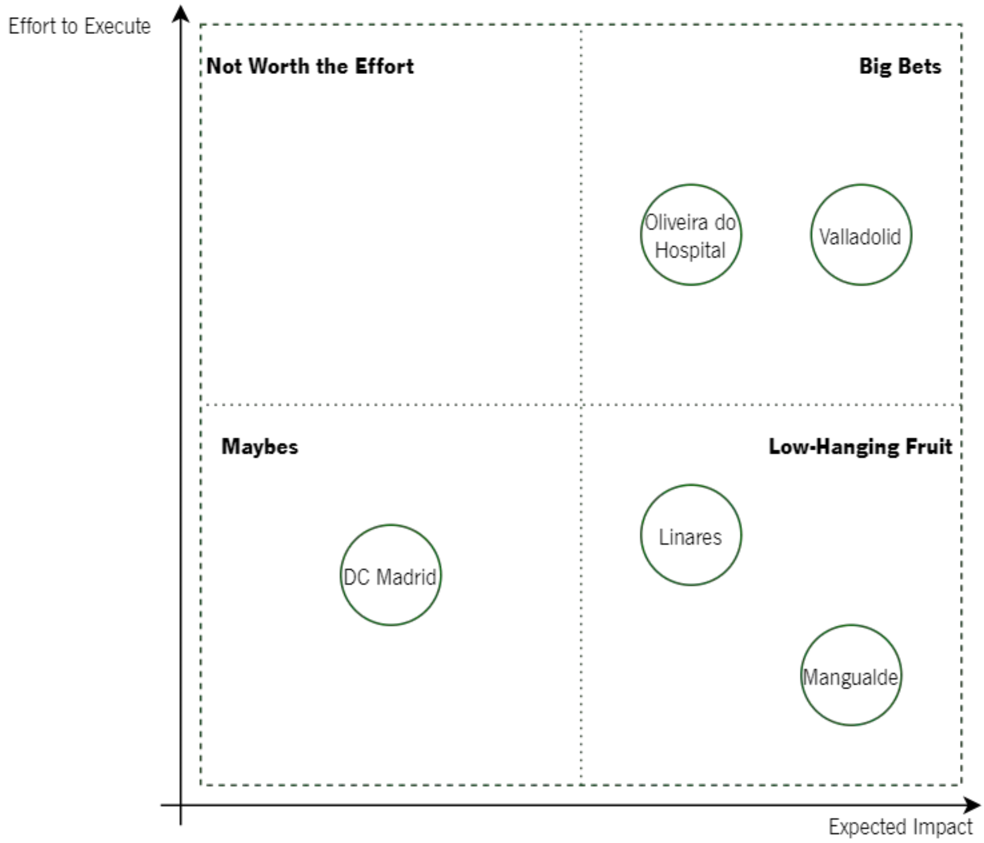


Figure 5.6: Implementation Matrix

The fundamental idea was to decide upon the plant where the pilot test would take place. As diagnosed, Mangualde and Linares, as the worst performers, are desirable candidates to be the pilot plant. Valladolid, Oliveira do Hospital, and DC Madrid have a better service level, so they should be left for the second phase of the implementation plan.

Considering that Linares and Mangualde are on the low-hanging fruits' quadrants, but the diversity of products and processes in Linares' plant make it more challenging to implement the new process for a pilot test.

A third-party logistics provider manages DC Madrid with service-level agreements, so, at this point, there is no reason for starting with that plant. Can be qualified in the maybe quadrant. Oliveira do Hospital and Valladolid are both performing better than the others. With the significant variety of processes and products, they would impact less the overall goal of increasing the customer service level and, therefore, should be considered a Big Bet.

In conclusion, after this analysis, the Mangualde plant was chosen to be the first plant where this new decision support system would be implemented.

After that, if the test is validated in Gate 4, Linares should be the next plant. Afterwards, Oliveira do Hospital and Valladolid can have the implementation at the same time and, ultimately, DC Madrid will start to use this new system.

As soon as the pilot plant was defined, the project team created a presentation and training sessions to start working with the in-plant teams. It was defined as a hyper-care period of two weeks and a trial duration of one month. After that month, where only the new Reporting Process was active, results were evaluated and compared with the historical data from the same month in the previous year. Those outcomes are presented in Table 5.2.

Table 5.2: Sales Order Items with OTIF = 0% at Mangualde Plant in September 2020

	Sales Order Items with OTIF = 0%	
Delay Reasons	**Number**	**%**
P00 - Planning/Production	107	24.32%
PL0 - Lack of Raw Materials: Chemicals	1	0.23%
PL1 - Lack of Raw Materials: Wood	6	1.36%
PL7 - Customer Service Request - Commercial	1	0.23%
PL8 - Quality Issues in Production	29	6.59%
PR2 - Technical Issues in Production	37	8.41%
L00 - Logistics (Transport/Warehouse)	10	2.27%
LT0 - Truck not arrived or delayed	2	0.45%
LT1 - Dimensions/Weight planned incorrectly	1	0.23%
LT6 - Truck not full	41	9.32%
LT8 - Wrong Delivery Date	7	1.59%
LW2 - Lack of Personnel	1	0.23%
LW3 - Delay in manual packaging	4	0.91%
LW4 - Layout/Capacity Issues	2	0.45%
LW8 - Stock not found	1	0.23%
Not Assigned	190	43.18%

From the analysis of Table 5.2, it is possible to conclude that the precise Delay Reasons represent 30.23%, compared to 0.91% from the same month in the previous year (Appendix C.1). With that increase, it is notorious the improvement caused by the new system. When the focus is on the sales order items without delay reason (*"Not Assigned"*), it corresponds to 43.18%, less 32.07 pp than September 2019, on which the area of unknowing was 75.25%, as shown in the Appendix C.1.

However, the value for the sales order items with the delay reason ”not assigned” set is still high. In the following iterations and tests on the other plants, deep analysis of the code behind the SAP system will be performed by the IT Team to conclude which procedures cannot assign the sales order items correctly.
With the trial, we can observe that *PL8*, *PR2* and *LT6* are the risks that most affect the overall service level in Mangualde, realising, together, 24.32% of the root causes behind the sales order items with OTIF equal to 0%.
At Gate 4, the results were reviewed compared to the ones obtained with the previous model in September 2019. From there, it was possible to assume an increase in the level of detail of the failures and deploy actions based on those results. The project team was delighted with those results and started working on phase 2 of the implementation strategy: apply this new decision support system at Linares Plant.

5.1.3 Results' Analysis

As proposed in the timeline created for the implementation strategy, this second phase's focus was to consolidate the results in Mangualde and implement the model in Linares. The approach was similar to the one used in the pilot test. Training sessions and presentations were facilitated to the in-plant teams, and a hyper-care period was defined.
In October 2020, the model was used in both plants, and the results were evaluated as presented below.

Table 5.3: Sales Order Items with OTIF = 0% at Mangualde Plant in October 2020

	Sales Order Items with OTIF = 0%	
Delay Reasons	**Number**	**%**
P00 - Planning/Production	65	15.89%
PL0 - Lack of Raw Materials: Chemicals	6	1.47%
PL1 - Lack of Raw Materials: Wood	3	0.73%
PL2 - Lack of Raw Materials: Paper or Sheets	4	0.98%
PL4 - Lack of SFG: Master Board	21	5.13%
PL6 - Wrong Manual Replanning	6	1.47%
PL7 - Customer Service Request - Commercial	9	2.20%
PL8 - Quality Issues in Production	28	6.85%
PR2 - Technical Issues in Production	31	7.58%
L00 - Logistics (Transport/Warehouse)	6	1.47%
LT0 - Truck not arrived or delayed	12	2.93%
LT6 - Truck not full	23	5.62%
LT8 - Wrong delivery date	8	1.96%
LW4 - Layout/Capacity Issues	3	0.73%
LW6 - Loading delay	1	0.24%
LW9 - Stock quantity ≠ allocated	1	0.24%

Not Assigned	182	44.50%

When comparing the results (Table 5.3) , in Mangualde, from October 2020 to the ones in October 2019, the following conclusions can be highlighted:

- The *"Not Assigned"* Delay Reasons have decreased 52.36 pp from 382 sales order items to 182. The items with no reason assigned now represent only 44.50% of the total items with OTIF = 0% comparing to 78.12% in 2019;
- The Precise Delay Reasons were only 6.54% in October 2019, and only one reason. Now, the methodology developed can name 14 Delay Reasons outlining 38.14% of the total number of failed items.
- Compared to the previous month, there are less automatic reasons with no specification, which means that results impact the production unit and the learning process created results. Also, there are fewer sales order items with the OTIF equal to 0%, denoting small improvement initiatives in the factory.

Table 5.4: Sales Order Items with OTIF = 0% at Linares Plant in October 2020

	Sales Order Items with OTIF = 0%	
Delay Reasons	**Number**	**%**
P00 - Planning/Production	180	30.20%
PL0 - Lack of Raw Materials: Chemicals	18	3.02%
PL2 - Lack of Raw Materials: Paper or Sheets	18	3.02%
PL3 - Lack of SFG: Impregnated Paper	12	2.01%
PL6 - Wrong Manual Replanning	1	0.17%
PR2 - Technical Issues in Production	16	2.68%
L00 - Logistics (Transport/Warehouse)	16	2.68%
LT0 - Truck not arrived or delayed	33	5.54%
LT1 - Dimensions/Weight planned incorrectly	15	2.52%
LT3 - Lack of Truck Capacity	8	1.34%
LT6 - Truck not full	21	3.52%
LT7 - Complete delivery not possible	2	0.34%
LW11 - Packaging weight difference	1	0.17%
Not Assigned	190	42.79%

In Linares (Table 5.4), it was the first month, but the results are already promising:

- The Precise Delay Reasons represent, nowadays, 38.14% and are described by eleven Delay Reasons. In October 2019, they only represented 8.12% and ten Delay Reasons;

- The sales order items with no specific reason assigned had a decrease of 344 sales order items, 54.38 pp. When comparing the impact of the *"Not Assigned"* items to the same month in the previous year, it is possible to conclude that it now embodies 42.79% when it was 66.79%.

