Development and Implementation of a Production Ramp-up Plan of Wooden Modular Structures

Andreia Barros Alves Tavares Taveira

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Orientador na FEUP: Prof. Eduardo Gil Da Costa

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

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"Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less."
Marie Curie

Abstract

The development of a Production Ramp-up plan for wooden modular structures is critical for companies seeking to effectively and efficiently scale their manufacturing operations. Modular structures, characterized by their prefabricated components and standardized design, offer numerous advantages such as reduced construction time, cost savings, and enhanced flexibility. However, the unique challenges associated with ramping up production of modular structures necessitate a comprehensive plan that addresses key aspects of the whole supply chain.

This dissertation presents a systematic approach to developing a production ramp-up plan for a company dedicated to producing prefabricated and modular structures with wooden substructures through implementing Lean Management. It begins with a thorough analysis of initial production model with the identification of the areas of potential constraints in order to determine the optimal production capacity needed to meet customer expectations when implementing the new production model.

The plan then delves into supply chain considerations, by identifying the capabilities that require more careful attention for effective management of the Ramp-up Production phase. Therefore, in order to successfully manage production ramp-up in a phase marked by increasing complexity and uncertainty, the solutions designed throughout the project were developed in order to provide a continuous flow through the whole process.

The proposed production Ramp-up plan takes into account the modular nature of the structures, outlining strategies for workforce allocation, and addressing the need for a skilled and flexible workforce to accommodate varying production volumes during the ramp-up. Additionally, it emphasizes the importance of standardization and clear communication procedures by ensuring a continuous improvement culture to uphold product standards and minimize disturbances. The implementation of daily management accompanied by Daily Kaizen tools is identified to enhance a smooth transition to high-volume manufacturing products and at the same time attain the specific Production Ramp-up requirements.

The defined solutions have demonstrated to help better manage complex production systems launch by providing a strategic roadmap that aims to capitalize on the growing demand for efficient and sustainable construction solutions.

By addressing the key considerations in order to reduce non-value-added activities, organizations can effectively navigate the challenges of scaling production, optimize resource allocation and deliver high-quality wooden modular structures that meet customer expectations while achieving operational excellence.

Keywords: Production Ramp-up, Lean Management, Modular Structures, Supply Chain Management

Resumo

Desenvolvimento e Implementação de um Plano de Aumento da Produção de Estruturas Modulares de Madeira

O desenvolvimento de um plano de aumento da produção para estruturas modulares de madeira é fundamental para as empresas que procuram aumentar as suas operações de forma eficaz e eficiente. As estruturas modulares, caracterizadas pelos seus componentes pré-fabricados e pelo seu design personalizado, oferecem inúmeras vantagens, tais como a redução do tempo de construção, a poupança de custos e uma maior flexibilidade. No entanto, os desafios únicos associados ao aumento da produção de estruturas modulares requerem um plano abrangente que aborde os principais aspectos de toda a cadeia de abastecimento.

Esta dissertação apresenta uma abordagem sistemática para o desenvolvimento de um plano de aumento da capacidade de produção de uma empresa dedicada à produção de estruturas pré-fabricadas e modulares com subestruturas de madeira, através da implementação de uma Gestão *Lean*. Uma análise exaustiva do modelo inicial de produção de estruturas de madeira é conduzida, com a identificação das áreas de potenciais constrangimentos, a fim de determinar a capacidade de produção óptima necessária para satisfazer as expectativas dos clientes aquando da implementação do novo modelo de produção.
Em seguida, o plano aprofunda as considerações relativas à cadeia de abastecimento, identificando as capacidades que requerem uma atenção mais cuidada para uma gestão eficaz do aumento da capacidade produtiva Assim, para gerir com sucesso o aumento da produção numa fase marcada por uma complexidade e incerteza crescentes, as soluções concebidas ao longo do projeto foram desenvolvidas de forma a proporcionar um fluxo contínuo ao longo de todo o processo.
O plano de aumento da produção proposto tem em conta a natureza modular das estruturas, delineando estratégias para a necessidade de uma força de trabalho qualificada e flexível capaz de acomodar volumes de produção variáveis durante o aumento da produção. Além disso, enfatiza a importância da normalização e de procedimentos de comunicação claros, assegurando uma cultura de melhoria contínua para manter os padrões do produto e minimizar as perturbações. A implementação da gestão diária acompanhada por ferramentas Kaizen diárias é identificada com o propósito de proporcionar uma transição suave para sistemas de produção de grande volume e, ao mesmo tempo, atingir os requisitos específicos a esta fase de aumento da produção.
As soluções definidas demonstraram ajudar a gerir melhor a introdução de sistemas de produção complexos, fornecendo uma visão estratégica que pretende capitalizar a procura crescente de soluções de construção eficientes e sustentáveis.
Ao abordar as principais considerações para reduzir as actividades sem valor acrescentado, as organizações conseguem enfrentar eficazmente os desafios da produção em escala, otimizar a afetação de recursos e fornecer estruturas modulares de madeira de alta qualidade que satisfaçam as expectativas dos clientes e ao mesmo tempo alcançar a excelência operacional.

Palavras-chave: Aumento da Capacidade de Produção, Gestão Lean, Estruturas Modulares, Gestão da Cadeia de Abastecimento

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Acronyms and Symbols

BOM – Bill Of Materials

CEO – Chief Executive Officer

FMEA – Failure Mode and Effect Analysis

KBS – Kaizen Business System

KPI – Key Performance Indicator

LL – Lean Leadership

LM – Lean Manufacturing

MTO – Make-To-Order

OEE – Overall Equipment Efficiency

OPL – One Point Lesson

OSB - Oriented Strand Board

PDCA – Plan, Do, Check, Act

QCD – Quality, Cost, Delivery

TFM – Total Flow Management

TPS – Toyota Production System

VSM – Value Stream Mapping

WIP – Work-in-Progress

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1 Introduction

The present dissertation project was developed in a corporate context within the scope of the Master's Degree in Industrial Engineering and Management at the Faculty of Engineering of the University of Porto. The work developed describes the application of KAIZEN™ philosophy and methodologies in the industrial production of prefabricated and modular structures with wooden substructure resulting from collaboration between Kaizen Institute Western Europe and a company in the modular wood construction industry.

The rise of modular construction in the real estate and construction market as an opportunity for a step change from traditional construction to offsite manufacturing style production has been attracting a new wave of attention and investment over the last years. The change in consumer perceptions of prefab housing, the increasing concern for building more sustainable houses, the maturing of digital tools by facilitating the design of modules and the change in mindset among construction-sector Chiefs Executive Officer (CEOs) constitute strong factors to suggest that the future of housing lies in building sustainable wooden houses (Bertram et al., 2019).

Therefore, the repositioning of market strategy with the modular approach has the potential to yield significant cost savings and productivity. However, capturing the full cost and productivity benefits of modular construction is not a straightforward proposition (Bertram et al., 2019). Careful optimization of material resources and production processes is essential to achieve scale and efficiency. For that purpose, modular manufacturers must invest in a well-defined and structured business model and plant to increase productivity and respond to demand. One way to achieve that goal is to accelerate digitization, establish standards and keep operations lean with the use of the Lean philosophy.

The main purpose of this study and the project developed between Kaizen Institute Western Europe and the client entails analyzing the current situation and identifying the root causes of the constraints that impact production capacity and service level to design and implement solutions to leverage the company's position in the real estate and wooden prefabricated house construction sector.

In this first chapter, a brief introduction of Kaizen Institute Western Group and the company in which the scope of the master thesis is developed is provided. Followed with that, is presented the sector in which it integrates the project. Next, the scope, motivations and objectives to be achieved with the project are presented. Finally, the methodology to be developed during the project and the structure on which this dissertation is based are defined.

1.1 Modular Wood Frame Construction Industry

The Modular Construction Industry of Prefabricated and Modular structures with wooden substructures is an Industry that has been present for more than two centuries in the construction and real estate market and has undergone an extraordinary transformation from the 1830s to the present day. According to the Deluxe Modular (2019), the first prefabricated

house was created in London by John Manning in pieces to be moved and assembled then to Australia.

As time evolved, the concept of prefabricated structures beyond simple homes began to take on a different dimension with the rise of Catalog Houses between 1908 and 1940. The main point of the concept consisted in order one of the catalog's 400 house plans and receiving it in easy-to-construct sections. This program was a catalyst for modular construction by enabling Americans to recognize the benefits of this kind of construction: reduction of construction time and buying price. However, the prefabricated modular houses market faced a tremendous boom in the 1950s with the end of World War II. Nowadays, as demand began to exceed the supply of existing buildings, applications to other sectors have become an opportunity, especially in schools, offices, and hospitals facilities due to the reduced costs and construction time provided by this solution.

The study conducted by Bertram et al. (2019) affirms that with the increasing digitization, modular construction can deliver cost savings of up to 20 percent if done right, being the labor and housing shortages the biggest predictors for this increase of demand.

Figure 1 shows the economic power of this opportunity, in which the European market and the United States of America can reach more than $130 million.

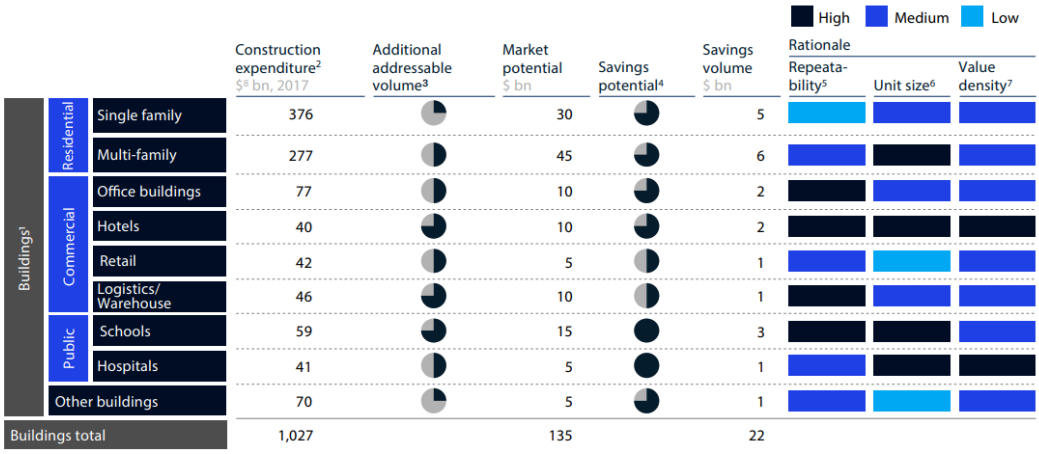


Figure 1 - US and EU savings of applying modular construction (Bertram et al., 2019)

Furthermore, many countries already show signs of having the appropriate conditions for the development of this industry, being Portugal one of these countries. The Portuguese market has been proving to be interesting and increasingly receptive. Therefore, many clients and investors are no longer limited to the traditional model. Seeking new materials and construction models, they rapidly understand the advantages of wood construction models and how they can be a solution for the high demand for houses, lack of labor and the increasing concern for sustainability.

Thus, it is in this context that the target company of the dissertation project is inserted.

1.2 Kaizen Institute Western Europe

Kaizen Institute Western Europe is a multinational company present in more than 60 countries that provides consulting and training services to companies and public institutions. Founded in Zug by Masaaki Imai in 1985, the purpose of Kaizen Institute is to support companies in the designing and implementation of processes to increase their performance and achieve exceptional results. At the present time, Kaizen has clients in more than 35 countries, with offices in more than 30 countries and performs projects in 14 different sectors, from discrete manufacturing to the public sector.

In Portugal, the Kaizen Institute has been operating since 1999 with some of the largest companies at national level and has more than 200 consultants in 3 offices around the country. The presence of Kaizen Institute in Portugal has been increasing over the last years and gaining visibility among the various industries in which it operates.

KAIZEN™ Philosophy

The word KAIZEN™ is the result of two Japanese words, "Kai" and "Zen", that mean change and better, respectively, which originated the KAIZEN™ philosophy and methodology. The main objective of this philosophy is to transmit a culture of continuous improvement by working directly with its customers to understand their problems and by training them to provide the required skills to solve the problems. According to the founder and president of Kaizen Institute and author of the Japanese word KAIZEN™, Masaaki Imai, KAIZEN™ is not only continuous improvement but is also everyday, everywhere and everybody improvement (Masaaki Imai, 1986). In other words, is a way where change for the better is turned into a daily habit with gradual improvements. Gaining support from the highest levels and from across the organization is essential for the effective application of Kaizen.

1.3 Project Framework and Motivation

This project focuses on the operational model of production of prefabricated and modular structures with wooden substructure of the client company.

The market for the construction of houses from wooden structures is a sustainable and competitive solution compared to steel and concrete structures, so its demand has been increasing by several investors and real estate agents. Thus, given the growing interest in developing carbon-neutral and high energy efficiency buildings in Portugal, it is necessary to ensure an adequate production capacity in view of the growth strategy and market positioning.

In this scenario, coupled with the need to ensure the start of production with the shortest possible lead time and at the same time meet the promised quality and sustainability requirements, it becomes imperative to establish an approach aimed at increasing the efficiency of the production capacity supported by a sustained management structure.

Considering Kaizen Institute's recognition as a consultant in the implementation and promotion of operational excellence and continuous improvement philosophy, the integration and application of the business model, KAIZEN™ Business System, aligns perfectly with the objective and needs raised by the client in question.

Thus, the integration in a project of application of the KAIZEN™ methodology in a Kaizen Institute's client, arises the motivation to contribute to the promotion and development of this philosophy.

1.4 Project Objectives

The scope of this project aims to respond to the challenge presented by the client to strategically position the company in the international sector of production, assembly and construction of sustainable houses prefabricated in wood, using modular construction technologies.

With this, the present dissertation project focuses on the development and implementation of a ramp-up production plan, to ensure a sustained long-term increasing of results of the core business. This increase in production capacity is based on the design of the company's operating model and project management for the assembly of the production line, focusing on the review of the current models employed, development of management tools for planning

and standardization of the production process and logistics with the support of KAIZEN™ philosophy.

Given the objective outlined, the importance of quantifying and evaluating the success of the model arises, by defining a main objective at the project level, supported by operational objectives.

At the project level, it was defined as objective the creation of flow across the entire organization, namely at the level of ordering, procurement, purchasing, planning and operations. With this, it is expected to achieve improvements in communication between the various departments, planning visibility, efficiency and autonomy of employees with a culture of continuous improvement and flexibility.

At operational level, it was defined objectives related to the production, namely compliance with production planning according to production volumes and with operational standards in all stages of the production process.

Taking the objectives into consideration, it is intended to answer the following key questions:

- What manufacturing strategy should be adopted to guide the production ramp-up implementation and what factors should be taken into consideration?
- What organizational strategy should be adopted to streamline workflows across the entire supply chain?
- How can a Lean Production system help to enhance the ramp-up process?
- How to provide teams in the various departments with problem-solving techniques, so that the causes of problems are dealt with immediately and communication flows within the company?

To make it possible to answer the formulated questions and evaluate their success, a main indicator at project level was defined: Number of equivalent houses produced.

Thus, the present project should allow significant gains at the level of these indicator and obtain the respective conclusions of the answers.

1.5 Project Methodology

The methodology followed in the Kaizen Institute's project involved five major phases interrelated with each other:

1. Definition of the project's scope and objectives: In this first phase, the focus area and objectives to be achieved in the project were defined, with clear identification of the activities of action. A Value Stream Mapping tool was used to map all the processes and information involved and obtain a global vision of the entire operating model;
2. Analysis of the initial situation: A characterization and analysis of the initial situation was carried out, to provide a deep understanding of the problem and opportunities for improvement, through observation and monitoring of the relevant activities of the operation and through data analysis and collection. With this, the root causes of the low level of performance, lack of planning and organizational structure previously reported were identified;
3. Solution Design: In this phase, the future vision for the project was designed, through the design of the operating model of the new production line, with concrete definition of the inputs to be received and restrictions. Consequently, a detailed work plan was developed with the various activities to be implemented divided into several stages within the timeframe and objectives defined for the project;

4. Implementation of the solutions: The implementation phase was based on the pre-defined work plan and the constant involvement of the various elements of the organization on a daily basis. The monitoring of deviations was followed in order to mitigate risks and adapt the methodology to each team for the next actions;
    a. Production Start-Up: This strategy supports the design and implementation of solutions developed. The foundations of the strategy are based on Lean Management methodologies, with the development of Daily Kaizen routines, implementation of operational standards and development of structured planning and problem-solving techniques.
5. Evaluation of solutions: The last phase of the project consisted of evaluating the success of the project, by analyzing the results of the indicators defined for the operational control of the operation that impact the performance.

These phases were spread over five months, as illustrated in the Gantt diagram in Figure 2.

Phases	February	March	April	May	June
Phase 1: Definition of the project's scope and objectives					
Phase 2: Analysis of the initial situation					
Phase 3: Solution Design					
Phase 4: Solution Implementation					
Phase 5: Solution Evaluation					

Figure 2 - Project's Gantt Diagram

1.6 Dissertation Structure

The document referring to the dissertation project consists of six chapters.

The first chapter presented the project, describing its scope, the companies involved, the motivation for its realization, the objectives, the methodology and the structure followed throughout the document.

The second chapter provides a literature review of the concepts, methodologies and theoretical models addressed to support the work developed throughout the project. More specifically, concepts related to the methodology and tools applied by the company, the Management of a Production Ramp-up and capabilities that impact a Production Ramp and the importance of Lean Management and its methodologies in Production Ramp-up are explored.

The third chapter is characterized by the initial state of the situation of the project developed in the company, with the characterization of the client's production model and organizational management with proper identification of the root causes of the problems encountered.

The fourth chapter integrates the design and implementation of the solutions, including the application of the model and tools deployed in the project.

The fifth chapter presents the results obtained from the implementation of the solutions.

Finally, in chapter six, an analysis and discussion of the results obtained is performed, as well as a presentation of the study’s limitations and identified future perspectives during the project.

2 Literature Review

In this chapter, a literature review of the concepts and methodologies that underlie this dissertation is carried out. With this, themes related to Production Ramp-up Management, Lean Management, and methodologies that foster continuous improvement in organizations are covered.

2.1 Production Ramp-up Management

The need to integrate new technologies and processes in response to product innovations and market pressure combined with the high complexity of production systems, makes Production Ramp-up a very complex and non-repetitive process (Stefanos Doltsinis et al., 2013). Hence, it is crucial to develop a strategy that can meet the desired operational performance characteristics.

Production Ramp-up is a concept used to describe the gradual increase in the volume of an organization's production of a product or service over time as a response to an increase in demand or to meet production targets. According to Terwiesch and Bohn (2001), is a phase in the product lifecycle between the end of product development and full-capacity production. As perceived in Figure 3, the Ramp-up phase includes the product and process development as well as the production system.

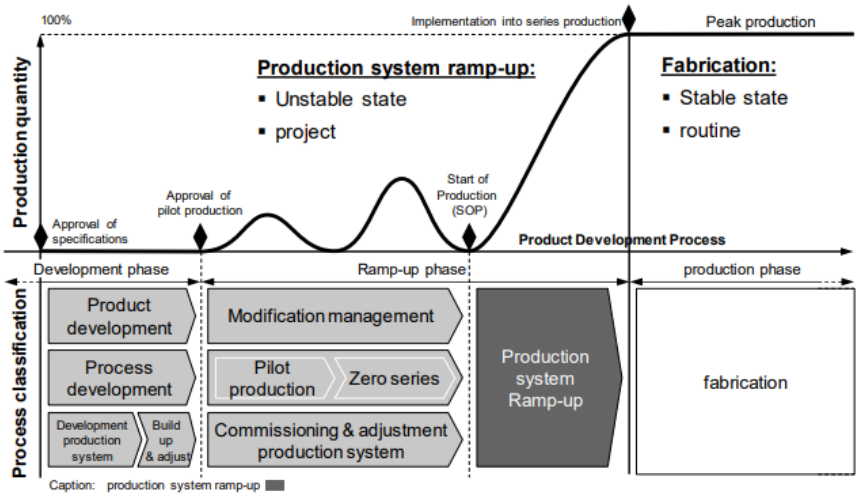


Figure 3 - Ramp-up Production phases ((Dombrowski et al., 2018)

The literature summarizes key characteristics related to the nature of Production Ramp-up that differentiate it from steady-state production (Schuh et al., 2005a; Doltsinis et al., 2013; Juerging and Milling, 2006; Haller et al., 2003; Sturm et al., 2003; Pufall et al., 2007; Gross and Renner, 2010). This comprises complexity, dynamics, variability, uncertainty, being non-recurring, non-repetitive, unique and interdisciplinary. In general, Production Ramp-up is a time of constant change and significant process variability with frequent reiterations.

These critical factors not only affect the implementation phase but also the preview and post phases. It is then no wonder to see that a change in management is required to address the uncertainty and complexity of this process. The involvement of all levels of the supply chain is required to ensure the right fit between product and process and the management of the realization and learning process.

According to studies, an effective Production Ramp-up largely depends on the experience of shopfloor engineers and their understanding of the production system's behavior in order to use that knowledge to support the decision-making process (Fjällström et al., 2009; Haller et al., 2003; Terwiesch and Bohn, 2001). As an organization develops confidence in its production process and carries out a continuous flow of production as well as developing its marketing abilities to market the product, the production volume starts to rise. Thus, at the end of the Ramp-up stage, it is expected the accomplishment of the intended goals along with the fulfillment of all targeted levels according to quality, cost and volume.

The triangle of Ramp-up reflects the importance of fulfilling all those parameters to define the success of a Ramp-up process in terms of a time-related view. Time-to-Volume corresponds to the time to reach full production volume; Time-to-Market is the required time to develop a new product while acquiring the appropriate degree of quality and is the base for a product to be ready to present to the final customer; Time-to-Payback is the time needed to attain the financial goals.

A well-planned Production Ramp-up Management must then be pursued to control the aspects that affect how the production ramp-up turns out. The purpose of managing a Production Ramp-up plan is to encourage decisions that result in the optimal use of time, money, and resources while attempting to reach predetermined ramp-up performance objectives.

Several authors present some proposals for a Production Ramp-up Management framework outlined in Table 1. Schuh et al., Desoi and Tücks (2004) suggest three different generic Ramp-up Production Management approaches that according to product variety, technology and logistic complexity, utilization, time and decoupling level of the situation suit differently well.

Table 1 - Production Ramp-up Management Frameworks

Strategy	***Purpose***	***Suits***	***Focus***
Slow Motion	Ramping up numerous variations simultaneously while maintaining a low volume level until all procedures have been validated.	High-automated production processes	Product variety Decoupling level
Dedication	Ramp-up of all variations with cumulative volumes and release of all of them together.	High product variety and logistic capability	Product variety Utilization
Step-by-step	Ramping up in sequence several highly complicated variations.	High technical complexity production processes	Product variety Decoupling level

In this context, the choice of a Production Ramp-up strategy must guarantee the exploitation of market opportunities in an early stage of the product life cycle in order to ramp up high-margin product variants first.

However, these strategies have some shortcomings in terms of what operational guidelines should be followed, since they only offer a broad insight on how to proceed with Ramp-up in a multi-variant scenario. Clark and Fuimoto (1991) look deeper in their research and present two distinct approaches for performing a Production Ramp-up that take into consideration a combination of three different aspects: choice of Ramp-up curve, operation pattern and workforce policy. One approach is entitled “Shut-Down” and implies low initial complexity due to material handling and workforce involvement, but task continuity and operational stability will suffer in the long term. The other approach is “Step-by-Step” and suggests consistency, control and assignment of tasks. Moreover, Terwiesch and Yi (2004) presents the Copy-exactly Ramp-Up framework that can be applied when there is a lack of early understanding of the transferred process, process improvement is challenging and tiny modifications have a significant impact on the business. The premise of this framework is that the process before production begins is frozen at some point so that a possible process improvement is blocked.

Therefore, the efficiency of the chosen framework is heavily dependent on the fit between the production capabilities and the decision taken on how to address the complexity level. Based on this, the foundation of guidance of Production Ramp-up Management must incorporate a comprehensive knowledge of key factors impacting Ramp-up and assessment of performed Production Ramp-up.

Investigations performed about the ramp-up of time to market and volume in manufacturing industries together with effective management, organization and strategy on product development allowed to point out some drivers that have an impact on the product ramp-up (Clark and Fujimoto, 1991):

1. Integrated product process linkage: Integration of problem-solving cycles in products and processes result in rapid model cycles with a high capacity to make production rapid and efficient without compromising the quality;
2. Integrated customer/product linkage: Integration of new production techniques must be monitored with appropriate new performance measurement systems to evaluate the impact of those new techniques;
3. Integrated supplier linkage: Implementation of close and continuous communications with suppliers to improve component integration and daily operational time;
4. Flexible, short-cycle manufacturing capability: Creation of short-cycle times generate imbalanced processes which require allocating efforts to align the workforce with the pace of production. A policy of continuous improvement, fast problem detection and solving must be adopted to enable the learning and performance rates of the workforce to be achieved.

Hence, considerations of product development performance and production decisions must be addressed to support a successful Ramp-up. Complex products with a lot of requisites, the transition phase reflects unique challenges for the design of the interaction between development and production due to the multiple systems, components and technology that require an extensive understanding. Engineering and design changes affect development and ramp-up phase that may result in high changes in the manufacturing process as well the relationship with suppliers. For this reason, production systems should constantly be controlled and managed at maximum speed to increase the pace of learning and provide the proper quantity and quality of information needed for successful control and management. Terwiesch (2001) outlines the importance of providing a smooth transition from pilot to volume production to significantly increase performance which must be accompanied by the establishment of clear managerial responsibilities and a cross-functional organization.

Therefore, the network and collaboration among all the parts assume a vital role in reaching the parameters.

Figure 4 provides a summary of the key factors and their dependencies that affect Ramp-up efficiency.

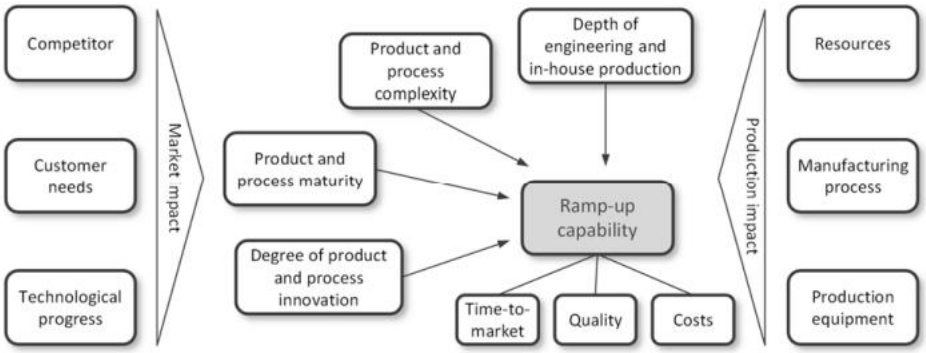


Figure 4 - Influencing Factors of Ramp-up Efficiency (S. Elstner and D. Krause, 2012)

Based on this, literature recognizes the complexity of managing and assessing the performance as a consequence of the difficult dynamic involved, multiple dependencies and communication with diverse work functions.

2.2 Capabilities for Supply Chain Operations Ramp-up

Implementing a successful Production Ramp-up requires a comprehensive understanding of the supply chain as well as the ability to plan, execute and adapt to changing circumstances. This involves identifying which capabilities should be considered and which strategic decisions should be made when formulating a Production Ramp-up Management strategy to fulfill the desired Production Ramp-up and be effective in business performance to bring the product to market more quickly. As a result, five individual fields of action have been identified (Kuhn, 2002): Production Ramp-up Planning and Controlling; Robust Production Systems; Modification Management in Ramp-up; Cooperation and Reference models for Production Ramp-up and Knowledge Management. Since an operative and management approach is pursued, emphasis on the following fields is placed: Production Ramp-up Planning and Controlling, Robust Production Systems; Modification Management in Ramp-up and Knowledge Management.

2.2.1 Production Ramp-up Planning and Controlling

Production Planning is the process of creating a detailed roadmap for the manufacturing or production of goods so that producers are in the correct places at the correct time to maximize their resources.

To guarantee a smooth and successful transition in the production system phase of the Ramp-up, comprehensive attention to activities that encompass Production Planning and Control needs to be performed.

Researchers pinpoint challenges in determining the required production capacity that accounts for the increased production volume, since many parameters such as worker productivity, yield rates or customer demand are not well understood at this stage. It is then expected to perceive reconfigurations in capacity investments during the process since as the learning process evolves, the knowledge of what should be the best economic capacity expansion strategy increases.

Moreover, miscommunication and gaps in resource and planning are frequently seen. The majority of methods and tools are equal to those employed in mature production, which leads

to unforeseen bottlenecks, time-consuming setups and fitting problems between product design and production system. Proper understanding and management of the workflow are required to develop a production sequence that accounts for the increased production volume, availability of resources and inventory levels (Haller et al.,2003).

Literature highlights the importance of cooperation and involvement of all parties. Lack of information and availability of external suppliers to support in a timely manner during this phase can be an issue in certain cases (Bohn and Terwiesch, 2001). According to Christopher (2005), most modern companies have gone beyond mere collaboration when it comes to integrating their business partners, with managers successfully integrating processes and information across the supply chain.

Additionally, a mechanism for capturing and evaluating the quality and progress of the system is critical and must be conducted. Quality problems are difficult to avoid because of inexperience, complexity and instability of the production process. Unexpected equipment failures and increased defective production products resulting from the physical and control level changes implemented are perceived. Causes such as poor positioning of sensors equipment, variations in process time and disturbances in plant service conditions lead to low machine availability and consequently to quality problems and high maintenance costs.

A zero Ramp-up time would be optimal, as the desired effective production rate would be reached with no production loss. However, real-world systems frequently fail to attain this ideal state. According to Production Quality theory (Marcello Colledani et al., 2018), the most significant performance indicator is the system effective throughput, denoted as TH^{Eff}. This concept is defined as the rate of conforming products delivered by the system and can be expressed as the total number of parts delivered by the system in given time.

Figure 5 states the cumulative throughput loss during Ramp-up phase.

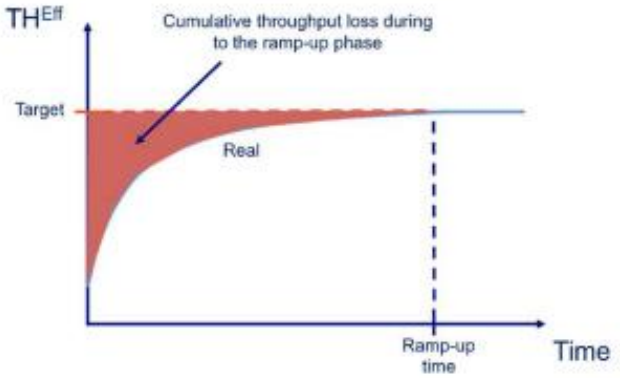


Figure 5 - Cumulative throughput loss of Ramp-up phase (Marcello Colledani et al., 2018)

The average effective production rate curve seen in a real systems following a reconfiguration is represented by the blue curve and the system's target effective throughput, TH^{Target} is repreented by the horizonal red line. The time it takes for the system to reach the desired production rate is known as the Ramp-up time and the red region represents the total throughput loss, TH^{Loss}.

As a result, understanding the root causes of the effective throughput losses that occur during system ramp-up and throughout the system life cycle is crucial and with that a diagnosis and measurements of performance need to be constantly performed (Winkler et al, 2007).

To predict potential losses that might arise during this phase, implies having a true vision of an organization's operations by understanding the various positions of products and raw materials in the supply chain at a certain time and determining the links between customers and suppliers (Liao et al, 2009). This visibility allows developing a production schedule that accounts for the availability of resources, adjusts inventory levels as needed and adequate

product delivery when and where to ensure they are adequate to support the ramp-up and economically meet customer expectations.

2.2.2 Robust Production System

The term robustness describes the stability against varying influencing conditions in critical conditions. It is a measure of a system's flexibility in circumstances of uncertainty and variety (Rosenhead, 1972). To influence and understand how to enhance robustness, it needs to be evaluated the tradeoffs between performance's stability and its level as well as those between the required input, the performance, and the final output.

Drivers such as the use of resilient processes, a closed loop for production control activities and functional breakdown influence the performance and maintenance of the whole system. Authors discovered that standardizing information on the flow of material during Production Ramp-up has a significant impact on creating a robust production system and with that achieving Time-to-Volume. This is closely related to Planning and Controlling capabilities, since disturbances in terms of scheduling, provision of tools, deployment delay or even loss of suppliers impact the whole system.

2.2.3 Modification Management

As the production system ramp-up phase assumes special importance due to the involvement of all the socio-technical elements (people, organization, procedures, technology) in performing at their full capacity according to the desired production, it becomes clear the vital role of the human elements in Production Ramp-up Management (Hans-Peter Wiendahl & Lutz S, 2002), highlighted in Figure 6. All the potential failures from previous phases that could not be foreseen or discovered may come to light during the development of the production system and result in pricey delays of Time-to-Market.

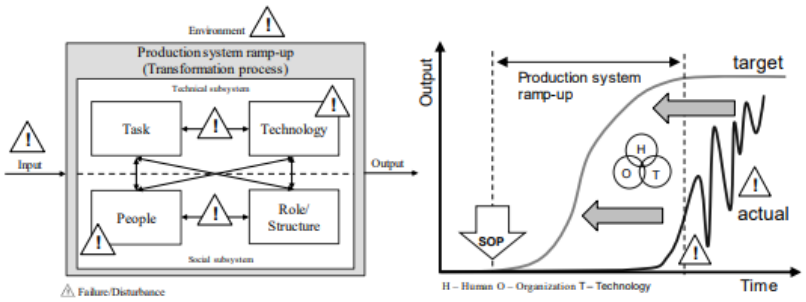


Figure 6 - Impact of human elements in Production Ramp-up (Sydow J, 1985)

A supportive management as well as a relevant organizational structure in order to be resilient towards deviations must be guided. Production managers recognize that including the greatest business strategies to enable the growth of their business will eventually fail if a culture of continuous improvement driven by excellence and growth is not settled.

Although the reaction of the organization and its employees to a system reconfiguration is difficult to predict, problems due to informal company procedures and lack of specific functions may arise. Effective communication, collaboration, and trust between external partners and teams of different departments inside and outside of an organization are crucial as well as flexibility and agility to quickly pivot in response to unexpected challenges. Without clear standard organizational skills and a structure capable of supporting decision-making, the learning process will be much slower and the loss of control in ramp-up management may be higher (Johansson & Jensen, 2011). According to Kaplan and Norton (1996), organizations must develop a supply chain that anticipates and drives change rather

than reacting to it. At the same time, they must champion the supply chain at the highest levels of the organization to ensure that supply chain capabilities are considered when developing a business strategy.

Therefore, successful change management is highly dependent on the implementation of organizational procedures and routines that enable personnel to collaborate and communicate across organizational and functional boundaries to detect difficulties and generate solutions (Tyre MJ and Hauptman, 1991).

2.2.4 Knowledge Management

The Ramp-up period is a key learning opportunity where management should play efforts in providing the best practices to enable process improvement in the shortest possible time through its people (Lenfle and Midler, 2009).

Kaski (2002) states the importance of having a highly qualified and dynamic workforce committed to the company's strategy and that's aware of the impact of their actions to help the company reach its outlined objectives. Literature (Pruett and Thomas, 2008) analyzes the impact of learning applied to product innovation and concludes that the learning curve process and the increase in the output rate of a Ramp-up are strictly connected. A lot of pressure on operators to learn and increase their performance is placed during the start of ramp-up which can result in overlaps in the learning process and affect efficiency enhancement (Terwiesch and Bohn, 2001).

Indeed, Knowledge Management plays a critical role in this field in ensuring that critical knowledge and information are effectively captured, shared and used with the purpose of solving business problems and supporting organizational improvements. Knowledge Management can be accomplished through a clear understanding of what kind of knowledge characterizes the company and what interactions between personnel need to be valued and transferred to create a plan with clear goals and educate personnel with correct competencies.

2.3 Lean Management in Production Ramp-up

Lean Management is a philosophy and a set of management practices popularized by Womack et al (1996). The concept of Lean Management originated in the automotive industry, specifically in the post-World War II era in Japan with the Toyota Production System and was later extended to almost all industrial sectors and services as a global solution to improve quality and efficiency. Lean provides an opportunity to respond promptly to customer demand and reduce waste by minimizing non-value-added activities (Bhamu & Sangwan, 2014). Thus, five fundamental principles are pointed out: value definition, value stream identification, continuous flow, customer pull and striving for perfection. Additionally, recent research (Netland and Powell, 2016) suggests that Lean is about the concept and practice of continuous improvements and three essential Ls: Learning, Leadership and Long-term Perspective.