After analysing the results from October 2020 at the two plants that had the model implemented, it was time to roll out that decision support system for the other three infrastructures: Valladolid, Oliveira do Hospital and DC Madrid. The outcomes had been consistent and starting to give an accurate picture of what is occurring at the supply chain to produce a low service level.

As defined in the implementation phase, if the results were promising and the teams were correctly using the support system, the company would implement the model, at the same time, for all the other units.

To promote a better understanding of the results collected at this stage, the combined results for November and December 2020 of the Delay Reasons for sales order items with OTIF equal to 0% will be the foundation for the analysis.

Table 5.5: SWE Average Sales Order Items with OTIF = 0% from November and December 2020

	Sales Order Items with OTIF = 0%	
Delay Reasons	**Number**	**%**
P00 - Planning/Production	351	9,63%
PG0 - Lack in delivery group stock	133	3,65%
PL0 - Lack of Raw Materials: Chemicals	110	3,02%
PL1 - Lack of Raw Materials: Wood	25	0,69%
PL2 - Lack of Raw Materials: Paper or Sheets	84	2,31%
PL3 - Lack of SFG: Impregnated Paper	26	0,71%
PL4 - Lack of SFG: Master Board	150	4,12%
PL5 - Master Data Issues	24	0,66%
PL6 - Wrong Manual Replanning	229	6,28%
PL7 - Customer Service Request - Commercial	50	1,37%
PL8 - Quality Issues in Production	180	4,94%
PR1 - Lack of personnel in Production	22	0,60%
PR2 - Technical Issues in Production	215	5,90%
PR3 - Excess Production	1	0,03%
L00 - Logistics (Transport/Warehouse)	207	5,68%
LE0 - External delay reason	72	1,98%
LT0 - Truck not arrived or delayed	37	1,02%
LT1 - Dimensions/Weight planned incorrectly	2	0,05%
LT2 - Wrong vehicle type / defect truck	4	0,11%
LT3 - Lack of Truck capacity	43	1,18%
LT6 - Truck not full	103	2,83%
LT7 - Complete delivery not possible	2	0,05%
LT8 - Wrong delivery date	12	0,33%
LT9 - Planned time different from the executed	18	0,49%
LW3 - Delay in manual packaging	12	0,33%
LW4 - Layout/Capacity Issues	3	0,08%
LW5 - Quality Release Delay	60	1,65%
LW7 - Stock damaged	2	0,05%
LW8 - Stock not found	3	0,08%
LW9 - Stock quantity ≠ allocated	8	0,22%
LW10 - Density value difference	1	0,03%
LW11 - Packaging weight difference	2	0,05%
LW12 - Loading mistake	3	0,08%
Not Assigned	1450	39,79%

From the analysis of the summary Table 5.5, the first detail noticed is the variety of precise Delay Reasons assigned during November and December 2020. All the plants are already using the new methodology, and the decision support system developed. Compared to November and December 2019 (Appendix C.2), there is an increase of 53.33% in the number of precise Delay Reasons, from 14 to 30.

Furthermore, the impact in terms of understanding why the customer service level is below the expected, there is much more information now. The unknowing area represented 68.02% in the two last months of

2019 and represented for the same time in 2020, 39.79%. Those percentages picture a decrease in the number of sales order items from 2159 to 1450.

To sump up the two comparisons in terms of precise Delay Reasons and area of unknowing, the new methodology outlines a significant improvement as summarised in the graphs below.

Focusing on the performance of the new model in the more recent implementations (Valladolid, Oliveira do Hospital and DC Madrid), it was required to:

- **Create new Delay Reasons for DC Madrid:** A third-party logistics provider manages the DC, and, for that reason, two new risks needed to be defined:
  - **External Delay Reason (LE0):** This is a reason in group logistics. When the product is not delivered due to failures in the warehouse or transportation from our partner in DC Madrid, the sales order item needs to be assigned with this reason;
  - **Lack of Delivery Group Stock (PG0):** This reason is in group Planning/Production. Suppose the planning team (central or in-plant) do not assign a specific group stock in a sales order item, and it influences the ability of our partner in DC Madrid to perform a perfect order. In that case, this delay reason needs to be selected for the item.

Even though the results are quite impressive and promising, there is also room for improvements. The number of automatic reasons with no precise delay reason is 15.31% for November and December 2020, meaning that a more effective and close work needs to be aimed at the plant's logistics managers. Additionally, the fact that there are still 39.79% of sales order items with OTIF equal to 0% with no reason assigned requires developing an updated version of the SAP transaction, further explored in Chapter 6.

In conclusion, the new methodology's encouraging results allow the promotion of new initiatives at the plant level to increase the service level. Simultaneously, this new process and system create enough awareness and knowledge to enable the development and deployment of large-scale projects at a central level. The main goal of these new initiatives is to increase the service level.

In the next section, two initiatives are proposed, and the potential outcomes are analysed.

5.2 Long-Term Strategies

Throughout this section, the long-term strategies will be explained, and exploratory results will be presented. The main focus will be on the potential to improve the customer service level. Comparison based on scenarios will be the approach used to compare the results if the strategies are implemented. The results of the new decision support system will be used.

5.2.1 Synchronization between Purchasing and Planning

In the previous chapters, the supply chain department was defined, and the reasons that affect the service level the most were identified.

When looking at the new methodology results, planning problems of lacking raw materials and semi-finished goods represent 10.84%. Studying the supply chain department structure, it is possible to see established teams for some critical areas of the supply chain, but there is no purchasing team within this department. Simultaneously, the planning of purchases and production planning do not follow the same principles and are not synchronised:

- The production planning follows the Material Requirements Planning (MRP) technique. The MRP emerged in the 1960s, and the planning function can be summarised as:
  - **Material Explosion:** The Bill of Materials is used to generate the demand for components due to demand for an end-item. It holds the information on what and how many components are required to produce an end-item;
  - **Lead Time Offsetting:** The lead time to produce the end-time is taken to offset the date the item is needed to determine the components' production date.
- The purchase of raw materials and the planning of those purchases are made following the safety stock. If the safety stock is reached, a purchase order is created. In the cases where there is no safety stock established, the purchase order is created with the sales order requisition. As Sonae Arauco works with a catalogue of products, there always is a safety stock guaranteed for wood-based panel components.

The MRP itself presents some shortcomings:

- **Capacity:** MRP expects the lead time to be constant despite how much work has been released into the production system, so it is implicitly assuming infinite capacity. This can create problems when production levels are at or near capacity. One way to address this problem is to make sure that the Master Production Schedule is capacity feasible. Advanced MRP systems provide more detailed capacity analysis proposing alternative production schedules when the current plan is not feasible;

- **Long Lead Times:** There are many pressures to increase planned lead times in an MRP system. MRP uses constant lead times when, in fact, actual lead times vary considerably. To compensate, planners typically choose pessimistic estimates. Long lead times lead to large Work-in-Process (WIP) inventories;
- **Nervousness:** MRP is typically applied on a rolling horizon basis. As customer orders firm up and forecasts become better, a new Master Production Schedule is fed to MRP, which produces updated planned order releases that may differ from the original. Even little changes in the MPS can result in substantial modifications in planned order releases.

The MRP weaknesses presented above and the different method used in purchase planning create a significant problem in the adherence and the ability to perform the production plan.

To improve the customer service level with measures concerning this problem, the following scenarios were framed:

- **As-Is Scenario:** The production planning and purchase planning are not synchronised. Furthermore, the purchasing teams are not working closely inside the supply chain department, creating even more barriers to effective planning between the requisition of materials and the finished goods' production;
- **To-Be Scenario:** Incorporate the purchasing team inside the supply chain team. The raw materials need to be planning using the same methodology of production planning. The master planners and the purchasing team need to work closely to ensure the suppliers' ability to deliver on time and in full the materials requested.

The first step is to transfer the purchasing team to under the supply chain group director's umbrella or create a new team exclusively focused on purchases related to production to improve the customer service level with the synchronisation between purchasing and production planning. The team will follow the same principle as the other supply chain teams with a team leader and purchase planners.

The organisational structure presented to the SC Group Director is displayed below:

More than creating a structure to emphasise the importance of the coordination between those functions, it is needed to use a different method for purchase planning.

Two hypotheses were discussed with the SC Group Director:

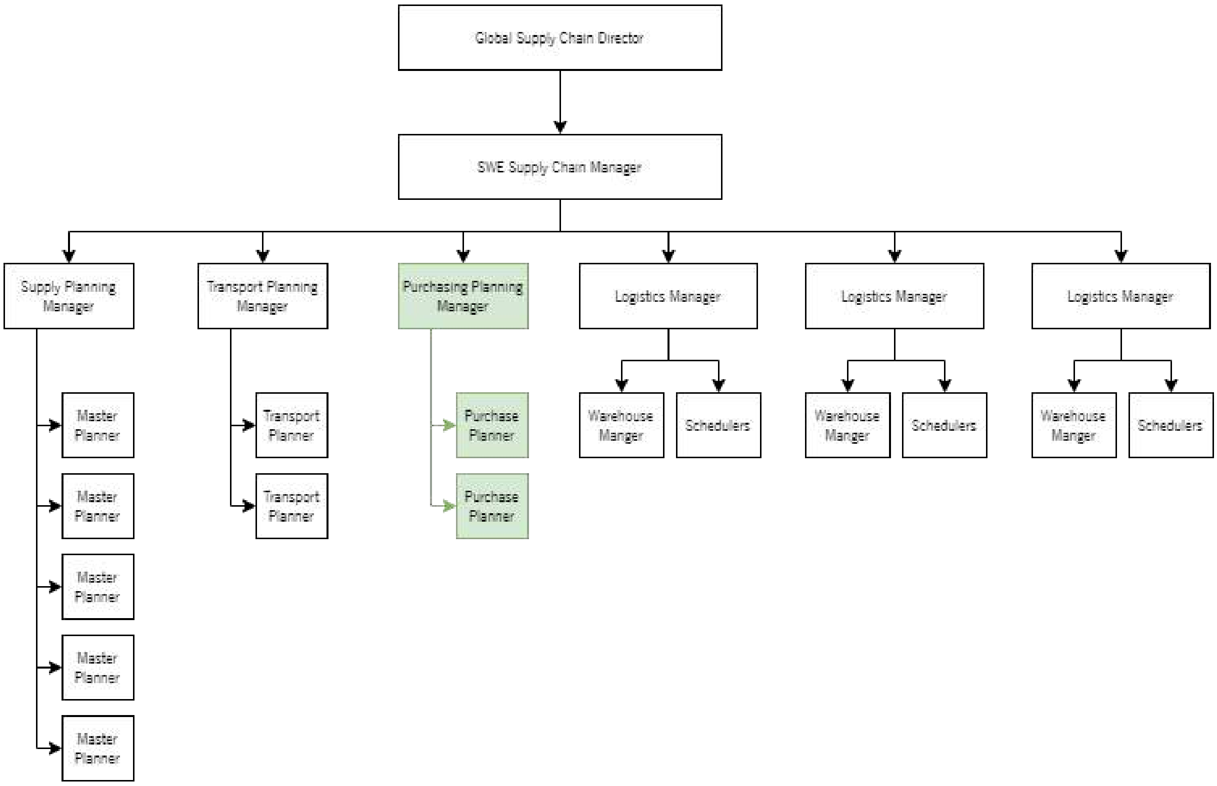


Figure 5.7: Proposed Supply Chain Department's Structure

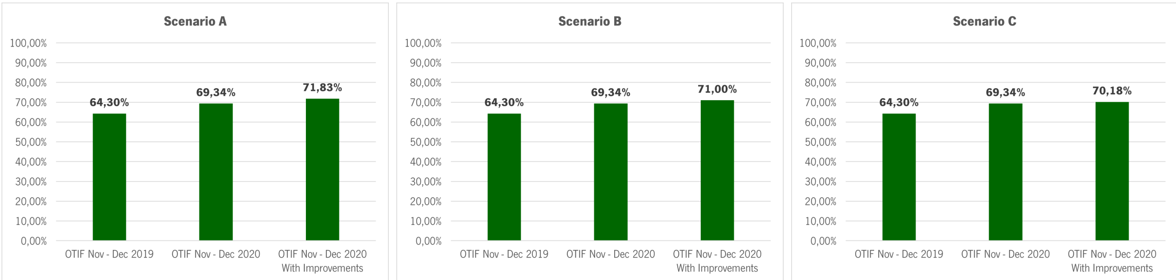
- Change the MRP System in use due to the shortcomings presented previously;
- Use the same MRP system for purchases' planning.

The first scenario was rejected due to the high costs of a completely new system or the SAP system's total restructure. The Covid-19 played a crucial role as the company limited the investment during the pandemic time.

The second one was tested on a theoretical level, simulating various scenarios to understand how much benefit will it bring to develop a new team for those purposes. The customer service level hypothetical improvement was studied on three scenarios:

- **Scenario A:** 75% of the sales order items improve with the Delay Reasons related to the lack of materials improve to perfect orders;
- **Scenario B:** 50% of the sales order items improve with the Delay Reasons related to the lack of materials improve to perfect orders;
- **Scenario C:** 25% of the sales order items improve with the Delay Reasons related to the lack of materials improve to perfect orders.

The scenarios presented above were tested, and the results are presented in the graphics below.



(a) SWE Region OTIF - Scenario A (b) SWE Region OTIF - Scenario B (c) SWE Region OTIF - Scenario C

Figure 5.8: SWE Average OTIF comparison between November-December 2019 to November-December 2020 - Improvement in the purchasing methodology

It is possible to draw some conclusions from the graphics above. The change in terms of purchase planning can positively impact the customer service level, even if the values are not on the targets defined. Also, with the change in terms of organisation, it is possible to develop and deploy new initiatives as two crucial teams: planning and purchasing are now working under the same umbrella.

5.2.2 New Methodologies in Warehouse and Transports

As the research project was developed in the supply chain central team that comprises both planning and transports teams, it was crucial to present another initiative, this time on the transport and warehouse level.

When studying the results obtained with the new model, the three reasons, regarding transportation and warehouse, that affect the most the service level were LT0, LT3 and LT6. Together with the transports central team, those reasons for failure were explored. Lack of truck capacity happens mainly in plants where there are in-plant responsibles for the assignment of trucks and transportation companies.

The transports central team was currently planning only the deliveries at Linares and is implementing a Transportation Management System. As soon as the current implementation is executed, this project will roll out to the other factories, like the project developed in Chapter 5. So, the topics where an initiative could be developed and deployed were LT0 and LT6. Following that, two scenarios were defined, for each reason:

- **LT0 - Truck not arrived or delayed**

- **As-Is Scenario:** Currently, the planning of transports is made using a First-In-First-Out approach. This methodology leads to long waiting times, and, consequently, some trucks do not have the opportunity to be loaded on the day they were supposed to. It can also negatively impact, as the long waiting times can result in unplanned safety breaks that are required to be done;
- **To-Be Scenario:** Together with the Transportation Management System implementation, a new approach for the planning of truck loading should be followed. With time-windows for loading, in-plant teams will ensure the trucks' correct loading and decrease the upstream problems.

- **LT6 - Truck not full**
  - **As-Is Scenario:** Some routes that are defined have serious difficulty in being performed on a regular basis. In consequence, numerous trucks cannot achieve the minimum quantities required for transportation. This leads to failure in meeting the client's requirements. Additionally, the dimensions of the products (weight and size) make the assignment of smaller trucks impossible for those routes;
  - **To-Be Scenario:** The company define an average value for the cost of performing these routes. The routes will be operated, and the improvement on the customer service level will be evaluated. This will be tested on a theoretical scenario using diverse hypothesis. Then the impact will be studied by the company's C-Levels.

To decrease the number of trucks with the delay reason *LT0 - Not arrived or delayed*, it is suggested to combine the Transport Management System with a Time-Windows approach compared to the actual First-In-First-Out methodology. With the system in use, the first truck to arrive is the first to be served, even if the panels' pallets are in further distances or with difficult access in the warehouse. Those factors increase the loading time and, in consequence, limit the number of trucks that can be loaded per day.

With a new approach based on Time-Windows, the warehouse team will prepare the cargo beforehand and decrease the loading time.

To develop a new system, some baselines need to be defined:

- Loading Time: average and standard deviation;
- Number of loading decks or loading spots;
- Number of forklifts assigned per truck.

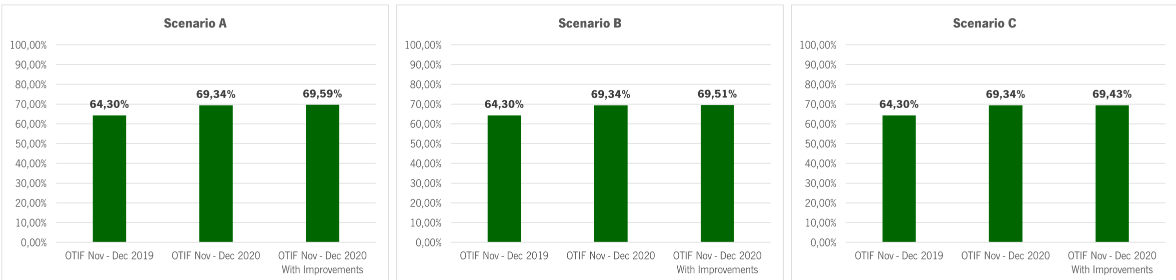
As the plants have different values for these guidelines, a specific approach needs to be developed in each plant.

For the Linares plant, the only one where the Transportation Management System is fully implemented, it was defined by the Transports Team that it is possible to load 50 trucks per day

It is also advised to use a location system within the warehouse to help in the forklifts' movements. This topic is explored further in the future research section.

The following scenarios were tested to understand the possible outcome with the Time-Windows:

- **Scenario A:** 75% of the sales order items improve with the Delay Reasons related to the *LTO - Truck not arrived or delayed* improve to perfect orders;
- **Scenario B:** 50% of the sales order items improve with the Delay Reasons related to the *LTO - Truck not arrived or delayed* improve to perfect orders;
- **Scenario C:** 25% of the sales order items improve with the Delay Reasons related to the *LTO - Truck not arrived or delayed* improve to perfect orders.



(a) SWE Region OTIF - Scenario A (b) SWE Region OTIF - Scenario B (c) SWE Region OTIF - Scenario C

Figure 5.9: SWE Average OTIF comparison between November-December 2019 to November-December 2020 - Improvement in the LTO

From the analysis of the scenarios illustrated in the previous graphics, it is possible to draw some conclusions: the implementation of time windows per se would not impact the OTIF significantly in terms of the number of trucks loaded per day. Instead, it creates room for improvements in the transports and warehouse management, being more the first step for a more meaningful initiative.

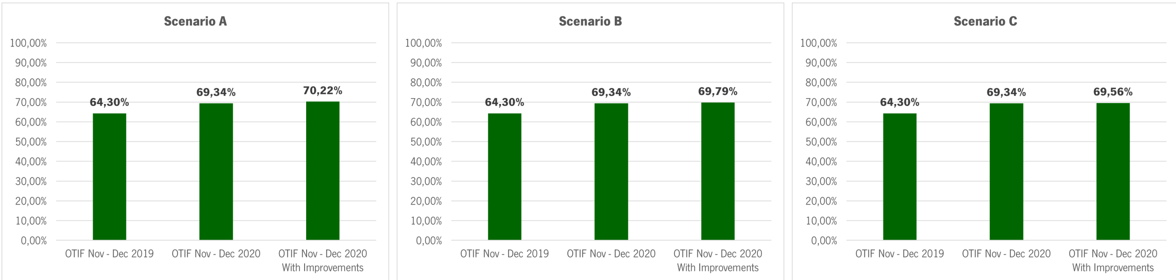
When analysing the second most impactful reason for logistics, it is suggested to study a trade-off between cost and a better customer service level.