The current complexity and uncertainty of Production Ramp-up projects, mentioned above, challenge manufacturer companies' competence to successfully carry out those projects. Manufacturers must conquer ramp-up projects in less time and with less capital while manufacturing more complex products in more complex processes and ensuring on-time production start-up. To prevent potential losses from jeopardizing the sustainability of manufacturers and to quickly achieve Production Ramp-up, the Lean concept and its methodologies become a powerful tool.

2.3.1 Lean Management in Production Ramp-up Planning and Controlling

Improving the capability of Production Ramp-up Planning and Controlling by mitigating uncertainty through the management of operations and coordination of supply chain activities implies early identification of disturbances to tackle in an effective way the aforementioned challenges. Researchers have focused on identifying the source of disturbances that in turn generate non-value-adding activities and produce speed losses (Almgren, 2000). Hansen and Grunow (2015) developed a capacity planning model during Production Ramp-ups and concluded that time-dependent Ramp-ups result in an overestimation of effective capacity and that Ramp-up capability should be planned in advance. Thus, reducing overall time and waste becomes a priority to be able to develop a capacity model according to the customer demand and the workforce.

According to literature (Womack et al., 1990; Liker, 2004), the Toyota Production System (TPS) proposed in the Lean Management philosophy emphasizes the relevance of eliminating inefficiencies and increasing output value. In the conventional production philosophy, the voice of the customer is frequently neglected, without having a clear identification of customer identity and preferences (Bhasin and Burcher, 2006; Liker, 2004). In opposition, Lean can deliver an efficient flow in production and focus on customers' requirements, with Lean Manufacturing and Logistics contributing significantly to this process.

2.3.2 Lean Management in Production Ramp-up Organization Style and Knowledge Management

Numerous experts acknowledge that creating and sustaining a culture that emphasizes value-adding, customer orientation and ongoing self-development during Production Ramp-up implementation depends heavily on Lean Leadership (LL) style (Dombrowski U, Mielke T, 2014).

Lean Leadership is defined as the ability to empower people by creating a vision, inspiring others, and aligning the team around a common goal with a methodical set of rules and methods for goal-oriented leadership, according to VDI guidelines (2012).

In complex socio-technical systems such as Production Ramp-up, LL can provide a number of principles to improve product quality by putting emphasis on the coaching principle. Enable managers, teams and individuals to become problem-solvers and decision-makers in order to improve decentralized processes, make them more valuable to the organization. Focus on transparency, employee skills development and participative value creation are LL principles considered to have a very high potential in creating a more agile organization that is better equipped to handle deviations in the Production Ramp-up phase. For instance, fostering a culture of continuous improvement by supporting and motivating teams during all the changes and nurturing an organizational focus of providing value to customers by gathering regular feedback and encouraging employees to participate should be applied.

2.4 Lean Manufacturing

Lean Manufacturing (LM) is a systematic approach to manufacturing and process improvement that originated from the TPS. The fundamental concept of Lean Manufacturing is to create more value for customers while minimizing waste and inefficiency in production processes. According to Womack et al. (1990), implementing a lean manufacturing strategy permits the strengthening of the phase sequence that leads to operational excellence, continuous improvement, and the elimination of non-value-added activities. Taichii Ohno (1985) defined anything that does not add value to the final product or contributes to its

transformation is designed by *Muda*. There are commonly recognized types of *Muda* in LM, known as *Seven Wastes*:

1. Overproduction: Producing more than what is required by the customer or in advance of demand, resulting in excess inventory and increased costs;
2. Waiting: Idle time and delays due to inefficient processes and workflow design;
3. Transportation: Unnecessary movement of materials and products within the production system lead to delays and increased costs;
4. Overprocessing: Performance of additional operations and resources to meet the customer requirements;
5. Excess Inventory: Maintaining excessive stock of raw materials, work-in-progress (WIP) or finished goods leads to an increasing of storage costs;
6. Motion: Unnecessary movement of people or equipment resulting in wasted time, effort and energy;
7. Defects: Errors and rework that result in defective products, customer dissatisfaction and additional costs.

Focusing on identifying the sources of waste must be a priority during the Production Ramp-up phase and with that the appropriate application of LM tools to increase productivity by reducing expenses and enhancing quality.

2.4.1 Daily Kaizen

Daily Kaizen is a program adopted to drive KAIZEN™ behaviors in all levels of natural teams focused on developing people, problem solving and sustained improvements. The aim of implementing Daily Kaizen is to move the organizational culture from traditional to KAIZEN™ to consistently increase the proportion of employees working on improvement and reduce recurrent problems and unstructured firefighting.

This program encompasses four levels: Daily Management, Standardization, Training, Coaching and Problem Solving.

The first level corresponds to the development of sustained practices for systematic monitoring of teams, analyzing deviations and root causes and identifying opportunities for improvement to foster a culture of daily continuous improvement. The key is to instill a sense of ownership, transparency and responsibility at an individual level. The Daily Management elements are the Daily Kaizen Meetings, *Gemba* KPIs and Countermeasures. The Daily meetings are accompanied by visual boards so that critical information is visible to the entire team. The use of performance and problem-solving boards improves work organization and planning, provides a PDCA (Plan, Do, Check, Act) improvement cycle, the visualization of Key Performance Indicators (KPIs) and establishment of countermeasures. The KPI's should represent the customer needs and provide insightful data on team performance to guarantee relevance and simplicity. The PDCA cycle is a four-step cyclical and problem-solving method that supports organizations accomplish progressive improvements and monitor activities conducted by the team to improve its work and the system (Netland and Powell, 2016). This tool offers time-saving opportunities during Production Ramp-up implementation by identifying problems in the early stages and eliminating ineffective actions. Level two ensures the establishment of better work standards to address the absence of structured methods and includes the use of tools like 5S, Standard Work, *Kamishibai*, *Gemba* Walks and the Help Chain. This level is crucial for the success of a Production Ramp-up Management due to the capability of providing a structured basis for how work should be performed and thereby reducing uncertainty and strengthening the process. Imai (1986) states that there is not

improvement where there are no standards. Moreover, the organization of physical space should be a priority not only to improve the morale and safety of employees but to improve efficiency.

Level three, Training and Coaching acquires a crucial role. The lack of motivation and commitment that may arise with the reconfiguration of the production system is reflected in misalignments where resistance to change and disconnection from the values jeopardize the objectives, as explained in Section 2.2.3. This level focuses on training leaders to foster collaboration and sharing knowledge between different teams and functions to break down silos, provide alignment toward common goals and accelerate the learning curve process during Production Ramp-up by guaranteeing that employees are provided with appropriate knowledge.

The fourth-level represents the highest level of Daily Kaizen and intends to create a culture of continuous improvement in the entire organization with the introduction of structured problem-solving to guide teams in searching and identifying the root causes of the problems. Most of the problems arise as the implementation occurs, therefore being able to solve them and establish countermeasures should be a priority to reduce the complexity and variability. Managers must put emphasis on going beyond standard changes to effective continuous and incremental improvements in order to achieve the desired production capacity in a sustained and long-term way (Mauborgne, 1999).

2.4.2 5S

5S is a low-investment, high impact Lean Manufacturing tool developed in 1950 introduced in the 1960s by Hiroyuki Hirano, that aims to eliminate waste by motivating and raising awareness throughout the company to develop a clean, organized, responsive, productive and safe work environment based on the application of five Japanese principles:

1. *Seiri* (Sort): Focus on separating necessary items from unnecessary ones;
2. *Seiton* (Set in Orer): Emphasizes organizing the necessary items in a structured and visual way;
3. *Seiso* (Shine): Involves regular cleaning and inspection of the work area to ensure good working conditions;
4. *Seiketsu* (Standardize): Development of standardized practices to establish consistency and uniformity in processes;
5. *Shitsuke* (Sustain): Focus on creating a culture of continuous improvement and maintaining the achieved results through discipline, commitment and involvement of everyone in the organization.

Literature (Moulding, 2010) evidences how effective this tool has proven to be, that to this day, it is still considered one of the main tools for waste reduction and optimization of quality and productivity.

The lack of 5S in *Gemba* will impact the Time-to-Market and Time-To-Quality of Production Ramp-up. By neglecting the correct organization of workspace and discipline during this phase marked up by a lot of changes, namely at the layout level and equipment introduction reflects in huge throughput losses.

A well-maintained workplace with established standardized processes improves the visual aspect of the plant, saves time required to find misplaced tools and reduces waste. In detriment of this, regular audits with reinforcement of the 5S practices, allow organizations to improve their workflow and increase efficiency and quality, setting the stage for long-term success.

2.4.3 Standard Work

Standard Work is of utmost importance during Production Ramp-up as it helps organizations navigate the challenges of increasing production while maintaining control and meeting customer expectations.

During Ramp-up, human operators may experience a slower learning curve than expected, resulting in excessive processing times of manual operations and cultural misalignments due to a lack of structured procedures and poor responsibilities definitions. Moreover, the joining of new employees during this process is common and without a standard and sequence of learning, integration becomes challenging.

Standard work is a detailed representation and documentation of the most efficient, safest and easiest method to perform a certain task, achieving the best link between human and machine work (Coimbra, 2009). It includes the key process steps, operator procedures, work locations, equipment used, sequence and quality checks, focused on simplification and observation. *Gemba* observation enables the identification of challenges and the adoption of improvement measures to address these challenges.

Therefore, defining the most effective and efficient methods for performing tasks ensures consistent performance across production process and organizational structure since reduces unnecessary steps and streamlines processes. It ensures that all employees understand their roles, responsibilities and expectations, promoting a cohesive and productive workforce and reducing risks associated with scaling up operations.

2.4.4 Kaizen Methodology

The Kaizen Methodology is inspired in the Toyota Production System that focuses on making small, incremental changes in processes and systems to achieve continuous improvement and efficiency in various aspects of an organization. The Kaizen Institute's management system is called the Kaizen Business System (KBS), and its primary is to create long-term value for customers, shareholders, and employees.

Figure 7 represents the Kaizen Business System structure.

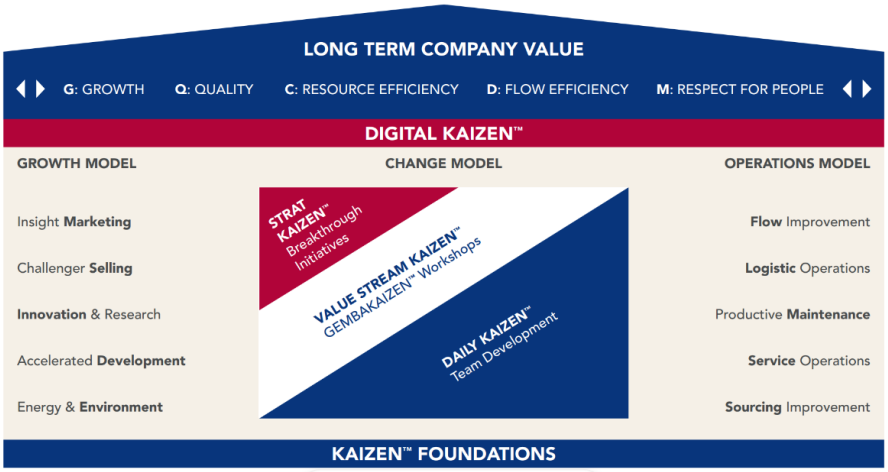


Figure 7 - Kaizen Business System (Kaizen Institute, 2021)

The Kaizen Change Model, the Growth Model, and the Quality Cost Delivery (Q.C.D) Model are the three models that make up KBS, and they are all focused on boosting sales and reducing expenses in organizations where Kaizen is implemented. The Growth Model has as its main pillars the accomplishment of the organization’s strategic planning to optimize added value and the Q.C.D aims at improving quality, efficiency and delivery of an organization's.

The Kaizen Change Model enables the development of a management system based on continuous improvement, people and excellence. It helps organizations overcome resistance to change that arises when the threat of shifting the organization's paradigms is present.

KAIZEN™ Principles

Kaizen Change Model is composed of five main principles:

1. **Know your customer:** This principle refers to the knowledge and perception of what the customer wants to achieve to enhance its experience based on what they value.
2. **Let it flow:** This concept is defined by the intention of reducing and eliminating the waste to achieve zero waste. Therefore, everyone in the organization must be focused on working towards removing any waste from the business at the expense of adding value to processes.
3. **Go to Gemba:** *Gemba* is a Japanese term meaning “the actual place”. It is related to leadership and awareness of what is happening at every organizational level. Therefore, can be perceived as following the action and finding where the value is created with the purpose of detecting waste and opportunities for improvement.
4. **Empower People:** This principle is about organizing and guiding the team with clear objectives with the support of the right tools and systems. Therefore, the involvement and alignment of everyone within the organization is crucial. In the KAIZEN™ philosophy, errors or mistakes are not punished, rather, they are viewed as changes for improvement and learning.
5. **Be transparent:** Transparency and objectivity are crucial. Hence, performance and improvements must be measured and tracked with real data to support the decision-making and determine the level of success.

These principles constitute the guiding lights for continuous improvement at every part of the organization, fostering a culture of autonomy, innovation and standardization. They dictate a turning point in the progression of quality, productivity and labor-management relations.

2.4.5 Total Flow Management

Total Flow Management (TFM) is one of the pillars of the Q.C.D model of the Kaizen Business System. This concept considers the end-to-end flow of products and services, from the initial stage of production or procurement through several stages, including manufacturing, distribution, warehouse, transportation and delivery to the end consumer. In order to establish a continuous and seamless flow, it focuses on coordinating and harmonizing all these processes by eliminating *Muda* and reducing lead time.

A product must undergo multiple operations before being available for market and for that, products must pass between different operations, creating the known product flow. Literature identifies the two most common production flows: Push and Pull flow. The Push flow system produces according to forecasts while the Pull Flow production is based on current customer orders. According to Chase et al. (2005), when using a pull-flow logic, "nothing will be produced until is needed." The pull system serves as a fundamental element in the context of Total Flow Management since it strives for continuous flow by synchronizing activities and ensuring a steady flow of work. Hence, having the capability to manage disturbances while being lean is crucial, and for that, hybrid flows by combining the two flow strategies should be addressed to maximize the benefits of both tactics (Lyonnet and Toscano, 2014).

Figure 8 represents the TFM model, consisting of three pillars in which the objectives are represented at the top of the representation.

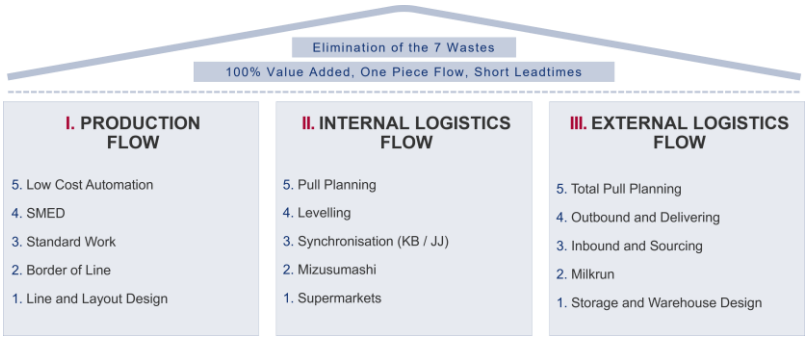


Figure 8 - Total Flow Management (Kaizen Institute, 2021)

According to the scope of this dissertation, the Production and Internal Logistics flow will be the two pillars of TFM further developed.

Production Flow

The Production Flow pillar of TFM aims to optimize the material and information flow of organizations within the production system in order to achieve operational excellence and gain the flexibility to respond to the market trend of customization. The *one-piece flow* model encompasses layout reorganization, through line balancing, in which the integration of operations and the distribution of the operators' load is done in a uniform way, to guarantee the work rhythm cadence. The creation and organization of the Border of Line allows minimizing the *Muda* of movement of operators and material, with the supply being done according to the dimensioning of the temporal consumption of consumables. Followed by this strategy, the development of standards for the value-added operations must be performed.

Table 2 resumes the Production Flow Strategies of TFM outlined.

Table 2 - Production Flow Strategies of TFM

Strategy	***Description***
Line and layout design	Design of facility layout according to processing sequences and material flow requirements.
Standard Work	Provides a baseline for continuous improvements by giving the necessary guidelines for understanding how work is processed within an area.
Border of Line	Physical location where the production references required for production must be placed to facilitate the operations.

Internal Logistics Flow

The Internal Logistics flow includes all efforts to improve communication between production and logistics to ensure that all internal processes are controlled and aligned with the objectives outlined. To build a pull planning system where customer orders set the pace, TFM presents five categories, in which the *Mizusumashi*, Leveling and Production Pull Planning categories assume a preponderant role in managing efficiently Production Ramp-up.

Table 3 presents the Internal Logistics strategies outlined.

Table 3 - Internal Logistics Strategies of TFM

Strategy	***Description***
Mizusumashi	Logistic operator responsible to perform internal logistics operations, concentrating all the *Muda*.
Leveling	Level capacity system responsible for defining an effective schedule for production lines and equipment.
Production Pull Planning	Customer-centric approach that aims to synchronize production with actual customer demand.

The primary goals of creating flow in logistics sector are on improving the efficiency of operations to collect and select the parts to be transported and then move those parts to the place of use and ensuring synchronization between supply and production start with proper line and equipment scheduling and production planning in according to customer needs (Coimbra, 2009).

Therefore, increasing the efficiency of parts collection by operators, implies the replenishment of the border line according to the previously defined time consumption of material with a logistics operator, called *Mizusumashi*, who does the internal transportation of goods using a standard fixed cycle time (Coimbra, 2013).

Production leveling is an important factor for the functioning of the whole system to reach the desired production capacity. The implementation of new equipment and product lines during Production Ramp-up requires defining what should be the production rate. This strategy establishes a constant and synchronized pace of work and prepares the company for market fluctuations by promoting flexibility.

According to this, the Production Pull Planning model brings a new paradigm. Defining the type of production strategy that each product must follow during Production Ramp-up as well as inventory management of finished products and components defines the beginning of Production Pull Planning. As a model that is more independent of forecasts, it allows the simplification of the information flow, as it responds to the replacement of a certain consumption and at the same time enables a proper understanding of the customer's needs and requirements when are not disclosed.

3 Problem Description

In this chapter is presented a contextualization of the initial state of the company before the beginning of the project. This is followed by the identification and characterization of the company's organizational structure and its production model, in which the main problems and their causes are identified. The overview of the original situation provides the basis for determining which areas require more attention for the design and implementation of continuous improvement solutions to effectively attain the desired strategic position in the market with a more stable Production Ramp-up.

For confidentiality reasons, the data provided throughout the project is affected by a factor.