As explained previously in this research project, most of the sales order items are fulfilled by a plant or distribution centre within that country, unless some specific materials are only produced in one plant.

Furthermore, the SWE Region comprises only the Iberian Peninsula. Consequently, there are short travel times between the plants and the customers. Due to those factors, a cost of 500 euros was defined, corresponding to deliver a truck not-full within the area described.

A scenario-based approach was followed to evaluate the improvement in terms of customer service level if the company decide to send those trucks with the additional cost:

- **Scenario A:** 100% of the trucks related to the *LT6 - Truck not Full* are delivered, in consequence, those sales order items improve to perfect orders;
- **Scenario B:** 50% of the trucks related to the *LT6 - Truck not Full* are delivered, in consequence, those sales order items improve to perfect orders;
- **Scenario C:** 25% of the trucks related to the *LT6 - Truck not Full* are delivered, in consequence, those sales order items improve to perfect orders.



(a) SWE Region OTIF - Scenario A (b) SWE Region OTIF - Scenario B (c) SWE Region OTIF - Scenario C

Figure 5.10: SWE Average OTIF comparison between November-December 2019 to November-December 2020 - Improvement in the LT6

Additionally, calculating the costs for the three scenarios it is possible to conclude:

- **Scenario A**: Corresponds to the improvement of 100 sales order items with the LT6 delay reason. For that improvement it is considered a cost of 50.000 euros.
- **Scenario B**: Corresponds to the improvement of 50 sales order items with the LT6 delay reason. For that improvement it is considered a cost of 25.000 euros.
- **Scenario C**: Corresponds to the improvement of 23 sales order items with the LT6 delay reason. For that improvement it is considered a cost of 12.500 euros.

5.2.3 Results' Analysis

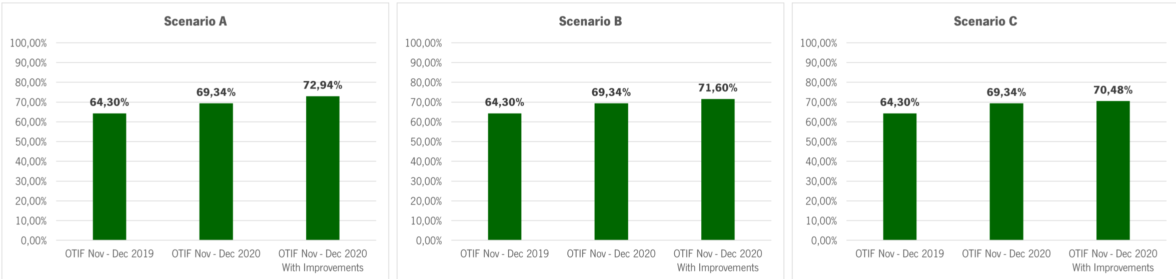
The proposals for the long-time strategies that are crucial for improving the customer service level have a significant impact on the OTIF. Therefore, it is imperative to analyse how would be the behaviour of this KPI if all the scenarios were combined and the expected results achieved. Accordingly, a comparison between the three stages was defined: optimistic, pessimistic and an intermediate one.

It is illustrated in the Figure 5.11 the impact on the OTIF.

As presented in the previous section, only improving the sales order items with the LT6 reason results in costs for Sonae Arauco, so it is possible to conclude:

- **Scenario A**: For the improvement in Scenario A, a cost of 50.000 euros is considered.
- **Scenario B**: For the improvement in Scenario B, a cost of 25.000 euros is considered.
- **Scenario C**: For the improvement in Scenario C, a cost of 12.500 euros is considered.

As presented, with those values, Sonae Arauco would improve the customer service level by 3 pp % to 71.96%. The target for the SWE Region OTIF is 75%, so, even with those initiatives, it is impossible to reach



(a) SWE Region OTIF - Optimistic Scenario (b) SWE Region OTIF - Intermediate Scenario (c) SWE Region OTIF - Pessimistic Scenario

Figure 5.11: SWE Average OTIF comparison between November-December 2019 to November-December 2020 - Combined Improvements

the target defined. However, if those new initiatives are developed, they will create a direction of change and the pursuit of improving other areas. As it is possible to see, implementing the decision support system created more awareness of the existent failures, allowing a significant improvement compared to the results in 2019.

To sum up, it is relevant to state that these are not standalone measures but only the stepping stone on pursuing "excellence" on the OTIF level. These create room for even more significant improvements' projects while solving the most impactful problems. Combined with the decision support system will undoubtedly increase its competitiveness and the overall satisfaction of its customers.

6. Conclusion

This closing chapter aims to go through the main findings in this master thesis. It critically reviews the answers to the research questions that were the main driver of this research project. The managerial and theoretical implications of a decision support tool for uncovering the main delay reasons will be explored. The process used in creating this system will be addressed as a complement to the stage-gate model, highlighting the advantages of using this method in a project involving multidisciplinary teams. It concludes with suggestions for possible developments in the field and in the work developed.

6.1 Critical Analysis of the Results

This research project was developed in the supply chain department of Sonae Arauco, a world-class manufacturer of wood-based panels. Its ultimate goal was to identify the leading root causes for the poor service level and develop a decision support system that would identify those causes and, consequently, recommend improvement directions that would enable Sonae Arauco to improve its service level. Together with that, it was necessary to create a better supply chain risk management process.

Merging the information extracted from Sonae Arauco's ERP system with a stage-gate based methodology, resulted in a structured approach for multidisciplinary teams working in a process improvement project. This new approach is considered an addition to the literature related with the stage-gate methodology and process improvement projects.

In the case study definition, it was required to understand all the supply chain department hierarchy and critical responsibilities. Additionally, the role of each plan in the manufacturing network was defined: products manufactured and interdependencies.

It was necessary to understand and design the current order-to-delivery- process and the process related to the definition and assignment of delay reasons for sales order items with OTIF equal to 0%.

Following a clear definition of the case study, the analysis phase started with describing the KPI used by Sonae Arauco to measure the service level and outline the immense "area of unknowing" related to the problem that was being studied. Doing this, it was found that 71% of the sales order items with OTIF equal to 0% had been "not assigned" with a delay reason.

Furthermore, the framework behind the "as-is" process was studied to allow the correct diagnosis and direction of change. Moreover, it was studied the customer service level performance in the different plants from different perspectives.

After that detailed analysis, the improvement proposals studied were divided into short-term and long-term strategies. The first focused on developing a new framework to identify delay reasons and a new reporting process based on a decision support system. The second aimed to improve the customer service level with initiatives on two vectors: synchronisation between purchasing and planning and new methodologies in warehouse and transports, representing the more impactful delay reasons.

Accordingly, with the estimated results for the short-term improvement proposal, the development and implementation of a new reporting process and decision support system it was obtained:

- Decrease in the area of unknowing related with delay reason, around 35%;
- Increase in the variety of the precise delay reasons, around 50%;
- The automatic process is now capable of assigned almost 70% of sales order items.

Although, even with these results, it is still impossible to have a system working on the target defined for the customer service level. This decision support system is now implemented and being used throughout all the SWE Region's plants. More than that, it is being developed to be adopted by all the other Sonae Arauco's plants.

For the long-term strategies, the theoretical results were not as promising as the ones presented before. However, the company is now switching the supply chain department structure to incorporate the purchasing team. The arguments presented in this dissertation supported that decision. They were pretty relevant in creating the awareness of how important it is to have the purchasing team connected with the planning team. Sonae Arauco expects even better results than the theoretical ones from this structural change.

With this approach was possible to answer the three questions defined at the beginning of this project:

- **What are the root causes that increases the risk of disruptions in the supply chain of Sonae Arauco?** The root causes were defined in table 5.1. Additionally, a glossary was defined to create a standardised understanding between all the plants;
- **Which root causes influence the system the most?** It was possible to determine that the root causes with more impact on the system were: Lack of Raw Materials (PL0, PL1, PL2), Lack of SFG

(PL3, PL4), Truck not arrived or delayed (LT0) and Truck Not Full (LT6), explored in the long-term strategies;

- **How can the reporting process be improved?** The reporting process was improved using a stage-gate based approach allowing the contribution of different teams. A new conceptual hierarchy model was created for delay reasons to create accountability between the different supply chain teams. New delay reasons were set based on the new functional areas defined, and a standardised definition was provided. Moreover, a new process was developed to monitor the reporting within the ERP system and defined new procedures and processes for the teams. This new reporting process was transformed into a decision support system to help the management team make decisions based on data.

In the following sections, it will be described the managerial and theoretical implications.

6.1.1 Managerial Relevance

This research project brings with it managerial implications not only directly related to the new decision support system and the decrease of the ”black-box” related to the poor service level but also concerning the underlying benefits of using a stage-gate based methodology to process improvement initiatives when multidisciplinary teams are involved.

It supports not only the need to have a structured approach in process improvement initiatives involving multidisciplinary teams. Also, by combining the innovation of the stage-gate methodology with the structure of the data collected from the ERP System, it is possible to create practical solutions and create more robust processes.

Ultimately, this approach can support initiatives by removing the functional silos existent between the multidisciplinary teams by granting greater communication and feedback points than usual methods.

To executives working on the process improvement, it shows how the time to develop new processes can be decreased using gate points to guarantee the alignment between all the parties. To Sonae Arauco’s Supply Chain executives, the new decision-support system created with this methodology helped decrease around 35% of the area of unknowing. Besides, it shows the impact that such an innovative solution can bring to the visibility of the supply chain operations, taking advantage of the best qualities of each team and creating a process that fits the pursuit of excellence. Supporting the use of this methodology in new initiatives will contribute to becoming a spur for better processes and giving transparency, awareness, and a sense of belonging to every team, creating a more stable base between all the supply chain functions. It also allows them to become more effective in their work as this methodology incorporates functions from other areas. In this dissertation, the close work of the IT Team throughout this process improvement project was essential to grant the data visibility and the creation of such a data-driven decision-support system.