3.1 Company Characterization

The client company that incorporates the present dissertation project is a business that operates in the area of prefabricated and modular structures with wooden substructure for houses, bungalows, accommodation modules, tourism and even commerce. With a unique concept, it integrates two business areas, in which one of them serves as a support and is subsequent to the other business area. The business areas of the company in question integrate the production of prefabricated structures in modular, timberframe panels, with successive assembly on-site at the construction site.

The projected acceleration in the growth of the company's turnover with a large-scale increase in the portfolio of customers and ongoing projects led to the initial manual industrial structure presenting major limitations in its capacity to respond to the growing level of demand, particularly in terms of production.

Given the goal of strengthening the strategic positioning as an international producer of wooden structures with a focus on innovation and sustainability, the company carried out an industrial investment, by acquiring new facilities and a completely new production structure with a high level of automation for the integrated industrial production of timberframe panels. Therefore, the priority of the company during this transition is to differentiate in the market by focusing on product innovation and development of manufacturing systems, accompanied with the intention to invest in the expertise of human resources and, in the way the company is structured.

3.2 Organizational Structure

The client company consists of an administrative group, in which the heads of the various departments report directly to the administration. Figure 9 represents the organizational structure of the company, in which the different hierarchical levels of the company are highlighted and how the teams relate to each other.

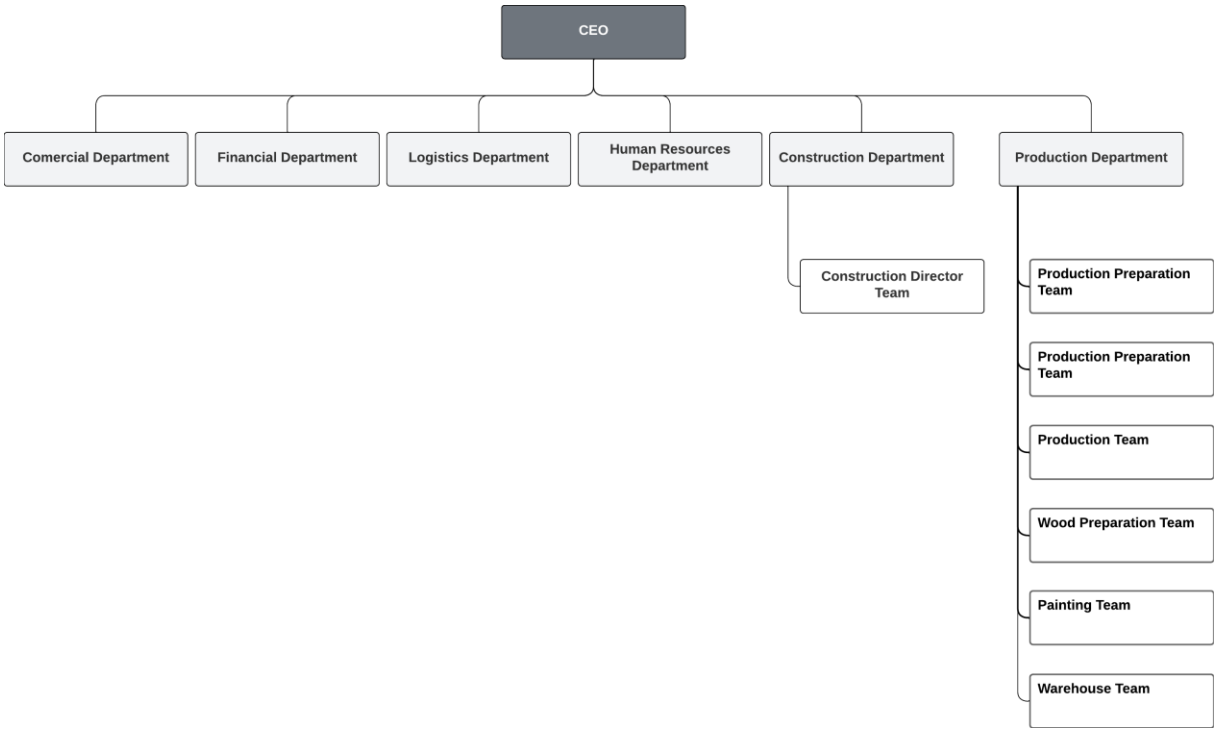


Figure 9 - Company Organizational Chart

It is possible to identify the presence of a functional organizational structure. According to Mintzberg (1979), the structure of an organization corresponds to the sum of all the ways in which work is divided into distinct tasks and, from which its coordination is achieved. In functional organizational structures, activities that are similar at the level of skills and resources used are grouped together and placed under the control of the same power (Daft, 1998). This type of structure is used mainly for small companies with a single product range, in which each department specializes in a certain function. This contributes to a more efficient use of resources and internal coordination, where authority and decision making is centralized at the top levels (Stoner and Freeman, 1995). These characteristics mirror in full the way the company is organized and establishes its relationships and communication between the different elements.

Each department of the organization is focused on its work priorities only. There is not a clear vision of the whole process, from the Commercial Department to the Construction Department, which often results in conflicts between what should be the focus and priority. The presence of functional silos between teams is a reality. According to Ensor (1988), a functional silo is a result of the absence of shared objectives within the organization due to top-down vertical communication. This behavior results in organizations with an essentially reactive attitude, where there is no mutual concern, conditioning the interaction between the members of the different functional units, as evidenced.

Moreover, most of the decisions are centralized on the CEO, which leads to a decision-making process that is quite slow and incapable of responding promptly to the problems that arise.

3.3 Production Process

In order to obtain a more in-depth view of the production process and to help understand and structure the situation presented by the company, it was used a process mapping tool, called Value Stream Mapping (VSM), in which the most relevant activities and the flow of material throughout the production process phases are highlighted. According to Mie Rother and John Shook (1999), VSM is defined as a lean tool that uses a flowchart to document each process stage, allowing to distinguish value-added and non-value-added processes, from the moment

the raw material is received until the final product is delivered. This tool allows the identification of the initial situation and enables the development of an implementation plan that maximizes the available resources and ensures materials and time are used efficiently during the transformation.

The current timberframe production structure is a limited structure, that includes a set of manual processes. Through the VSM of the production process, presented in Figure 10, it is possible to identify the current state of the production flow.

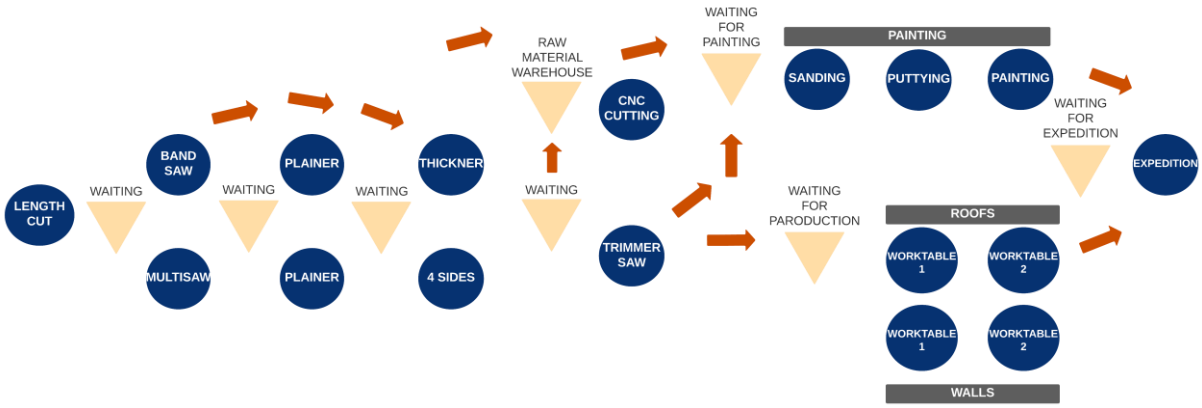


Figure 10 - Material Flow Map of the Production Model

The production process encompasses several areas, from the raw material storage area, manual and automatic wood preparation, wood panel assembly, finished product storage, carpentry and tooling warehouse. These various areas play a fundamental role in the production system of the company and are associated with a set of production processes.

To gain a clear understanding of all production processes, an in-depth overview of all relevant activities that comprise each of the areas is presented, by identifying and describing the activities involved in creating and delivering end-to-end value to the customer.

Manual Wood Preparation

The manual wood preparation takes place in the Manual Wood Preparation section, in which a set of activities are integrated to obtain the wood ready to be sectioned. The process begins with cutting the solid wood to the desired size. Subsequently, the faces of the wood beams undergo the appropriate planning to remove irregularities and confer the desired quality, and, lastly, a process to reduce the thickness and dimension is carried out.

Automatic Wood Preparation

In this section, the laminated wood from the raw material warehouse or the Manual Wood Preparation section is machined on the CNC according to the dimensions assigned in the preparation projects, and then used for panel assembly or painting.

Wood Panel Assembly

The assembly of the panels involves the assembly of walls and roofs. This assembly occurs in a fully manual production line consisting of a set of tables in which various operations take place. According to the production of walls and roofs different operations are involved.

For walls assembly, the process starts by assembling the frame. After that, the thermal insulation fleece is placed over the frame followed by the placement of the wood fiber. The wood fiber is fixed to the panel and, with that, the panel cavities are manual inflated, in order to obtain the proper thermal insulation. To ensure the accommodation of the inflated material, panels of OSB, are nailed on the structure and then thermally insulated. Finally, the lath is fixed over the panel.

In case of the assembly of roofs, the operations performed have some similarities. Firstly, the frame is assembled, and panels of Oriented Strand Board (OSB) are placed on the structure. Subsequently, the canvas is placed and fixed both inside and outside the frame. With this, thermal insulation is conferred, through manual inflation, and the wedge lath is fixed to the exterior of the panel. Therefore, the OSB panels are fixed, nailed and cut and the canvas is placed over that. After these operations, the produced panels are removed and stored for later shipment.

Carpentry

In the carpentry section, the wood beams coming from the Wood Preparation section undergo three major operations: sanding, puttying and painting. The sanding and puttying operations confer the desired finish and surface homogenization for painting. Following that, the painted beams are stored and sent to the construction site to be given the desired finish.

Through the analysis conducted to the production process of the initial production model is possible to perceive a lack of logical sequencing of operations and organization. The large movement of material and operators between operations and the supply of the consumed material is constant due to the long distance between the workstations and the warehouse. This implies accumulating logistical tasks, to the detriment of being focused on their own tasks. Improvements to the layout of the production line should be placed in order to eliminate these types of activities that don't add any value to the process since it slows production and increases lead time.

In addition, the lack of specifications for production hinders the production process. Most of the information provided in the drawings proves to be neither sufficient nor easy to read for the Production team, which translates into errors and great difficulties in performing the tasks, which, in turn, compromises production quality.

A lack of standardization and planning in the whole process is also perceived. There is no visibility of the type of material present since it is stored without considering the replenishment sequence and size of the wooden beams. Additionally, there isn't a proper definition and identification of the place where the material is to be stored. This impacts the production lead time and quality since part of the time is wasted looking for a certain wood beam or even reorganizing the space.

3.4 Production Planning

The planning process of a project for production and construction on site is prompted by the involvement of the various departments with two major phases: Commercial Phase and Architecture and Engineering Phase. These two phases are mediated by an intermediate phase of Licensing. The project execution process mapping is represented in Figure 11, in which an explanation of this information flow follows.

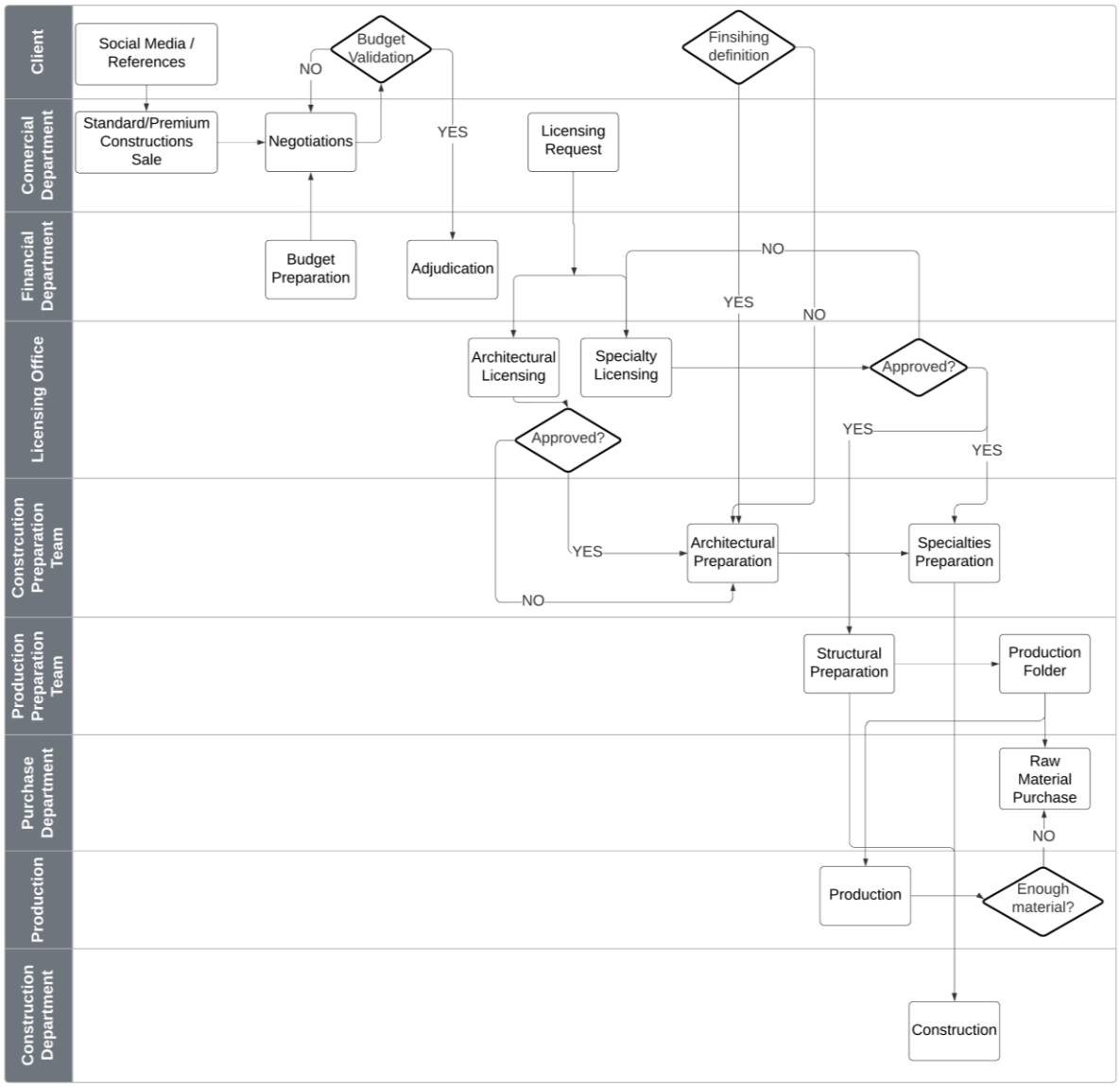


Figure 11 - Production Process Flow

The project planning begins in the Commercial Phase. The Commercial Department is responsible for the sale of standard and premium constructive systems of houses. In case the client formalizes the interest, the Commercial team starts the negotiations and validation of the budget prepared by the Financial Department. Most of the deadlines given to the customer are defined in a static way due to the lack of visibility of the production load-capacity. It is also to perceive the inability of this department to manage all processes as a result of inadequate planning and sufficient resources.

The intermediate phase is a phase dependent on external entities, which ensures the approval of the architectural and specialty licensing of the projects.

The Architecture and Engineering phase is divided into three major departments: Construction Preparation Department, Production Preparation and Construction Direction. The definition of the finishes with the client determines the beginning of the execution of the Architectural Preparation project by the Construction Preparation Department. This definition involves constant communication between the Commercial department and the client. In case finishes are not defined, the Construction Preparation Department proceeds with the start of the project. The lack of this information results in great uncertainty since it requires constant changes and revalidations with the client. Rework is a paradigm and is assumed as an integral part of this whole process. What should have been defined in 15 days takes several months to

obtain all the information. Moreover, the fact that most projects are on standby waiting for information to be received does not allow for a continuous workflow with standard process planning.

After receiving the Architecture Preparation, the Production Preparation Department starts the structural preparation. Most of the work developed by this department is dependent on the client requirements and specialties approval. The fact that the team proceeds with the preparation without having all approved from the external local identities, conducts in misunderstandings in terms of the client's needs.

Given this preparation, the Production Preparation team in parallel with the Production team tries to estimate and carry out the load-capacity balance to determine the production planning of the projects. Inventory management is done based on the material needs for each project based on the bill of materials (BOM). The Purchasing Department in parallel with the Warehouse Responsible is responsible for the purchase of required quantities of wood. In case production detects insufficient material, this is communicated to the Purchasing Department and the Warehouse Responsible. However, this communication is not clear, which leads to errors in terms of quantities requested and delays in purchasing and delivery time.

During this process, the Construction Preparation Department is in charge of preparing the architecture and specialties for construction that like the Preparation Production team are dependent on external approvals.

Given this information, preparation for on-site house construction starts. In order to meet the deadlines set with the client, the work starts without having the final project design and a work plan. This leads to a different expectation from the one idealized by the client and evidenced in the budget.

3.5 Improvement Opportunities

The implementation of the future production line intends to bring a high degree of complexity and technology to the current process.

The initial production structure evidences great disturbances in the production process and communication flow. The absence of proper planning due to the high variability perceived in the production process leads to operational inconsistencies in quality and output that impacts the efficiency of the whole organization.

Moreover, the fact that the company is growing and intends to adjust its entire production process to increase its production capacity, this initial flow that appeared to work and have results, may be a potential constraint in the Production Ramp-up phase. The absence of clear and open communication, with a low responsiveness and flexibility towards challenges shows the presence of a culture with little capacity to adapt to new procedures.

Table 4 summarizes the improvement opportunities previously identified and their causes, on which special attention should be placed when implementing the new production line.

Table 4 - Concerns and Causes for improvements

Concern	***Cause***
Unorganized work area and raw material warehouse	Absence of a culture of organization and discipline
Displacement to move material	Execution of unnecessary operations due to poor layout structuring and separation of logistical and production work
Unclear definition or absence of	Lack of standardization and work planning

specifications and processes	
Miscommunication between departments	Lack of transmission of information
High number of reworking	Errors in previous processes and planning changes
Delays in delivery of material order	Lack of information about ordered material with delayed communication and quantity errors
Construction start without final project design	Missing preparation of the construction start

With this, it is essential to adopt a strategy that aims to integrate the problems of the current line and potential problems during the implementation of the future line.