In terms of the collaboration for the process improvement, it became evident how it is necessary to have the multidisciplinary teams working together. The "as-is" process understanding of the central supply chain team combined with the in-plant experience of the supply chain in-plant teams and the ERP knowledge from the IT team was essential to the promising results of this new reporting framework. The management team was confident that without using the stage-gate-based methodology, it would be impossible to have all the teams working together without any skillset barriers or other obstacles.

As the main goal for today's companies is the customer service level, every action works around the customer. Therefore, the different teams must be aligned to guarantee the product is delivered on time expected by the client. For that to happen, both the central and in-plant teams must be intimately connected in every action. More than that, to allow the supply chain team to create new initiatives to develop the customer service, the IT team must provide reliable and precise data. Furthermore, they need to create support systems based on the supply chain reality, but with the technology and know-how only possible to be developed by them. In the specific case of this project, the contribution of the sales and commercial team was also crucial for the understanding of the main customers' pain points.

For any process improvement team, the long-term goal must be having projects in which business functions are so tightly aligned that it is hard to create a separating line between them, creating more robust processes for the organisation.

6.1.2 Theoretical Relevance

The research scope of this dissertation has the goal of not only contributing to the literature on the importance of uncovering service failures- with particular interest on the customer service level and the KPI OTIF but also to the benefits of the use of a stage-gate based methodology when developing process improvements projects.

The hope is that this master thesis can facilitate the development of how process improvement is approached and be beneficial for process improvement executives in reflecting and understanding their process change projects. Moreover, for them to acknowledge the benefits of using an approach that stimulates the interaction and connection between different teams and use their best skillsets to transform and disrupt business and operations processes.

Also, based on the stage-gate framework first introduced by Cooper (1990), this work aims to add to the research on this methodology ability to transform the way process improvement projects are dealt with. Closing gaps between different teams while maintaining a customer-driven focus and the top management involvement, together with tough go/kill decision points and how they can tangle in a real case study environment, supports what could be the future of process improvement. For researchers in the vast process improvement field, it may serve as an opportunity to identifying more effective ways to enhance cross-functional teams collaboration and accelerate improvement projects with better in-company project success (speed, scope, prioritization, and budget).

6.2 Limitations Faced

This chapter aims to describe the several challenges felt over this research project, focusing on collecting data, implementing a different methodology for process improvement and the impact the Covid-19 pandemic had on the project development.

The existence of functional silos, diverse access to information, different understandings for the exact same topic, and many uncovering areas to explore were some of the biggest challenges intensely experienced over the execution of this project.

1. **Data collection:**

   The correct data analysis is the foundation for any improvement process project. Therefore, it is evident that the data's proper structure and content are fundamentally relevant.

   Sonae Arauco already had a web app to collect the SAP data and transform it into visual dashboards. However, it was noticed that much of the data collected from there presented some false information. More than that, it was required to analyse data provided by the different Logistics Managers. Their information was vague, not standardised and often very dubious. Also, although the SAP was running and supporting the entire operation together with Qlikview, many steps were still performed manually. This meant that direct observation was needed regardless because the information at disposal was not enough to get a sense of the full range of inefficiencies.

Another challenge was in the way the system was automatically assigning delay reasons. There was no information on the procedures and routines used by the SAP, and it was required to discovering it by diving deep inside the transaction in use.

Furthermore, when the Logistics Managers were performing their monthly reports, the codes and definitions used for the delay reasons were not the same for all of them. Constant contact was required to define and design the "as-is" process and the data analysis method.

2. **Process Improvement Methodology and Functional Silos:**

   One of the benefits of the stage-gate methodology is the enhanced connection between cross-functional teams. As the project required people from different teams, this approach sounds very appealing for driving this process improvement project.

   The author of this dissertation found many functional silos, and the teams were working individually when developing and designing new processes. The teams were only meeting if required to get some information and not working closely on the project. This was one of the significant barriers in implementing such a methodology that pursuits the interconnection and intimately connected work.

   To overcome that it was defined ground rules for the projects and created interdependencies between different teams work. Additionally, biweekly meetings were defined, and a member of each team was present in most gates' decision body helped in overcoming this barrier.

3. **Covid-19 context:**

   One of the advantages of a decision support system based on data mining is the capacity to translate data into relevant insights, turning "Hows" into "Whys" without going through difficult, dull, and complex observations of how the process is executed or performing. However, in the Analysis phase, after having a concise story to tell based on the data collected and the answers gathered, it is necessary to dive deeper into the root causes of the process, which are hardly transparent in the data.

Even though a stage-gate-based methodology can accelerate process improvement projects by connecting cross-functional teams, involving top management, and focusing on the customer, it requires permanent contact between all the bodies.

This is even more important when studying complex processes that depend on multiple variables, such as a manufacturing network disperse into two countries with interdependencies. Because this case study was entirely in a company environment, the pandemic context put a break on the meetings, contacts with the Logistics Managers and weakened the opportunity to observe directly how the plants were operating. Additionally, the Covid-19 context made it impossible to rely on some data due to the closing of borders, trucks staying with our products throughout the pandemic and customers closing due to the sanitary measures implemented at different times by the different countries.

6.3 Future Research

Ideally, in a process improvement project that comprises a data-driven decision support system, it would have gathered and understood data proactively and created some predictive intelligence out of it. In a second phase, it would be possible to predict the failures the system will present. The decision support system will serve as a guide for new initiatives by providing correct data but also will help the supply chain team act beforehand and prevent delivery failures. Additionally, statistical analysis can be done with the predictive data to understand how reliable and effective is the developed system.

The exploratory data analysis that is conducted in this research project is the basis of the proactive data mining methodology. With this analysis, it is possible to create the path to enable the use of predictive techniques in the company allowing the creation of proactive strategies to mitigate risks, while developing the need of transparent and reliable date in the decision-making process.

In addition and focusing on the customer service level, it would be precious to do further research on the impacts of the new decision support system. A new version should be developed to overcome some problems found in the first version and allow a complete identification of the delay reasons to all the sales order items with OTIF = 0%. Still in the decision support system, it is necessary to further develop the shop floor control connection and to aggregate this function with the model already created to ensure even better and more reliable and relevant results. Furthermore, the focus should be on training the teams and guaranteeing that the process and the procedures are being done.

A third path for future research is related to the long-term strategies defined in the previous chapter. At the time of the project, Sonae Arauco did not have any location system implemented in the warehouses. A project was being developed on the warehouse's layout and capacity but not on strategies for locating the products. It would be advised to develop a new method focusing on positions inside the warehouse to facilitate access to some pallets. In the literature, it can be found that some methodologies can be adopted, such as barcodes or RFID.

Besides the focus on the operational side of this new decision support system and the advantages of using correct data to support new improvement initiatives, further research can be performed on how process improvement projects can be leveraged using this stage-gate-based methodology to generate more impactful process innovation. This approach of enhancing the cross-functional teams' connection and hard decision points may contribute to developing and designing new processes along all the company business functions. Also, more research is needed on how this approach can foster companies to develop a more fluid way of daily working.

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A. Qlikview: Dashboard System

Qlikview is the system used by Sonae Arauco to create dashboard directly from the data collected in the SAP. The main dashboard used during this researh project was the dashboard *Service*.

A.1 Qlikview: Overview

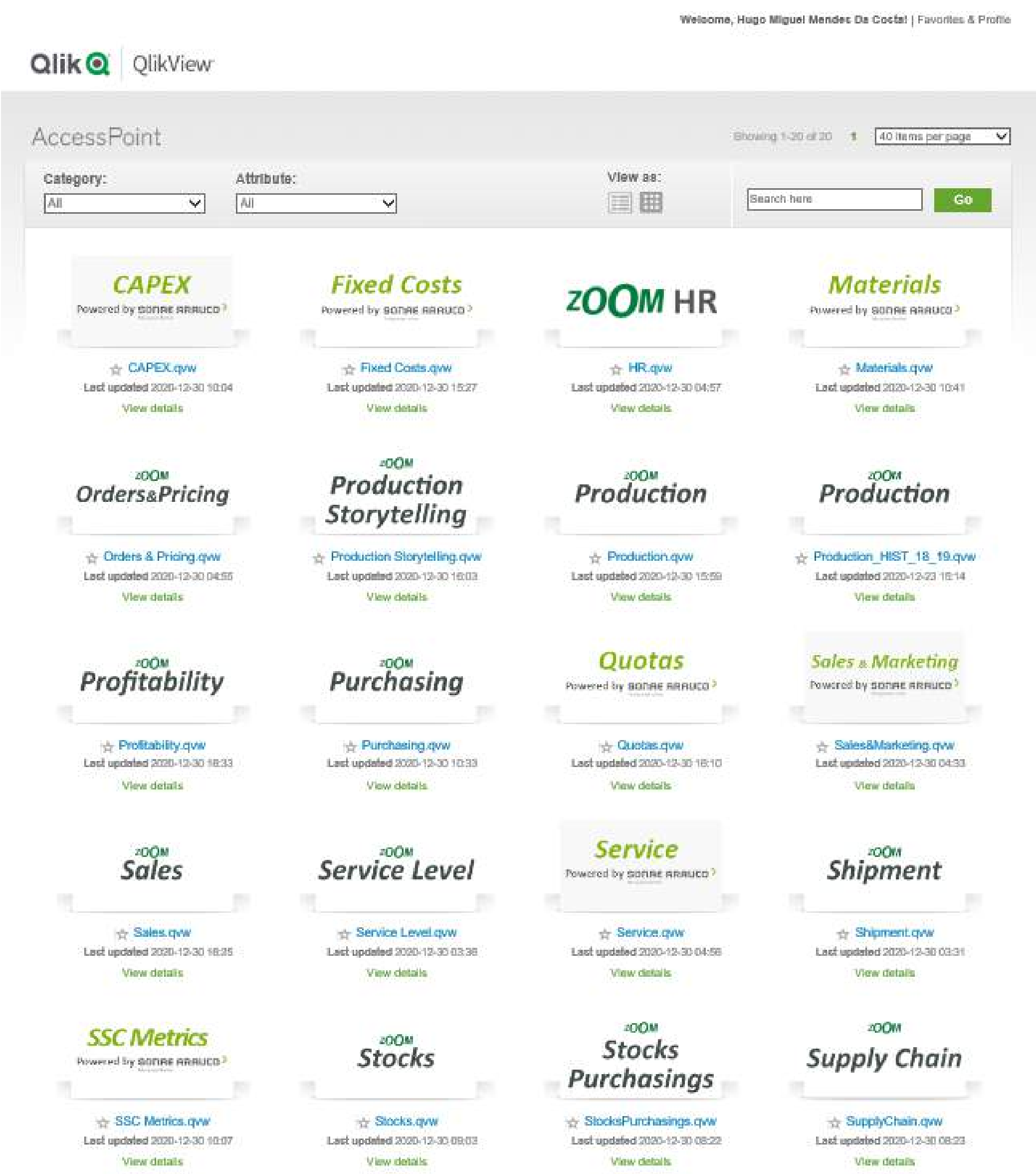

Figure A.1: Qlikview Dashboard

A.2 Qlikview: Service Dashboard

The Service Dashboard present diverse filters and allows the user to create custom views. It shows every information related with the KPI OTIF and the variation between the Lead Time confirmed to the customer and the actual Lead Time. It can present preset graphics as highlighted in the next subsection.

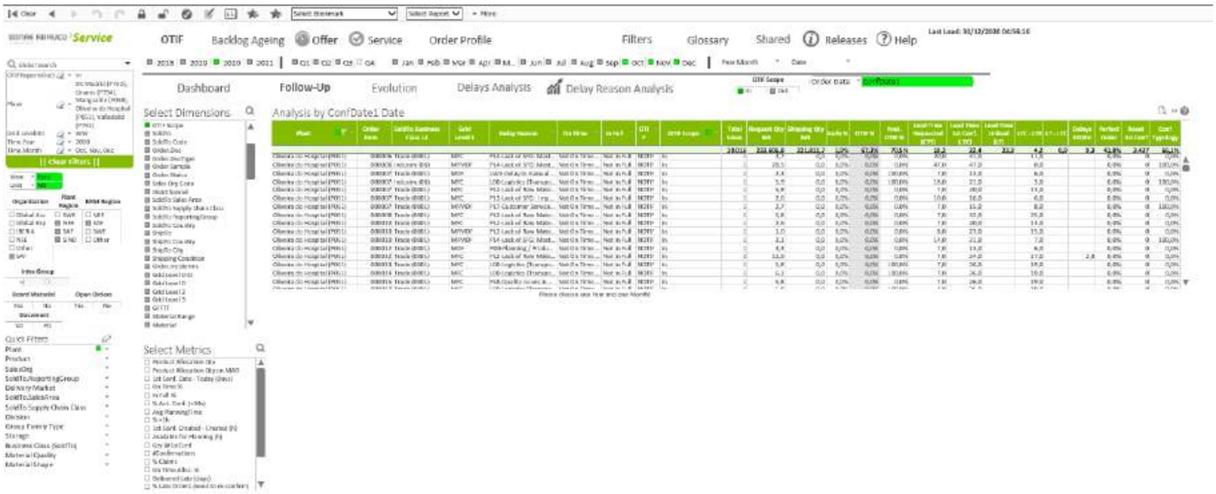

Figure A.2: Qlikview: Service Dashboard Overview

A.2.1 Service Dashboard: OTIF and Target

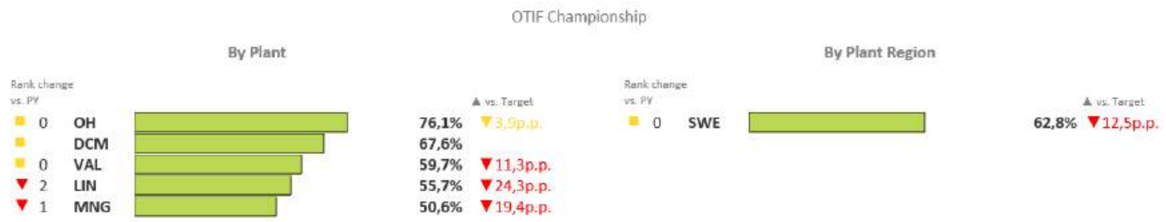

Figure A.3: Qlikview: OTIF and Target for the SWE Region

A.2.2 Service Dashboard: Pareto Graphic

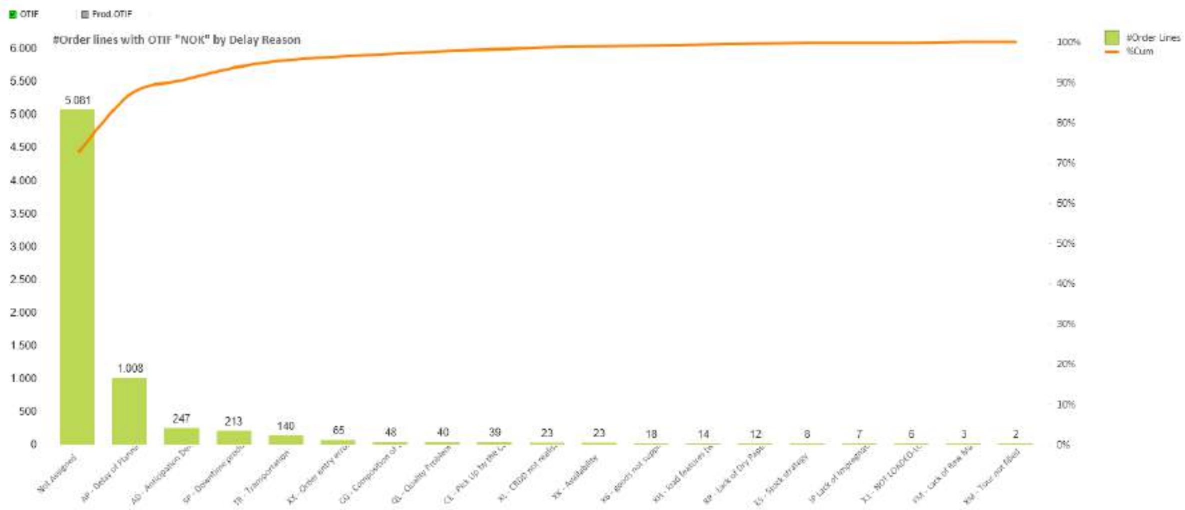

Figure A.4: Qlikview: Pareto Graphic for Delay Reasons

B. Customer Service Level Analysis: OTIF

B.1 OTIF per Plant

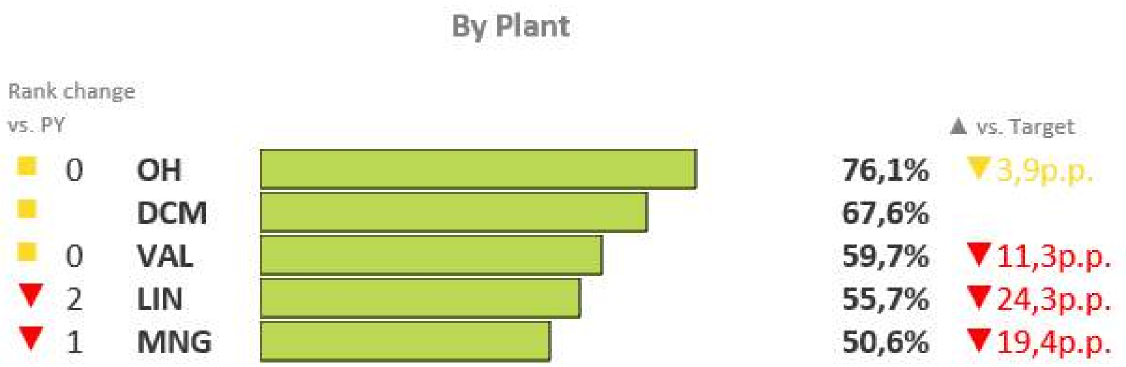

Figure B.1: OTIF per Plant, from September 2019 to February 2020

B.2 Review Report

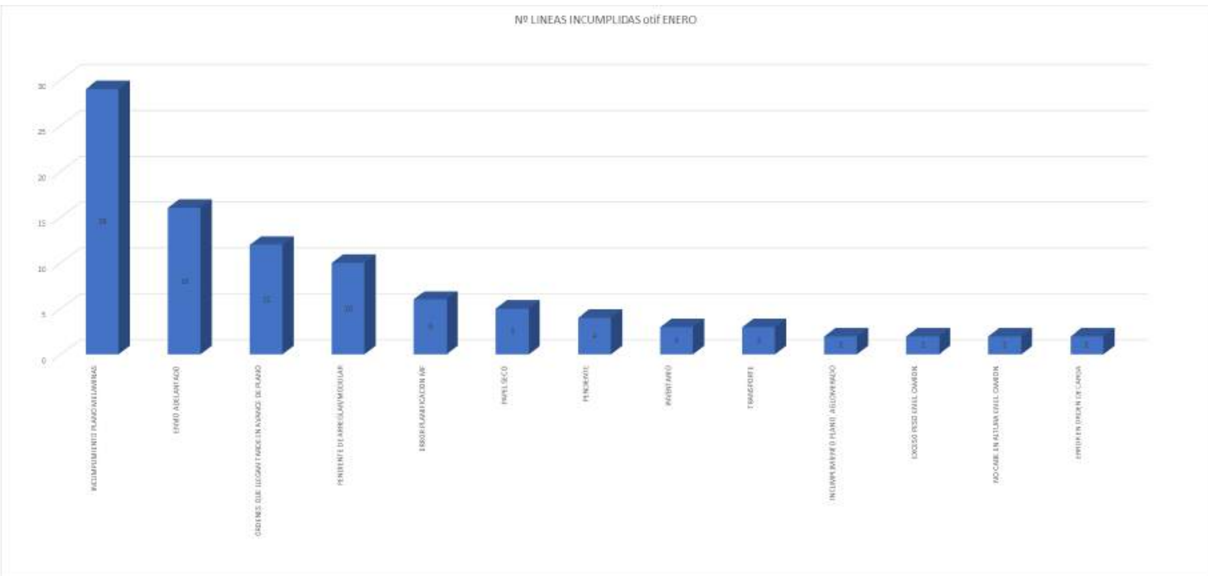

Figure B.2: Review Report January 2019 - Linares

B.3 Customer Segment Analysis

B.3.1 Industry - Global Key Account

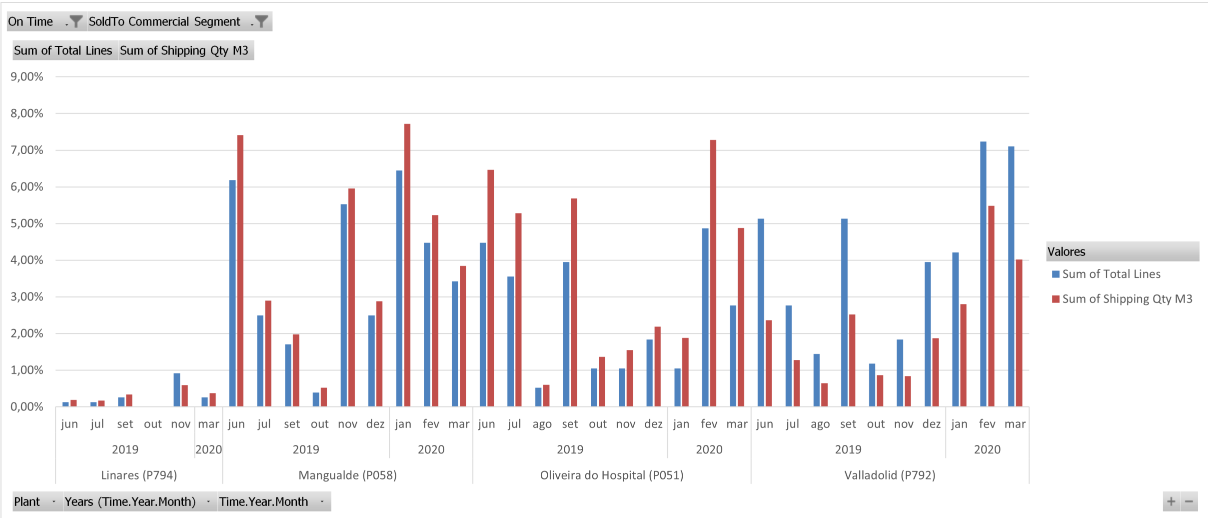

Figure B.3: Global Key Account Analysis

B.3.2 Industry - Key Account

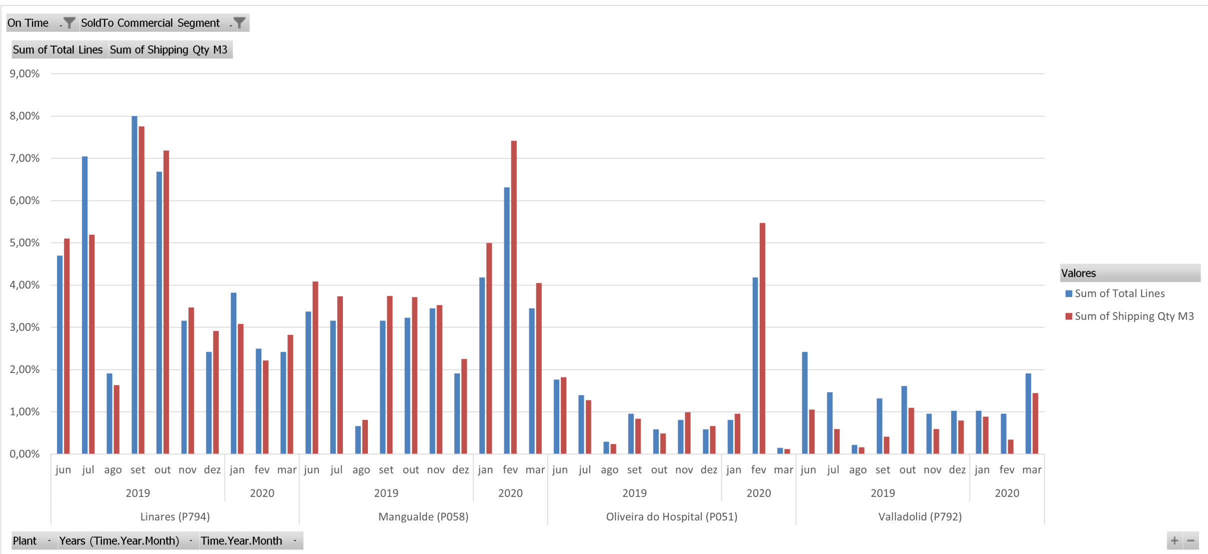

Figure B.4: Key Account Analysis

B.3.3 Industry - Standard Account

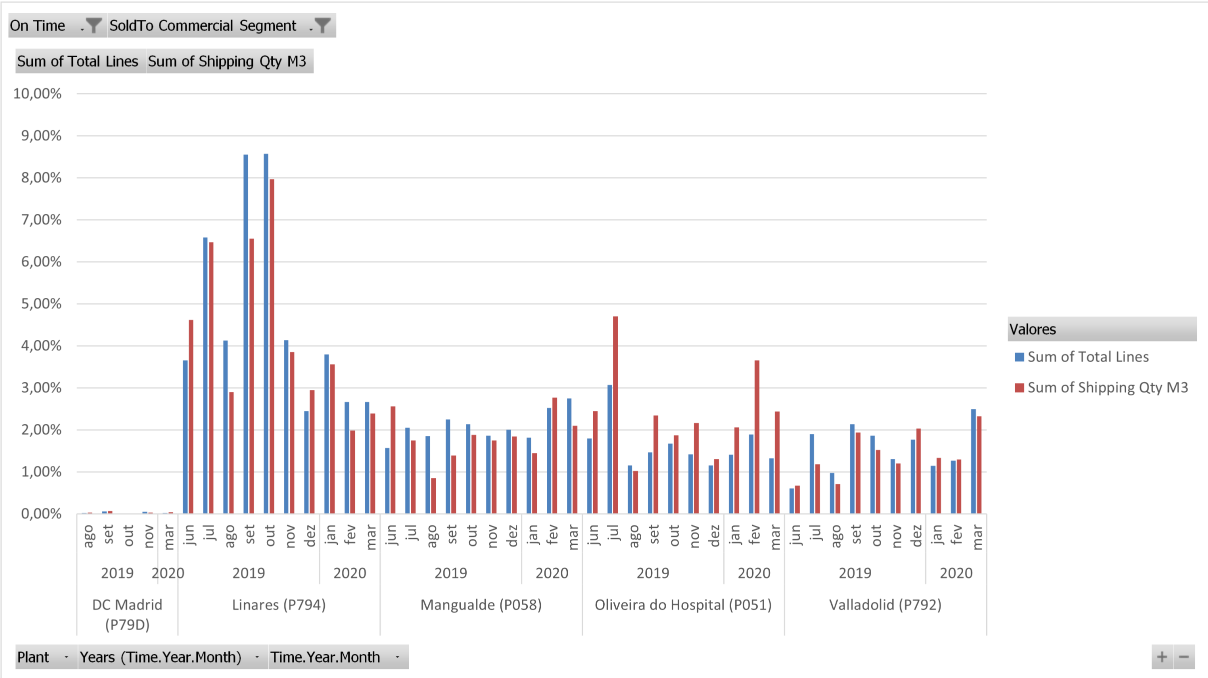

Figure B.5: Standard Account Analysis

B.3.4 Trade - Innovus Premium Dealer

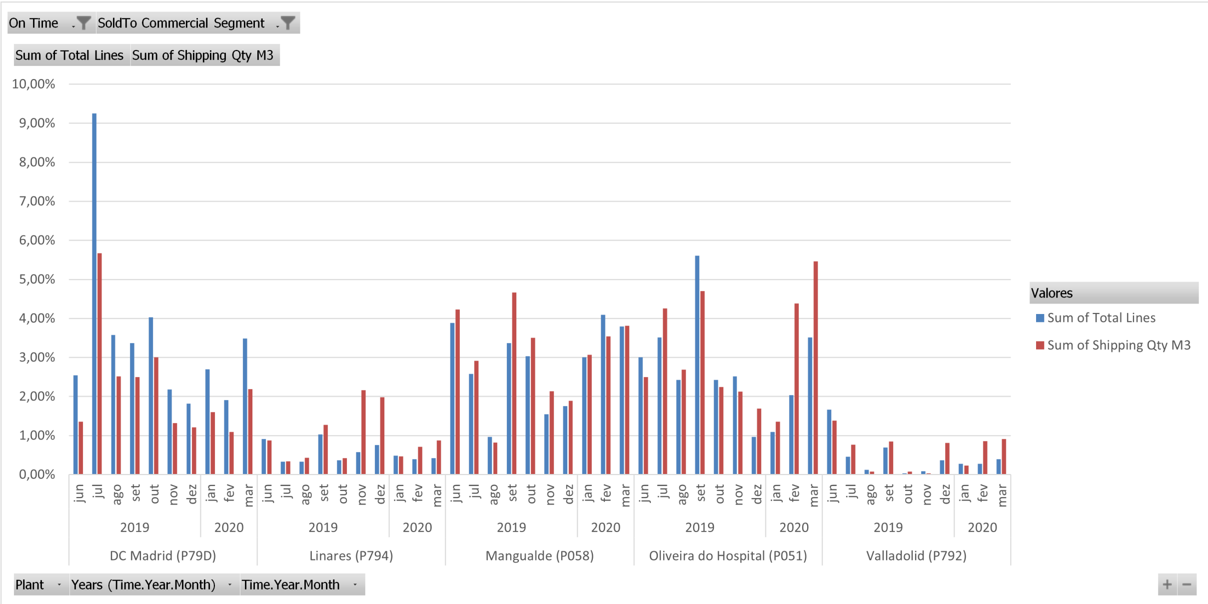

Figure B.6: Innovus Premium Dealer Analysis

B.3.5 Trade - Innovus Standard Dealer

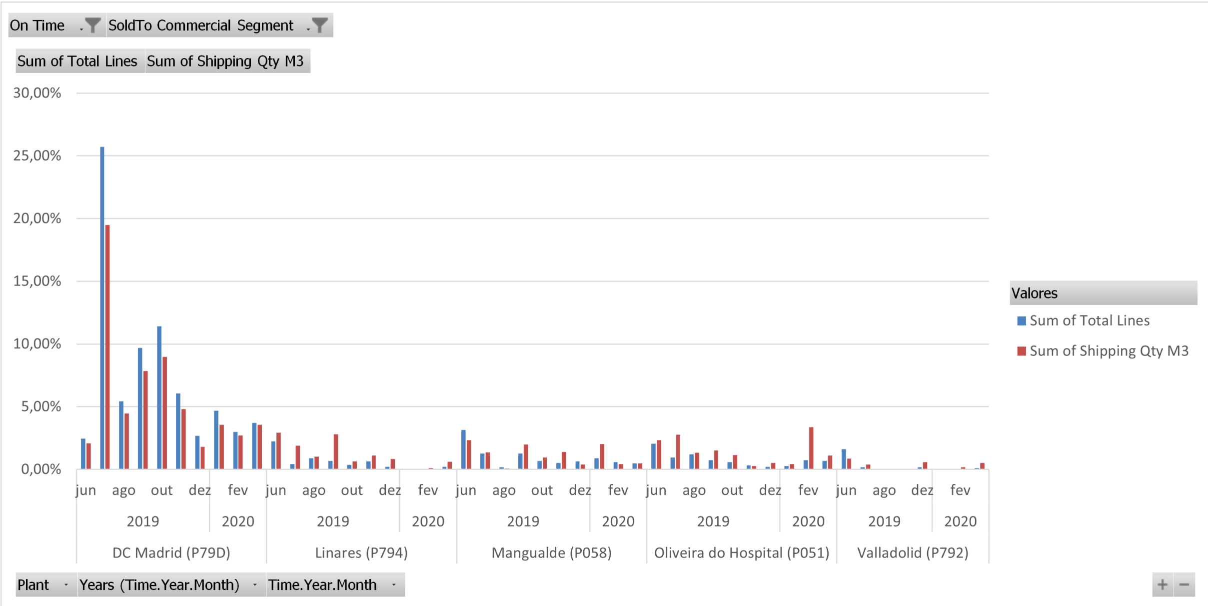

Figure B.7: Innovus Standard Dealer Analysis

B.3.6 Trade - Standard Dealer