4 Solution Design and Implementation

This chapter combines the potential areas for improvement identified in Chapter 3 and the design and implementation of multiple initiatives that contribute to the attainment of a successful management of a Production Ramp-up based on the outlined future vision of the timberframe production line.

4.1 Timberframe Production Model

The future vision of the timberframe production structure presents a high degree of complexity, incorporating two semi-automated production lines, with integration of new operations and materials to the production process. This new production process requires a high level of synchronization, knowledge about the use of technological equipment and communication throughout the value chain.

Figure 12 illustrates the layout of the new production model, where the investment in these production processes intends to increase production capacity and the company's repositioning in the market. The intended vision of one of the lines is for the assembly of walls and the other for roofs.

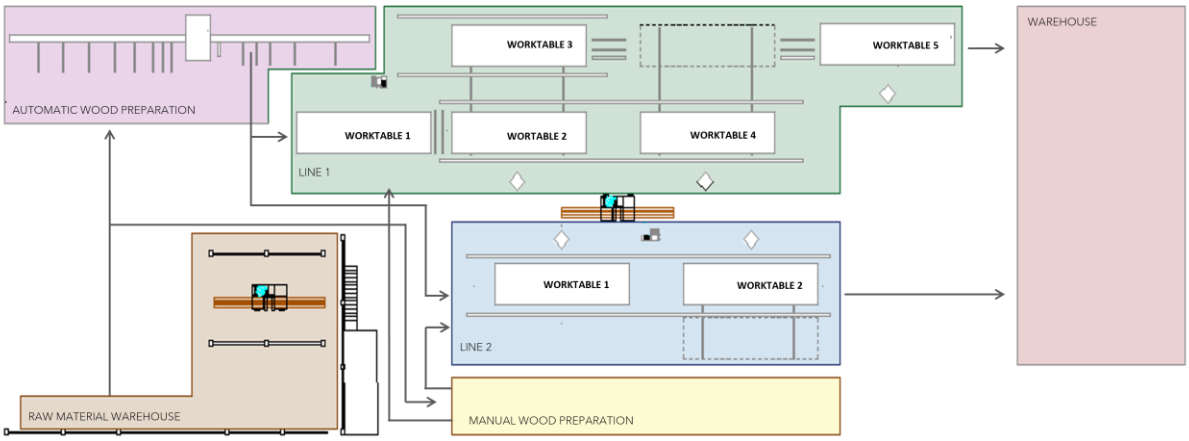


Figure 12 - Layout of the new Production Line

In order to understand in greater detail the influencing factors of the introduction of the new production model, a comparative analysis of the degree of novelty and automation of the production process was conducted. Figure 13 represents the results of an initial estimation of the influence of these factors.

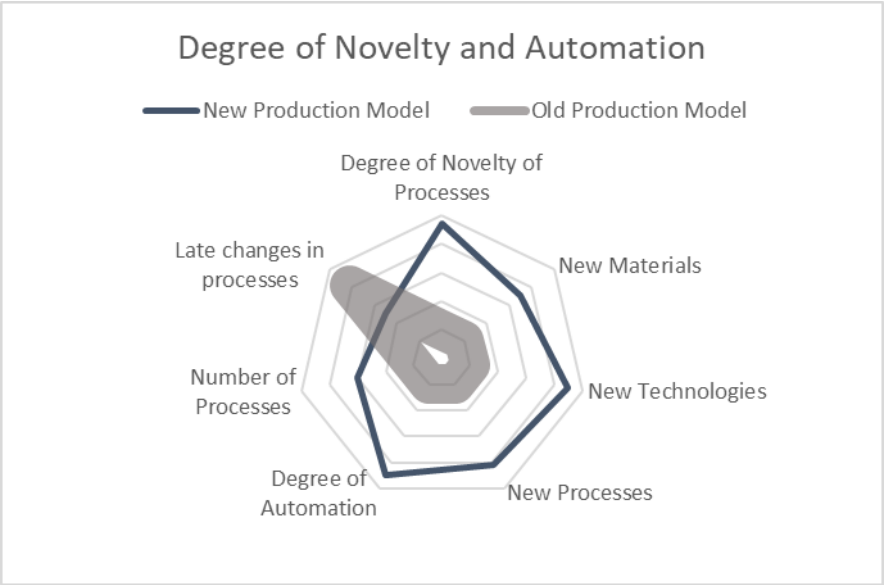


Figure 13 - Influencing factors of Production System

Points closer to the edge of the circle can be interpreted as being more significant for the Ramp-up, such as degree of automation, technology and novelty of processes. These results have interference in the production process and resources, conditioning the proposed time-to-market, costs and quality, as supported by the literature in Section 2.1. Thus, it is essential to proceed to a risk analysis based on the degree of product and process innovation and complexity. Table 5 summarizes the potential risks identified for each influencing factor.

Table 5 - Risk Analysis of Influencing Factors

Influencing Factors	***ID***	***Potential Risk***
Degree of innovation	R1	Lack of experience in handling new materials
	R2	Additional tasks to perform is required
	R3	Low maturity of processes and equipment
Degree of Complexity	R4	Lack of knowledge of new operations and equipment
	R5	Incapacity of fulfilling functional requirements
	R6	Internal organizational conflicts

Despite high levels of uncertainty, the assessment of impact and probability of those risks must be conducted to ensure the shortest possible response time. The risk assessment was obtained by multiplying the impact and probability and the results are shown in detail in Appendix A.

Figure 14 represents the Risk Assessment Matrix according to the results obtained. It is possible to perceive that the points that are in the upper right corner present a higher risk, i.e., risks R4 and R5.

For the evaluation of Ramp-up Production Capability, must be taken into account the individually assessed risk factors, in which special attention must be placed on the fact that knowledge regarding the equipment is reduced and therefore hinders the process in achieving the requirements that the organization promises to deliver. Therefore, the selection of measures must address the problems summarized in section 3.5 as well as the individually assessed risk factors to meet in a more stable way the planned targets.

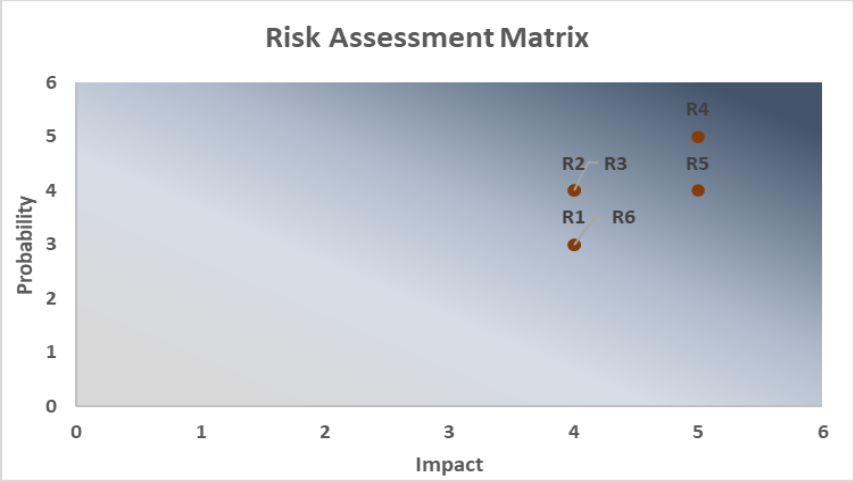


Figure 14 - Risk Assessment Matrix

4.2 Production Capacity Line Design

To understand the production potential of each of the lines, is crucial to analyze and establish what the production capacity of each line can be. This concept is essential to make an assertive sales projection according to demand and to support strategic decisions. To define this capacity, the organization must determine what its maximum available production capacity can be, represented in Equation 4.1. For this it is necessary to take into consideration the daily available time (Opening Time) and the time needed to perform each operation.

$$\text{Maximum Production Capacity (h)} = \text{Opening Time (h)} / \text{Bottleneck Cycle Time (h)} \quad (4.1)$$

The initial vision presented by the organization comprises only Parallel production of walls on line 1 and production of roofs on line 2. However, two strategies were considered in addition to this assumption to investigate the flexibility of each of the lines: Exclusive, and Dedicated Production. Exclusive Production assumes only the production of walls on both the line established for walls (Line 1) and the roofing line (Line 2). By contrast, Dedicated Production comprises the production of both walls and roofs on line 2.

The analysis of the productive capacity for each of these strategies involves determining the cycle time of each operation. Cycle time is the actual time it takes to complete a specific task from start to finish. Table 6 shows the cycle times of each station to produce a panel. It is possible to identify the operations responsible for conditioning the production process of each of the lines for each strategy, that is, the bottleneck. On line 1, worktable 3 constitutes the bottleneck due to Inflation, while on line 2, both in the exclusive wall or roof production process, worktable 2 is the limiting station of the process. Appendix B presents in detail the cycle time for each operation performed in each worktable.

Table 6 - Cycle times of each station of the lines

Line	*Type of Production*	*Station*	*Time / Station*
1	Walls	Worktable 1	41 min
		Worktable 2	1h 13 min
		Worktable 3	1h 17 min
		Worktable 4	50 min
		Worktable 5	56 min
2	Walls	Worktable 1	2h 19 min
		Worktable 2	2h 55 min
	Roofs	Worktable 1	1h 54 min
		Worktable 2	2h 16 min

In order to simulate a real forecast of what will be the typical production of houses at maximum production capacity based on customer demand, the equivalent units method was used. This method considers ongoing and finished production, by assuming the existence of a single production unit, in which the area of each house and respective linear meters of walls and roofs are converted into equivalent houses. It was considered for the determination of the equivalent unit, the production of a 142,8 m^2 house, in which 96,90 linear meters correspond to walls and 380,80 square meters to roofs. The definition of the number of worktables required to produce the model house becomes crucial (Equation 4.2), so the worktable size and maximum worktable occupation of each line must be taken into consideration.

$$\#\ \text{Production of Worktables}_i = (\text{Panel Linear Meters (m)} / \text{Worktable Dimension}_i\ (\text{m})) / \text{Worktable Occupancy}_j\ (\%) \quad (4.2)$$

Where:

j, is the index of the production line (j=1,2)

The production process is quite complex, so in accordance with the organization was considered the production of an additional worktable to produce both interior and exterior walls on line 1 and roofs on line 2. This strategic decision impacts the theoretical definition of the number of worktables to be produced for each type of panel presented in Equation 4.3.

$$\text{Worktable Occupancy}_j\ (\%) = \#\ \text{Theoretical Production of Worktables}_i / (\#\ \text{Theoretical Production of Worktables}_j + C_j) \quad (4.3)$$

Where:

j, is the index of the production line (j=1,2)
C, is the occupation factor of the production worktable for each line (C=1,2)

Although each worktable in line 1 allows for a higher occupancy than in line 2, each house implies the production of a greater number of wall panels than roofs, which reflects in a greater number of worktables to produce. Thus, it is necessary to produce 11 walls and 10 roofing worktables for the model house.

With this assumption, the daily production capacity of the line was determined, represented in Equation 4.4.

$$\text{Daily Productive Capacity (Equivalent Houses/day)} = \text{Opening Time (h)} / (\#\text{Production of Worktables (un)} \times \text{Bottleneck Cycle Time (h)}) \quad (4.4)$$

Table 7 displays the daily production capacity values for each production strategy, whereby for Dedicated Production, the proportion factor of the number of wall worktables needed to be produced on line 2 is considered.

Table 7 - Production Capacity for different production strategies

Production Strategy	***Production Capacity (# Equivalent Houses/day)***
Exclusive Production	0,6
Parallel Production	0,3
Dedicated Production	0,56

Exclusive production proves to be the one to take the most advantage from the production of each line, since it presents the highest value, 0.6 Equivalent Houses / day. However, on a commercial level, this strategy is not the most advantageous. The organization intended not to produce everything on the material to be applied at a later stage after the implementation of the new production line, so it would not be possible to produce only walls. To take benefit of the level of automation of each equipment, the strategic decision made by the organization was to privilege the possibility of producing both walls and roofs on line 2, Dedicated

Production, where the reference to be reached is 0.56 Equivalent Houses/day. Appendix C shows in detail the procedures taken to determine the capacity of production for each strategy and number of worktables required to produce.

With the goal of reaching productive capacity, a metric was established at the project level to provide the necessary basis for assertive decision-making. The indicator to be used is the number of equivalent houses to be produced weekly, whose target to be reached is dependent on the opening days of the week and Overall Equipment Efficiency (OEE). OEE is the gold standard for measuring production productivity. This metric is dependent on three quantifiable factors: Availability, Performance and Quality (Baluch et al., 2012). By measuring OEE and the underlying losses, valuable information is obtained on how to systematically improve the production process.

According to Nakajima (1989), an OEE of 85% should be the value that any company should aim for. However, based on discrete manufacturing industry standards, an OEE of 60% is considered a standard value since it is the most common value present in the industry. An OEE of 40% usually refers to companies that are starting their innovation strategy and are beginning to measure and monitor efficiency and productivity indicators. Thus, the theoretical OEE considered at the beginning of the implementation of the Production Ramp-up is 40% with the intention of being increased to the industry standard value.

The OEE assumes the evaluation of the number of equivalent houses produced, the weekly available time and the daily productive capacity considering the maximum efficiency. With this, it is intended to evaluate the success of the implementation of the Production Ramp-up plan on a weekly basis, in order to identify potential deviations and develop strategies aimed at reducing waste.

Equation 4.5 shows the OEE calculation implemented for the production system in question.

$$\text{OEE (\%)} = \sum \text{Weekly Production Capacity (Equivalent Houses / Weekly)}_j \,/\, (\text{Weekly Opening Time (days)} \times \text{Production Capacity (Equivalent Houses /Day)}) \quad (4.5)$$

Where:

j, is the index of the production line (j=1,2)
Production Capacity, considered for a 100% efficiency

4.3 Production Flow Improvements

In order to increase the desired production capacity, an adequate production workflow is essential to guarantee alignment between the shopfloor and the other departments.

4.3.1 Operation Balancing

The implementation of the new production lines implies the reallocation of operators to the new worktables. For this, production must be organized by leveling the production load between operations and worktables to achieve a more uniform workflow.

This balancing of operations implies a careful analysis of cycle times and respective bottlenecks. There are two methods to reduce the average per-item time of an operation: increasing the number of operators or modifying the processes to decrease the cycle time. Since the bottleneck of line 1 corresponds to worktable 3, due to the Automatic Inflation process, it’s not possible to modify the layout and the sequence of the production process must be respected. With this, the combination of different operations by the worktables is not possible.

To ensure that each worktable does not last longer than the cycle time, it is necessary to allocate the number of operators that balances the cycle time of each operation by the bottleneck cycle time.

Determining the number of operators (Equation 4.6) implies knowing the Takt Time. According to Taiichi Ohno (1998), Takt Time is the result between the daily operation time by the number of required parts and allows determining if a given process is able to meet a given demand.

$$\text{Number of Operators}_j = \sum \text{Operations Cycle Time}_j\,(h) \,/\, \text{Takt Time}\,(h) \quad (4.6)$$

Where:

j, is the index of the production line (j=1,2)

However, as the desired demand to be obtained with the increase of production capacity is unknown, this concept becomes difficult to apply, thus the values provided by the supplier were used as reference. According to the supplier, the ideal number of operators would be two for each worktable. However, given the level of automation of the operations performed on worktable 3, 4 and 5 of line 1, it is possible to allocate one operator to more than one worktable. Appendix A shows the configuration of the allocation of operators by worktables.

4.3.2 Border of Line Dimensioning

The definition of the border of the line in the implementation of new production lines has a great impact not only in terms of visual and space organization, but also in terms of support between production and logistics. As the border between the production line and the logistic circulation area, the border of line should be designed to minimize the *Muda* of operator movement and to be as ergonomic as possible. For this, an inventory of consumables and tools for each worktable and respective quantities was carried out. This information permitted the design and sizing of the border of line with all the needed materials for each operation, in order to ensure that it would be functional. For this, the production layout was analyzed to ensure that it is located at strategic points and its repositioning is done in a bidirectional way. According to the existing space, it works in a bidirectional way: the front part of the stand is for the operators' use and the back part is for replenishment.

With this, a pilot stand was prepared with the presence of each of the component boxes and their identification. The main objective was to simulate the size of the border of line and the daily operation to identify possible difficulties with the implementation of the concept and, after validation, to replicate for all the worktables of each of the lines.

4.3.3 Visual Management and Organization

The implementation of the new production model as well as the new initiatives adopted must be followed by a high level of discipline and organization of the entire production space. Level 2 Daily Kaizen is a simple and highly effective tool to implement, through the application of the 5S tool and Visual Management. It allows for easy identification and access to tools and materials, reducing the time spent searching for or retrieving items, improving accessibility, safety and eliminating unnecessary movements. The implementation of 5S involves creating a culture based in thinking and acting by observing. As a result, this strategy was implemented on the border of line and space between the two lines. The strategy includes the implementation of all five steps, through removing all unnecessary tools from the workplace, the creation of cleaning kits and a dedicated schedule for the maintenance of the space at the end of each production day, accompanied by visual identification on the shopfloor. The next step included the organization of all the materials and tools, by defining the appropriate position in the implemented border of line and identification with labels. To facilitate organization, floor markings were made. This assumed a crucial role in preventing equipment breakdowns.

Each line was also identified with different colors as well as the operators. Moreover, the sequence of warehouse organization was defined, in which each type of material is arranged

according to its use for production and the placement of tools in the borders of line was defined. Figure 15 illustrates the organization defined for the raw material warehouse.

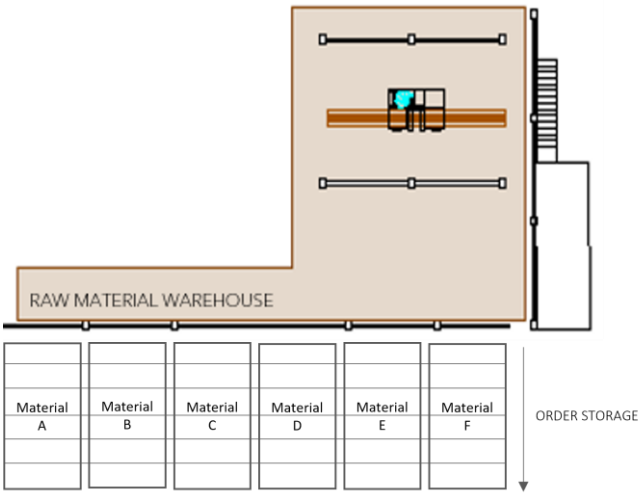


Figure 15 - Design of the Raw Material Storage Sequence

The establishment of this organization requires a high level of discipline and for that the role of the team leader is crucial. To this effect, the teams were monitored and trained, with the purpose of encouraging them to incorporate this organizational culture into their daily routine in a sustained manner.

4.3.4 Standard Work

Given the variability and difficulties inherent to the implementation of the production process, the concept of Standard Work is essential. The definition of work standards from manual wood preparation to the actual construction of the house makes it possible to eliminate unnecessary procedures and increase the efficiency and quality of the entire value chain. Thus, it is intended to ensure that all operators are informed about the best production practices, so that they follow the most efficient flow of tasks.

This methodology of standardizing operations implies a clear knowledge of the production process, which corresponds to Level 3 of the Kaizen Business System's Daily Kaizen methodology. Table 8 shows the steps required to develop and implement the necessary standards (Coimbra, 2009).

Table 8 - Implementation Steps for Standardization

Methodology	***Objective***
Purpose definition	Provide clear guidelines to workers about the production of the new line, reducing ambiguity and enabling faster skill development.
Operation observation	Observe the CNC programs and assembly operations on the automated tables.
Improvement identification	Identify areas of inefficiencies and difficulties in the use of the new production machines and implement improvement measures.
Procedures Standardization	Standardize the production model according to the new method, through the leveling of practices.
Procedures Consolidation	Ensure compliance with the new work practices, through continuous support.

An operating model of the organization was developed, from the Commercial Department to the Construction Direction Department. This operating model is intended to be a visual representation of how the organization delivers value to its internal and external customers. Moreover, its creation has the objective of helping each collaborator to understand their roles in the organization in order to document the procedures each department must follow to meet the requirements of the business and its customers and reduce *Muda*. This model is divided into four sections:

- **Processes**: This section includes all the required standards for successful management of operations. It includes visual and detailed instructions of the tasks to be performed, called One-Point Lesson (OPL). At the production level, standards were developed for wood preparation and panel production, as well as workplace organization and cleaning. At the level of other departments, the focus was on the development and planning standards for meetings and procedures, and for that, an assessment of all the activities that needed to be standardized was conducted;
- **Equipments**: To ensure the correct use and safety of the new equipment, the programs required were understood and the respective sequence of instructions and setups were developed;
- **Systems**: This section addresses the information systems to be implemented in the future, when the production system is stabilized, namely at the level of stock and financial management;
- **People**: This section includes the structure of each department and its functions. To achieve the desired production capacity, enable sustained growth and proper alignment with the objectives of the organization, the structures were reorganized, through the reallocation of responsibilities and people. An example of the standard created was the Leader's Standard Work for Production Team Leader. This standard intends to eliminate non-value-added activities and better organize the work to ensure that the new standards are being followed and the time spent on strategic issues and longer-term planning becomes a priority.

This strategy is especially important in the implementation of Production Ramp-up, since the need to hire and relocate workers implies their onboarding and training. For an appropriate integration and to accelerate the individual performance and learning process of how to work in the new highly automated production system, these standards help to better understand the changes and provide visual support that can be consulted at any time. Appendix D represents examples of the standards developed related to the processes section of the Operating Model.

Process Confirmation

To ensure control of the execution and compliance with standards, a high level of monitoring is required. The solution adopted to verify compliance with standards was the use of *Kamishibai* and the *Gemba Walk*. These tools aim to assist in building sustained results and are used by various hierarchical levels and different frequencies.

Kamishibai tool requires the development of simple questions with integrated visual management, whose answer is of the boolean type (Ok/Nok). In case of a negative answer to one of the points, the card must be turned to the red face, otherwise, it is turned to the green face. The Production Team Leader had the responsibility in his Standard Work to ensure the monitoring of the production process and compliance with work standards and organization of the shopfloor. Additionally, to ensure the follow-up of the results obtained through each audit performed, a process indicator was developed that aimed to evaluate the presence of the number of red cards in *Kamishibai*. Appendix E shows the example of a *Kamishibai* adopted

for production, in which compliance with the 5S and standards of the established operations is evaluated.

The *Gemba Walk* and its register are essential to visualize and understand the production process, confirm standards, and identify possible constraints, through the involvement of operators and leaders so that it is possible to identify opportunities for continuous improvement. For this, a mobile application was implemented to be validated weekly by the Production Director. Figure 16 shows the developed mobile application.

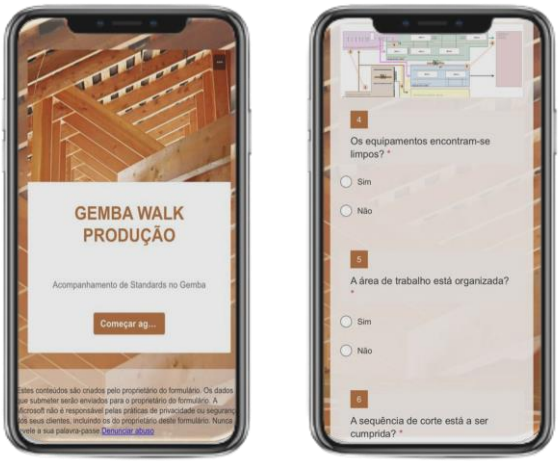


Figure 16 - Gemba Walk application

Similarly, to *Kamishibai*, this application was intended to monitor the evolution of compliance with 5S and process and quality standards. With this, the route of the critical points to be evaluated was defined, which included the raw material and finished product section and the respective production lines for walls and roofs. In the case of non-compliance with the standards, corrective or preventive actions would be developed, depending on the impact that non-compliance would have. The development of these actions was based on the application of the PDCA cycle, the problem analysis and the solution method mentioned in Section 2.4.1. Appendix F presents the route established for *Gemba Walk*, the topics addressed for each work area and the respective action.

4.4 Internal Logistics Flow Improvements

Measures to ensure a proper optimization of the flow of materials and information in *Gemba* during this phase are crucial in order to increase the efficiency of processes and promote stability.

4.4.1 Supply Logistics Circuit

Production Ramp-up often requires increased quantities of components to be delivered to the assembly lines, thus the creation of an internal logistics system to support the production lines must ensure the efficient use and movement of material and contributes to the streamlining of production process. Thereby, by ensuring the availability of components and reducing the material handling of workers, internal logistics reduces disruptions and enables a smooth increase in output.

To supply the line according to the real time consumption of the components, the first step involves the quantification of the necessary quantity to be stored of each consumable in each box present at the border of line, as well as the raw material. This value is dependent on the storage capacity of the boxes, ease of transport, and, consequently, the frequency with which the replenishment of the material is done, without neglecting the ergonomic principle of the

border of line and the availability of material. Thus, it is necessary to define a logistics operator, called *Mizusumashi*, which concentrates on the responsibility of supplying all the material necessary for the assembly of the panels and their removal at the end of the line. The solution presented for the *Mizusumashi* is a logistics operator assisted by a forklift, used to transport consumables and wood raw material in conveyors.

Once the layout of the transport has been defined, it is necessary to dimension the quantity of each box for each consumable, through the frequency of replenishment, for the lines to have sufficient autonomy for sequenced production. In addition, it is necessary to guarantee the standard logistic circuit, taking into consideration the layout. This circuit must incorporate all the replenishment points, and must be as efficient as possible, by ensuring the collection of empty boxes from the border of line, delivering them to the Tooling and Raw Material Warehouse and replenishing the quantity defined for the N-1 cycle box material. This replenishment occurs by the *kanban* system. The method consists of establishing a flow control protocol and stock replenishment through full box, empty box.

Figure 17 represents the first iteration for the logistic circuit to be performed by *Mizusumashi* and its respective supply points for the two production lines and removal of the finished panels at the end of each line.

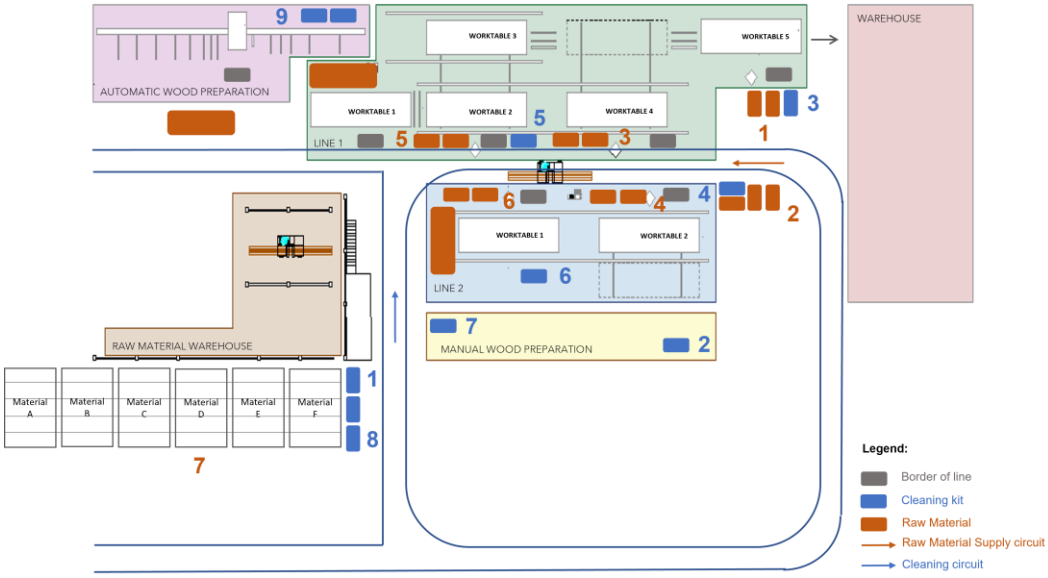


Figure 17 - Logistic circuit of *Mizusumashi*

The line must have daily work autonomy. For this, it is necessary to determine the actual frequency of the logistic operator that guarantees this principle, through the practical applicability of the designed theoretical solution. The *kanban* sizing depends on the frequency of *Mizushumahi*. To guarantee that all the material is available during the replenishment period, the quantity to be had of each reference must ensure the satisfaction of demand during the delivery time and safety quantity (Ávila and Cavaco, 2008). The number of *kanbans* represents the number of boxes that should be filled and naturally consumed (Equation 4.7).

$$\text{Number of Kanbans} = (D \times L+W) / C \quad (4.7)$$

Where:

D, is the Average Demand per unit time
l, is the Lead Time, here interpreted as the time for order replenishment
W, is the Safety Stock, usually corresponds to 10% of the average demand during the delivery time
C, is the capacity of a box, usually corresponds to 10% of daily demand

To mitigate the variability in component consumption, it was decided to use the double box system, in which each reference should be equal to the consumption during two cycles of the

Mizusumashi and one more unit of consumption for possible variations. Simplifying Equation 4.7, the quantity of boxes referred to is obtained (Equation 4.8).

$$\text{Number of Kanbans} = (2 \times D) / C + 1 \quad (4.8)$$

Where:

D, is the Average Demand per unit time
l, is the Lead Time, here interpreted as 2 cycles of *Mizusumashi*
W, is the Safety Stock, here interpreted as 1 unity of transport
C, is the capacity of a box, usually corresponds to 10% of daily demand

The quantity of each box must also consider the maximum incorporation factor of each component. This implies the value to be set must be a multiple of the maximum quantity that a component can integrate to ensure that there are no shortcomings in material availability.

4.4.2 Production Pull Planning

The planning of the production process to increase production capacity involves the adoption of a Pull strategy, in which production is aligned with demand. To achieve excellent performance results, this methodology requires the application of the involvement of all parts responsible for the productive process.

For this, it is first necessary to define the strategic plan for attaining the designed production capacity. This planning lies in establishing objectives and policies appropriate to the organization's resources that are transformed into efficient operational results. Since the implementation of the new lines requires a high technical complexity, a high level of flexibility is required to attain the requirements as well process visibility at the moment, instead of in retrospect.

Moreover, to increase the level of the desired customization, a high level of detail from Construction and Production Preparation is indispensable, so many of the details are designed from scratch and specific to each project. Therefore, the strategy to be adopted for the final product implies a Make-to-Order (MTO) strategy, in which the panels are produced and assembled in response to the client's order. Figure 18 represents this planning strategy.

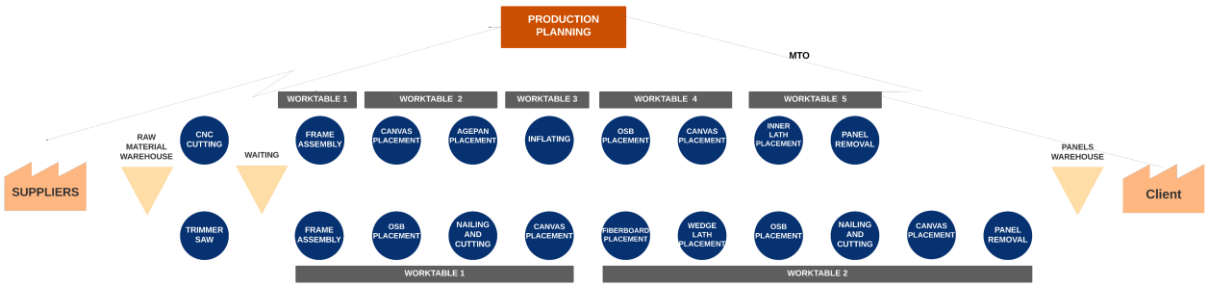


Figure 18 - MTO Production Planning Strategy

Based on this, execution planning follows. This planning defines the way in which the whole production system will be planned and sequenced.

Given the existence of different projects and dynamic priorities, it is necessary to have a model capable of measuring production capacity and adjustable to changes, so that it is possible to meet the growing volume of demand and take full advantage of the production capacity of each line. For this, a digital tool in Microsoft Excel was built, called the Logistics Box. The development of this tool is intended to increase the reliability of delivery times agreed with the customer and, at the same time, to enhance the communication of information between the various departments.

The first step of the tool requires the addition of the new project in the Project Portfolio based on confirmed sales by the Commercial Department. This implies indicating the name of the client, the number of houses to produce, the total area of the house, total linear meters of walls

and roof area. Then the type of information provided must be defined. If the Architecture is not yet approved, the information made available corresponds to a "Projeção" (Projection), if not the "Real" (Real).

The tool provides an estimate of the number of equivalent houses for each project, according to the assumption of the area of the model house considered. In addition, it presents detailed information on the number of worktables for walls and roofs required and the number of production days. The required number of production days is dependent on the daily available time, bottleneck cycle time, and maximum worktable occupancy of each of the lines (Equation 4.9).

$$\text{Production Time (days)} = (\#\ \text{Worktable Production}_j\ (\text{un}) \times \text{Bottleneck Cycle Time (h)}) / \text{Opening Time (h)} \quad (4.9)$$

Where:

j, is the index of the production line (j=1,2)

According to this, the production priority is defined. Depending on the delivery time defined with the client, there are three possible states: "*Em Espera*" (On Hold), "*Planeado*" (Planned) and "*Fabricado*" (Produced). The status is updated to "*Planeado*" (Planned) if it is considered a priority for production by the delivery date defined with the customer and the production time of this, otherwise, it remains "*Em Espera*" (On Hold). With this, it is possible to have visibility of the projects waiting for Architectural approval, entered for production priority, finalized for delivery to the construction site, as well as the time needed to produce each house. This enables the company to adjust to meet fluctuations in demand, allowing to level out the production load.

Figure 19 shows the information provided by the tool with the introduction of the initial project data.

								LINHA 1 (Dias)	LINHA 2 (Dias)		EM SÉRIE	FATOR MODELO	
TIPO INFO	STATUS	PROJETO	QTY	ARE	Metros Lineares Par	Area de Cobertura(L	#Mesas Par	#Mesas Coberi	T.Paredes	T.Paredes	T. Lages/Coberi	T.Total	CASAS EQUIVALENTES(m2	CASAS EQUIVALENTES (mParede
REAL	1.Fabricado	Project A	1	436,9	442	436,9	45	20	7,8	17,6	6,1	23,7	3,10	4,60
REAL	1.Fabricado	Project B	1	239,7	147,9	241,4	15	11	2,6	5,9	3,4	9,3	1,70	1,60
REAL	1.Fabricado	Project C	1	388,3	469,2	241,4	48	11	8,3	18,7	3,4	22,1	2,80	4,90
REAL	1.Fabricado	Project D	1	436,9	442	436,9	45	20	7,8	17,6	6,1	23,7	3,10	4,60
REAL	2.Planeado	Project E	1	436,9	442	436,9	45	20	7,8	17,6	6,1	23,7	3,10	4,60
REAL	2.Planeado	Project F	1	436,9	442	436,9	45	20	7,8	17,6	6,1	23,7	3,10	4,60
REAL	2.Planeado	Project G	1	436,9	442	436,9	45	20	7,8	17,6	6,1	23,7	3,10	4,60
PROJEÇÃO	2.Planeado	Project H	1	510	442	510	45	23	7,8	17,6	7	24,6	3,60	4,60
PROJEÇÃO	2.Planeado	Project I	1	510	442	510	45	23	7,8	17,6	7	24,6	3,60	4,60
PROJEÇÃO	2.Planeado	Project J	1	510	442	510	45	23	7,8	17,6	7	24,6	3,60	4,60
REAL	2.Planeado	Project K	1	78,2	34	227,8	3	11	0,6	1,2	3,4	4,6	0,60	0,40
REAL	2.Planeado	Project L	1	688,5	375,7	683,4	39	31	6,7	15,2	9,4	24,6	4,90	3,90
REAL	2.Planeado	Project M	1	137,7	88,4	289	9	13	1,6	3,6	4	7,6	1,00	1,00
REAL	2.Planeado	Project N	1	168,3	110,5	357	12	16	2,1	4,7	4,9	9,6	1,20	1,20
REAL	2.Planeado	Project O	1	231,2	161,5	484,5	17	22	3	6,7	6,7	13,4	1,70	1,70
REAL	2.Planeado	Project P	1	226,1	153	489,6	15	22	2,6	5,9	6,7	12,6	1,60	1,60
REAL	2.Planeado	Project Q	1	178,5	103,7	357	11	16	1,9	4,3	4,9	9,2	1,30	1,10
REAL	2.Planeado	Project R	1	227,8	168,3	455,6	18	21	3,1	7,1	6,4	13,5	1,60	1,80
REAL	3.Em Espera	Project S	1	261,8	161,5	528,7	17	24	3	6,7	7,3	14	1,90	1,70
							0	0	0	0	0	0	0,00	0,00
							0	0	0	0	0	0	0,00	0,00
							0	0	0	0	0	0	0,00	0,00

Figure 19 - Portfolio of the Logistics Box Tool

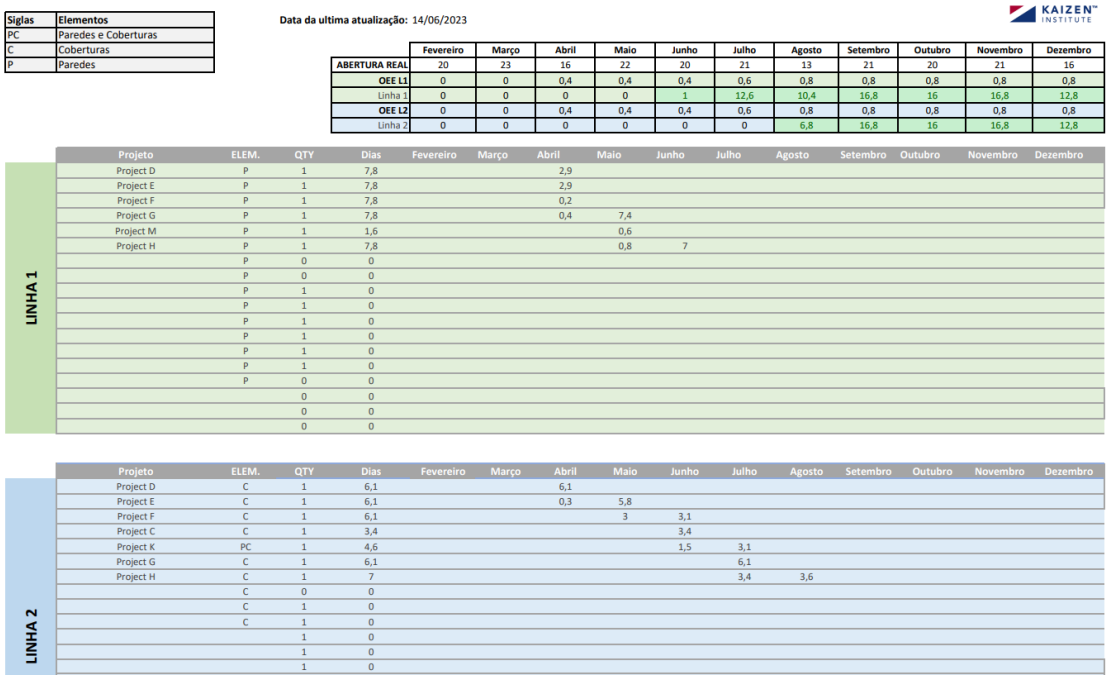
Subsequently, the production sequence is defined. The sequence of production is dependent on the required production time and the available capacity of each line for each month based on the theoretical OEE considered.