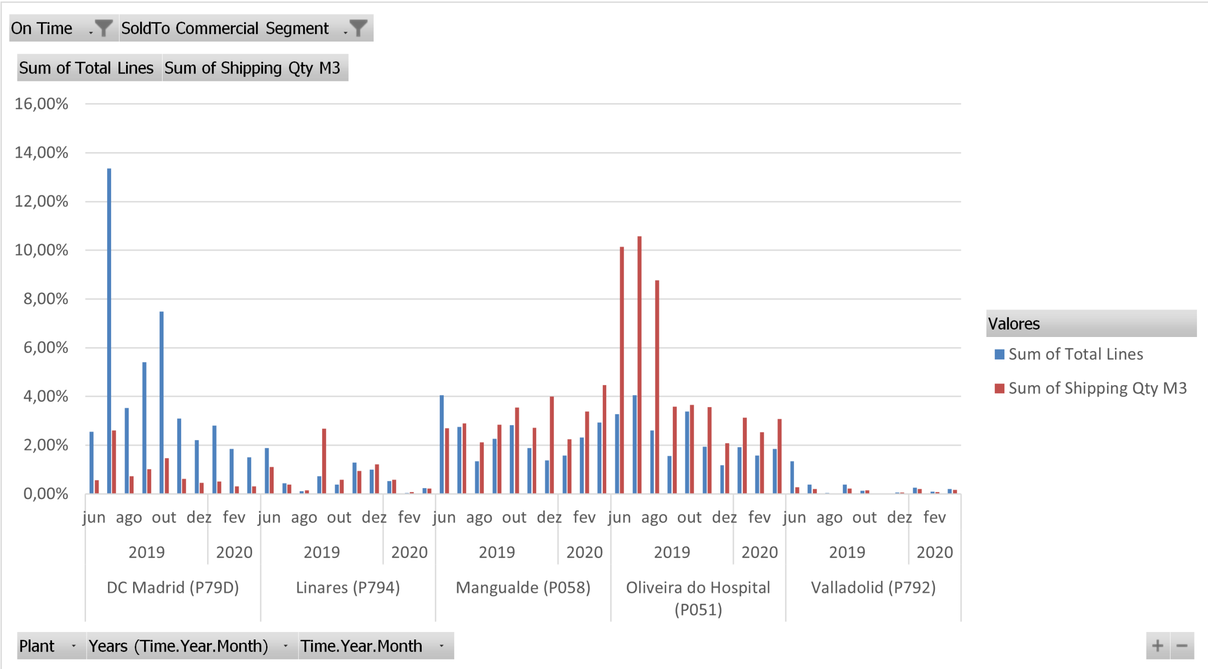

Figure B.8: Standard Dealer Analysis

C. Improvement Initiatives

C.1 Pilot Test in Mangualde

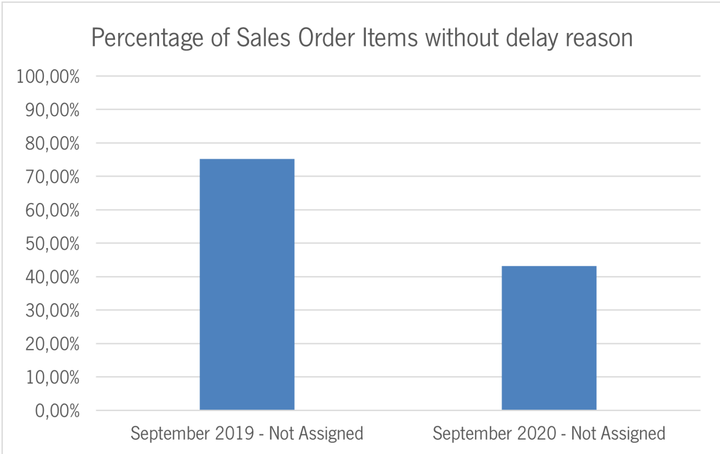

Figure C.1: Comparison between September 2019 to September 2020 - Mangualde Plant

Set'19		
EMPTY	**380**	
Not Assigned	380	75,25%
SALES	**1**	
CE - Pick Up by the Customer	1	
SUPPLY CHAIN	**124**	
AD - Anticipation Delivery	45	0,91%
AP - Delay of Planning/Production	79	
Total Geral	**505**	

Figure C.2: Precise Delay Reasons September 2019 - Mangualde Plant

C.2 New Decision Support System - Cruising Speed

L00-Logistics (Transport/Warehouse)	207	5,68%
LE0-External delay reason	72	1,98%
LT0-Truck not arrived or delayed	37	1,02%
LT1-Dimensions/Weight planned incorrectl	2	0,05%
LT2-Wrong vehicle type / defect truck	4	0,11%
LT3-Lack of Truck capacity	43	1,18%
LT6-Truck not full	103	2,83%
LT7-Complete delivery not possible	2	0,05%
LT8-Wrong delivery date	12	0,33%
LT9-Planned time different from execute	18	0,49%
LW3-Delay in manual packaging	12	0,33%
LW4-Layout/Capacity Issues	3	0,08%
LW5-Quality Release Delay	60	1,65%
LW7-Stock damaged	2	0,05%
LW8-Stock not found	3	0,08%
LW9-Stock quantity ≠ allocated	8	0,22%
LWA-Density value difference	1	0,03%
LWB-Packaging weight difference	2	0,05%
LWC-Loading mistake	3	0,08%
Not Assigned	1450	39,79%