The tool presupposes the introduction of the project name and the type of production strategy defined according to a code. In line 1, the code is “P”, which corresponds to the production of walls, and in line 2, in the case of the production of roofs only, the code to insert is a “C, and in case of the walls and roofs production is required to insert a “PC”.

The first attempt assumes the allocation of the production load in days necessary to produce walls and roofs in the month that there is availability provided by the system, for each line. If the number of days exceeds the availability of the month, the tool indicates the impossibility of production in that month for each line, so that the missing days must be allocated to the following month. The tool enables to divide the production into several months and thus

maximize the load. For example, to produce roofs of Project F, 48% is produced in the month of May and 52% in the month of June.

Figure 20 presents the Logistics Box, the information of a production order of a project and its planning after capacity reservation.



Siglas	Elementos
PC	Paredes e Coberturas
C	Coberturas
P	Paredes

Data da ultima atualização: 14/06/2023

KAIZEN INSTITUTE

	Fevereiro	Março	Abril	Maio	Junho	Julho	Agosto	Setembro	Outubro	Novembro	Dezembro
ABERTURA REAL	20	23	16	22	20	21	13	21	20	21	16
OEE L1	0	0	0,4	0,4	0,4	0,6	0,8	0,8	0,8	0,8	0,8
Linha 1	0	0	0	0	1	12,6	10,4	16,8	16	16,8	12,8
OEE L2	0	0	0,4	0,4	0,4	0,6	0,8	0,8	0,8	0,8	0,8
Linha 2	0	0	0	0	0	0	6,8	16,8	16	16,8	12,8

LINHA 1

Projeto	ELEM.	QTY	Dias	Fevereiro	Março	Abril	Maio	Junho	Julho	Agosto	Setembro	Outubro	Novembro	Dezembro
Project D	P	1	7,8			2,9								
Project E	P	1	7,8			2,9								
Project F	P	1	7,8			0,2								
Project G	P	1	7,8			0,4	7,4							
Project M	P	1	1,6				0,6							
Project H	P	1	7,8				0,8	7						
	P	0	0											
	P	0	0											
	P	1	0											
	P	1	0											
	P	1	0											
	P	1	0											
	P	1	0											
	P	0	0											
		0	0											
		0	0											
		0	0											

LINHA 2

Projeto	ELEM.	QTY	Dias	Fevereiro	Março	Abril	Maio	Junho	Julho	Agosto	Setembro	Outubro	Novembro	Dezembro
Project D	C	1	6,1			6,1								
Project E	C	1	6,1			0,3	5,8							
Project F	C	1	6,1				3	3,1						
Project C	C	1	3,4					3,4						
Project K	PC	1	4,6					1,5	3,1					
Project G	C	1	6,1						6,1					
Project H	C	1	7						3,4	3,6				
	C	0	0											
	C	1	0											
	C	1	0											
		1	0											
		1	0											
		1	0											

Figure 20 - Production Planning of Logistics Tool Box

The use of the tool presupposes the weekly update in parallel with the Commercial Department and the Production Preparation team of the projects in progress, which is subsequently sent to all departments.

Along with this strategy, optimizing the worktable occupation is essential to be able to meet the estimated production load. For this, a Microsoft Excel tool was developed, in which the sequence of panels to be produced is defined according to the size, thickness, type of panel and at the same time must guarantee the maximum possible occupancy determined for each production line. In case the optimization of the worktable's occupancy has not been guaranteed or the size of all the panels to be produced exceeds the possible worktable's dimension, the tool warns a red or yellow visual alert to the user that the sequence is not possible. Figure 21 demonstrates the sequence of panels to be produced obtained with the tool. Worktables whose summation value is in yellow indicate that the minimum dimension to be guaranteed has been exceeded, so the panel sequence should be relocated, if possible, in order to avoid difficulties during production.

Tipologia	# Mesa	Soma de L	# Paineis por Mesa	% de Ocupação
Ext.	1	9828,0	4	82%
Ext.	2	11112,8	4	93%
Ext.	3	10758,1	3	90%
Ext.	4	11374,3	3	95%
Ext.	5	9192,5	2	77%
Ext.	6	9192,5	2	77%
Ext.	7	10391,2	4	87%
Ext.	8	11020,8	4	92%
Ext.	9	10243,5	2	85%
Ext.	10	11766,9	2	98%
Ext.	11	10108,9	1	84%
Ext.	12	9376,0	1	78%
Ext.	13	7216,0	1	60%
Ext.	14	7198,0	1	60%
Int.	15	9359,5	1	78%
Int.	16	7980,5	1	67%
Int.	17	8172,1	1	68%
Int.	18	8172,1	1	68%
Int.	19	11480,6	2	96%
Int.	20	11320,0	2	94%
Int.	21	11084,3	3	92%
Int.	22	11134,1	6	93%
Int.	23	11309,0	5	94%
Int.	24	11069,6	6	92%
Int.	25	10188,4	5	85%
Int.	26	10957,6	5	91%
Int.	27	9903,0	3	83%
Int.	28	7499,9	4	62%
Int.	29	4543,6	5	38%

	1	2	3	4	5	6	DATA
1	30	31	10	29			
2	11	12	14	32			
3	13	15	16				
4	17	2	4				
5	5	6					
6	7	8					
7	9	18	19	21			
8	22	23	27	33			
9	24	34					
10	1	25					
11	3						
12	20						
13	26						
14	28						
15	35						
16	36						
17	78						
18	80						
19	54	55					
20	77	63					
21	64	65	66				
22	67	68	69	71	72	59	
23	73	74	75	76	50		
24	37	38	39	40	42	61	
25	43	44	51	52	53		
26	56	57	58	60	62		
27	45	47	49				
28	48	70	41	46			
29	79	81	82	83	84		

Figure 21 - Optimization of worktable occupancy

4.5 Communication Flow

A well-established communication flow during the implementation of this process is crucial to ensure that relevant information is shared promptly across all departments, from the Commercial phase to the Construction phase.

This solution comes at the detriment of the new planning system. In order to be able to attain the production capacity, it is necessary that all phases preceding Production are finalized. For this, the correct sequencing of processes must be established, avoiding that each department starts its work without having all the information available, and thus reducing the time spent in constant revalidations with the client, changes due to changing requirements, and lack of approvals from external entities.

The Flowchart in Figure 22 reflects the changes introduced with the new planning strategy. Revalidations at the end of the Architectural Preparation for Production and Construction process with the customer were removed from the process, as the requirements are approved initially, which allows the creation of a smoother flow. All the activities that do not add value are eliminated, allowing to reduce the number of stand-by projects.

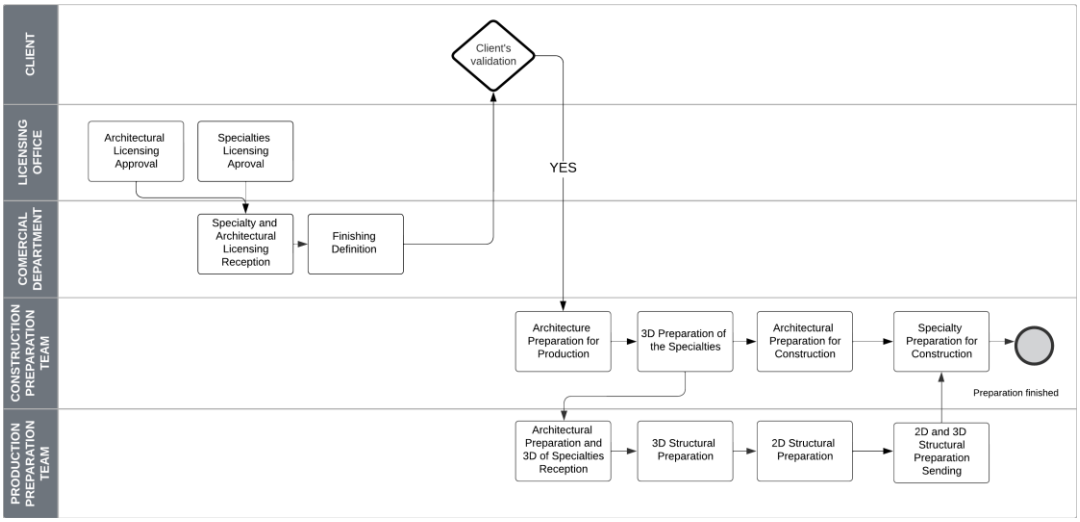
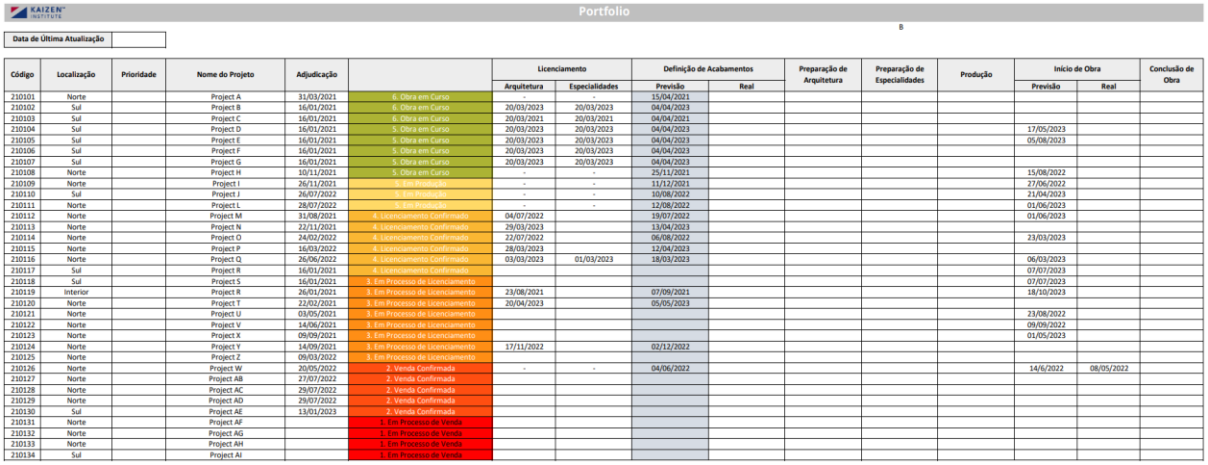


Figure 22 – Improved Production Process Flow

Additionally, a visibility tool for the approval status of each of the phases was created, in which each department can see on what date it was validated and define the priority of the work. This tool presupposes the input of the project's name and the respective update of the dates of each phase on a weekly basis. After the approval of the Architectural License, the tool indicates the deadline for the definition of finishes, according to the established timeframe of 15 days. If this date is not met, the tool issues a red visual alert for the project in question. Figure 23 represents the tool created in which the status of each project is shown.



Portfolio

Data de Última Atualização

Código	Localização	Prioridade	Nome do Projeto	Adjudicação		Licenciamento		Definição de Acabamentos		Preparação de Arquitetura	Preparação de Especialidades	Produção	Início de Obra		Conclusão de Obra
						Arquitetura	Especialidades	Previsão	Real				Previsão	Real	
210101	Norte		Project A	31/03/2021	6. Obra em Curso	-	-	15/04/2021							
210102	Sul		Project B	16/01/2021	6. Obra em Curso	20/03/2023	20/03/2023	04/04/2023							
210103	Sul		Project C	16/01/2021	6. Obra em Curso	20/03/2021	20/03/2021	04/04/2021							
210104	Sul		Project D	16/01/2021	5. Obra em Curso	20/03/2023	20/03/2023	04/04/2023					17/05/2023		
210105	Sul		Project E	16/01/2021	5. Obra em Curso	20/03/2023	20/03/2023	04/04/2023					05/08/2023		
210106	Sul		Project F	16/01/2021	5. Obra em Curso	20/03/2023	20/03/2023	04/04/2023							
210107	Sul		Project G	16/01/2021	5. Obra em Curso	20/03/2023	20/03/2023	04/04/2023							
210108	Norte		Project H	10/11/2021	5. Obra em Curso	-	-	25/11/2021					15/08/2022		
210109	Norte		Project I	26/11/2021	5. Em Produção	-	-	11/12/2021					27/06/2022		
210110	Sul		Project J	26/07/2022	5. Em Produção	-	-	10/08/2022					21/04/2023		
210111	Norte		Project L	28/07/2022	5. Em Produção	-	-	12/08/2022					01/06/2023		
210112	Norte		Project M	31/08/2021	4. Licenciamento Confirmado	04/07/2022		19/07/2022					01/06/2023		
210113	Norte		Project N	22/11/2021	4. Licenciamento Confirmado	29/03/2023		13/04/2023							
210114	Norte		Project O	24/02/2022	4. Licenciamento Confirmado	22/07/2022		06/08/2022					23/03/2023		
210115	Norte		Project P	16/03/2022	4. Licenciamento Confirmado	28/03/2023		12/04/2023							
210116	Norte		Project Q	26/06/2022	4. Licenciamento Confirmado	03/03/2023	01/03/2023	18/03/2023					06/03/2023		
210117	Sul		Project R	16/01/2021	4. Licenciamento Confirmado								07/07/2023		
210118	Sul		Project S	16/01/2021	3. Em Processo de Licenciamento								07/07/2023		
210119	Interior		Project R	26/01/2021	3. Em Processo de Licenciamento	23/08/2021		07/09/2021					18/10/2023		
210120	Norte		Project T	22/02/2021	3. Em Processo de Licenciamento	20/04/2023		05/05/2023							
210121	Norte		Project U	03/05/2021	3. Em Processo de Licenciamento								23/08/2022		
210122	Norte		Project V	14/06/2021	3. Em Processo de Licenciamento								09/09/2022		
210123	Norte		Project X	09/09/2021	3. Em Processo de Licenciamento								01/05/2023		
210124	Norte		Project Y	14/09/2021	3. Em Processo de Licenciamento	17/11/2022		02/12/2022							
210125	Norte		Project Z	09/03/2022	3. Em Processo de Licenciamento										
210126	Norte		Project W	20/05/2022	2. Venda Confirmada	-	-	04/06/2022					14/6/2022	08/05/2022	
210127	Norte		Project AB	27/07/2022	2. Venda Confirmada										
210128	Norte		Project AC	29/07/2022	2. Venda Confirmada										
210129	Norte		Project AD	29/07/2022	2. Venda Confirmada										
210130	Sul		Project AE	13/01/2023	2. Venda Confirmada										
210131	Norte		Project AF		1. Em Processo de Venda										
210132	Norte		Project AG		1. Em Processo de Venda										
210133	Norte		Project AH		1. Em Processo de Venda										
210134	Sul		Project AI		1. Em Processo de Venda										

Figure 23 - Portfolio Status Tool

This provides an overview of the inputs required from each team and their respective time horizon, so that there is visibility of the processes and information needed to be defined a priori.

4.6 Organizational Management

Without a strong commitment and transparency of top management, it is not possible to efficiently reduce market and technical uncertainty of Production Ramp-up. The organization must be able to provide a quick and efficient response to changes in action.

4.6.1 Knowledge Management

Knowledge regarding the operation of each production line, especially automated operations, is low. Automated operations require a high knowledge of the equipment and programs used, so the focus should be on developing and leveraging the skills of more experienced operators to transfer their knowledge to others.

The skills matrix is a tool used to map the skills required for the proper functioning of each production line and understand the skill level of each operator and which areas require greater investment. The first step must be to create a visual chart with the skills to be developed for each operation, and then the respective qualification of the level of knowledge of each operator in the different skills on a scale of 1 to 4. This allowed the identification of which operators needed to be trained.

According to this, a development and training plan was implemented, in which it was defined who would be responsible for the training, who would receive it, and when it would take place. The operators who had a higher level of knowledge, whose assignment had a score of 4 in the competence matrix assumed the role of trainer and coach to those who had received a qualification of 1. The OPLs previously created played a crucial role in supporting the learning process.

This strategy allows the optimization of the available resources, without implying a high economic investment in external training and at the same time allows to decrease the instability and time spent on understanding the specifications of the project drawings and, in turn, in rework. Figure 24 represents the skills matrix developed.