P00-Planning / Production	351	9,63%
PG0-Lack in delivery group stock	133	3,65%
PL0-Lack of Raw Materials: Chemicals	110	3,02%
PL1-Lack of Raw Materials: Wood	25	0,69%
PL2-Lack of Raw Materials: Paper or Shee	84	2,31%
PL3-Lack of SFG: Impregnated Paper	26	0,71%
PL4-Lack of SFG: Master Board	150	4,12%
PL5-Master Data Issues	24	0,66%
PL6-Wrong Manual Replanning	229	6,28%
PL7-Customer Service Request-Commercial	50	1,37%
PL8-Quality Issues in Production	180	4,94%
PR1-Lack of personal in Production	22	0,60%
PR2-Technical Issues in Production	215	5,90%
PR3-Excess Production	1	0,03%
Total Geral	3644	

Not Assigned	2159	68,02%
AD - Anticipation Delivery	150	4,73%
AP - Delay of Planning/Production	515	16,23%
CG - Composition of Load	30	0,95%
ES - Stock strategy	7	0,22%
FM - Lack of Raw Materials	1	0,03%
IP Lack of Impregnated Paper	2	0,06%
QL - Quality Problem	34	1,07%
RP - Lack of Dry Paper	8	0,25%
SP - Downtime production	103	3,25%
TR - Transportation	93	2,93%
X1 - NOT LOADED-LOADING CAPACITY	4	0,13%
X6 - goods not supplied-warehouse	15	0,47%
XH - load features (weight,size...)	12	0,38%
XK - Availability	16	0,50%
XL - CRDD not realistic, becaus MTO	23	0,72%
XM - Tour not filled	2	0,06%
Total Geral	**3174**	

Figure C.3: Comparison between November and December 2019 and November and December 2020