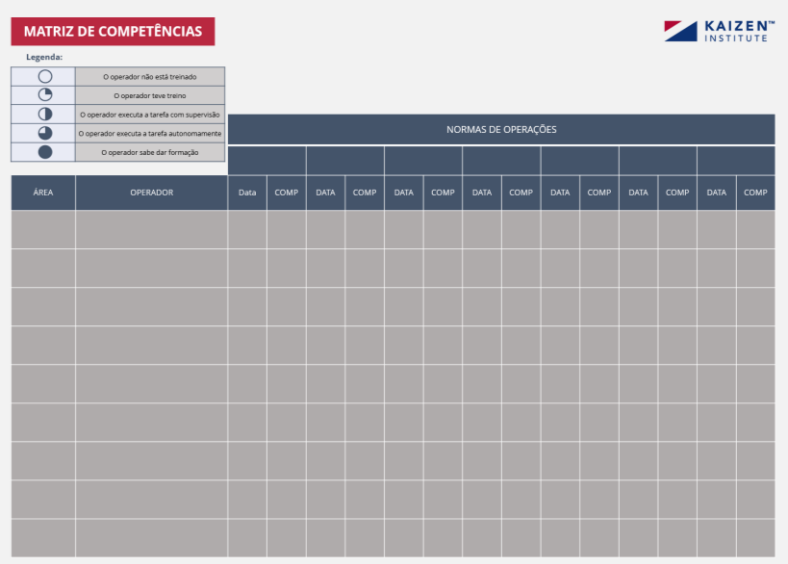


Figure 24 - Skills Matrix

4.6.2 Daily Kaizen

The application of daily management tools throughout the organization intends to create a culture of transparency, communication between the various departments and promote a culture of continuous improvement to ensure a more effective and responsive response.

To this end, formal moments of communication and performance evaluation were established. At the level of each department, a routine of daily meetings was implemented with the purpose of fostering team planning, communication and promoting continuous improvement processes.

These meetings are supported by a tool, called Daily Kaizen Board, which includes three fundamental pillars: People, Performance and Continuous Improvement. The People section comprises the Agenda, Planning and Attendance list and aims to coordinate the team. The Performance pillar comprises the indicators, in which progress is monitored visually and the Continuous Improvement pillar includes the PDCA cycle to involve teams in identifying constraints and developing improvement actions.

They are intended to be concise and allow each team to plan their activities adequately on a weekly basis to meet objectives, anticipate potential problems and ensure the correct flow of information. With this, the time that would be dedicated to problem-solving is minimized.

The design of the Daily Kaizen board was developed in collaboration with each team and customized according to the needs of each department. All boards have in common the agenda, attendance list, weekly planning and improvement cycle. However, for the Construction Preparation Department, a broader view of each stage of the project was intended, so a section dedicated to this macro planning was also implemented. In the Production Preparation Department, the projects in backlog, that is, those that are pending to enter in execution, were highlighted in the board. This allows the team to define its priorities, avoiding work overload. In the Production Department, the skills and training matrix strategy developed to optimize the learning process was included.

To define the indicators for each department, a careful analysis of what would be the best metrics to evaluate was required. Knowing what to measure and how to measure it is crucial for ensuring that teams are assessed in accordance with their performance and aligned with the strategy set for productive capacity.

For production, the measurement of three process indicators was defined: Plan Compliance, Productivity and Number of Flips. Compliance with the plan aims to ensure the defined production on a daily basis, comparing the actual production with the planned theoretical production. This metric is important for the motivation of the operators. The Number of Flips corresponds to the number of movements made by the worktable throughout the day on each line (Equation 4.10). The target set for each line is dependent on the OEE considered, daily opening time and bottleneck cycle time, identified in Section 4.1.1. As line 1 has a bottleneck cycle time of 1h 17min and OEE to be achieved of 60%, it is expected to achieve 4 flips, in contrast to line 2, the target is 2 flips.

$$\#\ Flips_j\ (un) = (OEE\ (\%) \times Opening\ Time\ (h)) / Bottleneck\ Cycle\ Time_j\ (h) \quad (4.10)$$

Where:

j, is the index of the production line (j=1,2)

Productivity is measured by the number of linear meters/square meters produced respectively for each line (Equation 4.11). Given the different capacity of the worktables, different values were established, with line 1 expected to produce 120 m^2 and line 2, 50 m^2.

$$Productivity_j\ (m^2) = \#\ Flips_j\ (un) \times Expected\ Area\ Occupancy_j\ (\%) \quad (4.11)$$

Where:

j, is the index of the production line (j=1,2)

At the Production Preparation level, the Optimization of Table Occupancy was defined as an indicator for each project, whose goal to be achieved depends on the expected occupancy of the worktable area (Equation 4.12).

$$Optimization\ of\ Table\ Occupancy_j\ (\%) = \#\ Theoretical\ Worktables\ to\ Produce_j\ (un) / \#\ Actual\ Worktables\ to\ Produce_j\ (un) \quad (4.12)$$

Where:

j, is the index of the production line (j=1,2)

In relation to Construction Preparation, the intention was also to evaluate Compliance with the Plan and the Number of Equivalent Houses Produced. The evaluation of the Number of Equivalent Houses produced (Equation 4.13) is intended to ensure the proper pace of execution of the preparation of architecture and specialties. Each weight assigned to each stage depends on the number of days required for its execution.

$$Number\ of\ Equivalent\ Houses = 1/6 \times Architectural\ Preparation\ for\ Production + 1/2 \times Architectural\ Preparation\ for\ Construction + 1/3 \times Specialty\ Preparation\ for\ Construction \quad (4.13)$$

The implementation of these meetings requires continuous monitoring, so that they are able to autonomously define the planning and develop solutions based on the results of the indicators. Appendix G represents the example of the Daily Kaizen Board developed for the Production team.

Finally, it was established a formal weekly meeting with all the Team Leaders of each department, called Value Stream Meeting. This meeting has a similar structure to the meetings implemented for each department, with the three pillars present. However, it differs in providing a macro view of all teams. The intention was for all departments to have visibility of the weekly planning of each team and, with this, define the order of priority for production, by consulting the planning tool (Logistics Box). This meeting allowed for increased transparency and communication problems, by sharing the work developed and

collaboration, enable the quick identification of problems and analysis of their causes. Figure 25 represents the structure of the Value Stream Meeting.

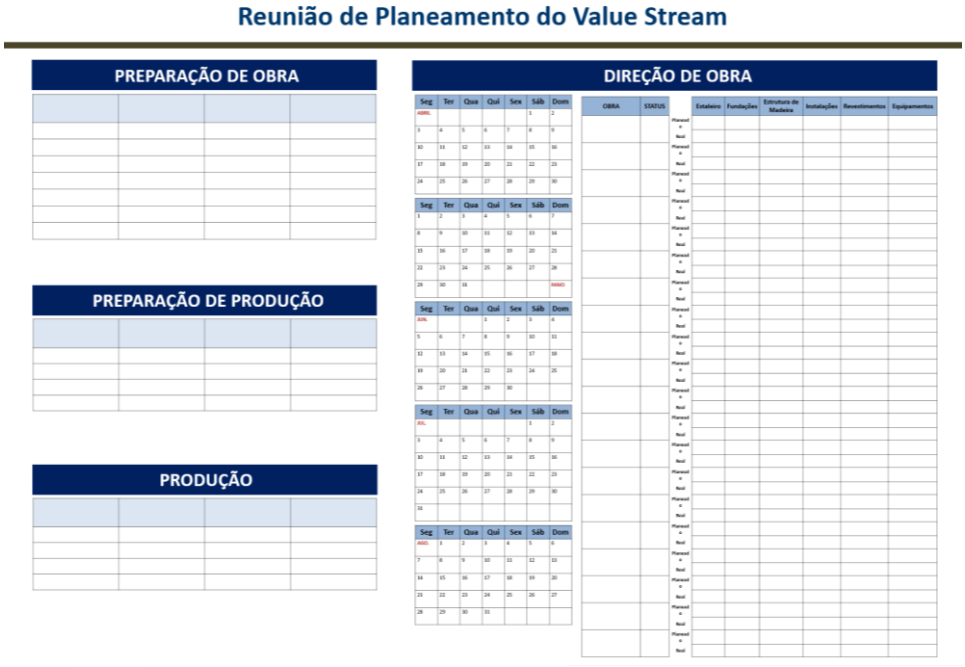


Figure 25 - Value Stream Meeting Board

To acknowledge all the operators and managers about this strategy and the Lean methodologies implemented, it was previously conducted a training session about these principles. This training is essential to ensure that the implementation of the changes has positive results in the short and long term and that they are well received by the company.

4.7 Considerations on Design and Implementation Solutions

The design of the solutions presented throughout this chapter aims to contribute to a more sustained implementation of the new production process, reducing ramp-up time and costs and therefore increasing ramp-up performance.

However, many of the designed initiatives require a great ability to adapt to change and a great collaborative spirit. Therefore, the management of Production Ramp-up must be conducted step-by-step with a gradual implementation of the initiatives, in order not to disturb the balance of the structure of the work teams and managers.

This intends to properly train, educate and direct the workforce on how to conduct production while addressing the difficulties with the new production processes. For this, the design of initiatives based on lean theoretical foundations aims to provide the teams with tools to be able to streamline workflows across the entire supply chain.

5 Results

This chapter aims to present the results obtained through the implementation of the solutions designed and described in the previous chapter.

5.1 Production Process

By analyzing the results of the implemented initiatives, it is possible to perceive significantly improvements that allowed the organization to effectively minimize time-to-market in a more stable way.

The operations balancing, through the definition of the number of operators required for each worktable, allowed to reduce the effects caused by bottlenecks. In addition, the implementation of a properly organized and dimensioned border of line reduced the time spent on non-value-added activities, namely on material search and movement. These initiatives contributed to the fulfillment of the daily planning outlined in the Daily Kaizen meetings held and, in turn, to better management by the operators, making clear the production needs of the production.

In addition, the implementation of Daily Kaizen meetings has strengthened these results. The constant interruptions that were frequent in the initial months have decreased, due to the establishment of standards with the best procedures to be adopted in each area, as well as the compliance of operators in carrying out 5S work in instructions. By incorporating additional useful demand information into processes, allowed to reduce the variability and risks associated to the degree of product and process innovation inherent of this phase.

Moreover, the training plan allowed the development of essential skills to work on different worktables along the line. Even though the learning process happened gradually, workers showed slight improvements in activity speed as well as in quality. The knowledge sharing helped employees grow their leadership skills and increased collaboration between teams. Appendix H highlights the development of skills after the implementation of the training plan.

Although it is not possible to quantitatively evaluate the results obtained through the implementation of these actions, clear improvements are evident at the qualitative level. The positive impact of the Daily Kaizen meetings has fostered motivation and created a culture of continuous improvement and teamwork. Teams are focused on monitoring the daily production goals and respective problems that arise as the implementation of the new production process is being developed.

5.2 Production Planning

The implementation of weekly Value Stream Daily Kaizen meetings allowed each team of each department to define their planning in a structured way and according to the defined production sequence. The fact that everyone is involved in the design of the future state, from the CEO to all levels of the organization has promoted communication and transparency

between the various departments. Moreover, the fact that every team is now more focused on exposing difficulties, identifying the root cause of problems and developing actions to tackle the problems allowed the development of cross-functional relations between departments.

The implementation of the planning tool, the logistic box, had a great impact on this planning. From an ad-hoc planning, it was transformed into a structured planning, in which the production sequence is defined according to the production capacity of each line for each month and the delivery dates agreed with the customer. The weekly review of the production plan allowed avoiding situations of under or over capacity, by ensuring the correct balancing of the weekly production load. This has increased the response capacity to the customer and, consequently, customer satisfaction.

In addition, the worktable capacity optimization strategy allowed better use of each production line. Figure 26 shows the results obtained for the worktable capacity optimization indicator implemented to produce wall panels on line 1.

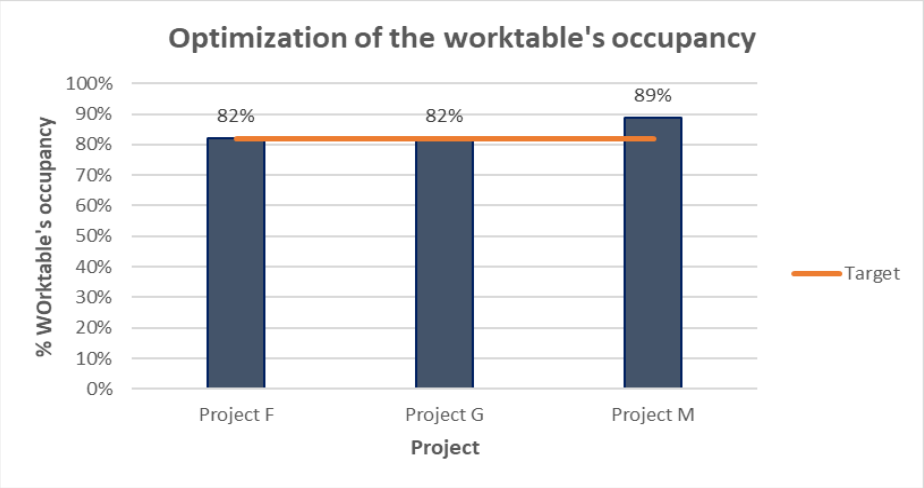


Figure 26 - Optimization of the worktable's occupancy

It is possible to verify that the optimization performed guarantees the set goal of 82% of worktable occupancy for line 1. This means that the actual number of worktables to be produced is in accordance with the theoretical number previously determined from the Logistics Box. However, the first iteration performed with this tool lacked some constraints in the production process. The fact of not prioritizing the placement of panels of equal thickness and size on the table made it difficult to perform the operations and respective removal of the panels at the end of line 1. With this, the optimization applied to the second and third project already reflects these changes.

This optimization impacted the daily production planning. The fact that the team leader began to define the daily production according to the sequence of occupation obtained with the tool allowed to establish the desired production rhythm based on the number of flips expected to achieve mentioned in Section 4.5.2.

Figure 27 reflects the results of the number of flips performed in line 1 in May. It is possible to perceive a difficulty in achieving the target. The fact that the implementation of the new production system is very complex due to the inherent technology, it is difficult to predict the occurrence of disturbances. Adaptations of the process flow are still occurring with a lot of experiments happening which in some cases implies stopping production. The gaps in data can be explained by the occurrence of production downtimes. Line 1 is also conditioned by a more complex set of operations, which hinders the production process. In addition, the difficulty in removing the panels at the end of the line prevents the establishment of a continuous flow, in which work in process is still constant. As a result, it is perceived the

displacement of operators to remove and store panels. Moreover, equipment breakdowns are frequent, which implies long repair times.

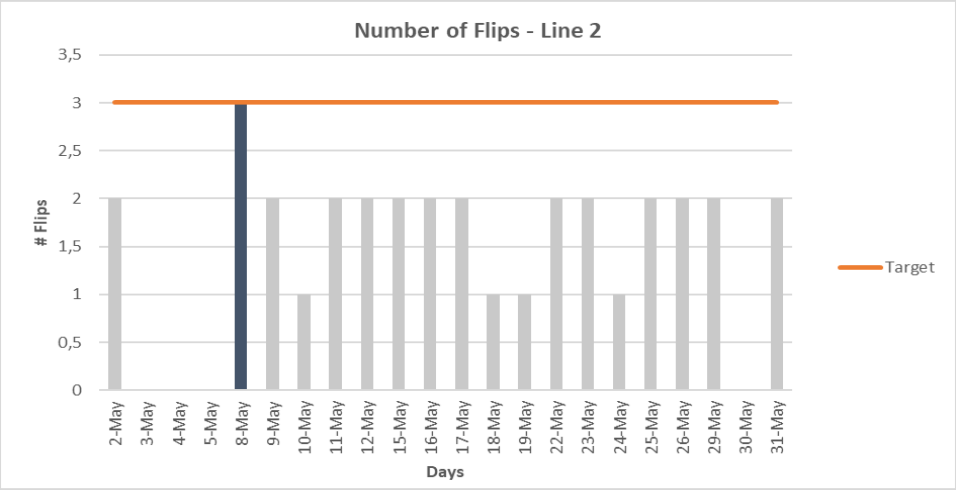


Figure 27 - Number of Flips in Line 1

Figure 28 reflects the results of the number of flips obtained for line 2. The problems stated in line 1 are the same for line 2. However, the fact of being impossible to apply the worktable optimization due to the restrictions on moving the panels at the end of the line, led to a higher number of flips, yet without guaranteeing maximum worktable occupancy.

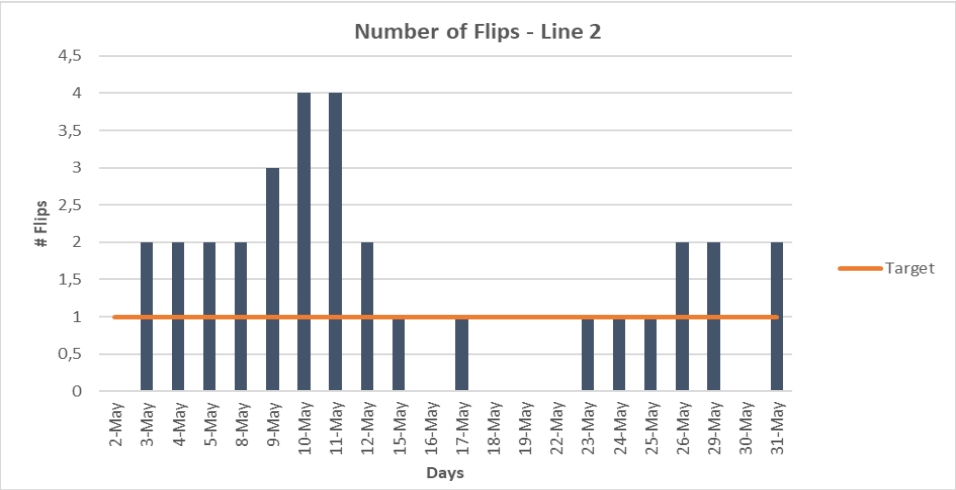


Figure 28 - Number of Flips in Line 2

5.3 Production Capacity

Most of the initiatives developed reflect positive changes at the organizational level, namely in improvements to the flow of information, planning mechanisms and communication, however, a careful analysis of the global quantitative objectives outlined is required.

Figure 29 shows the results obtained from the indicator of the number of equivalent houses produced weekly as the OEE respectively.

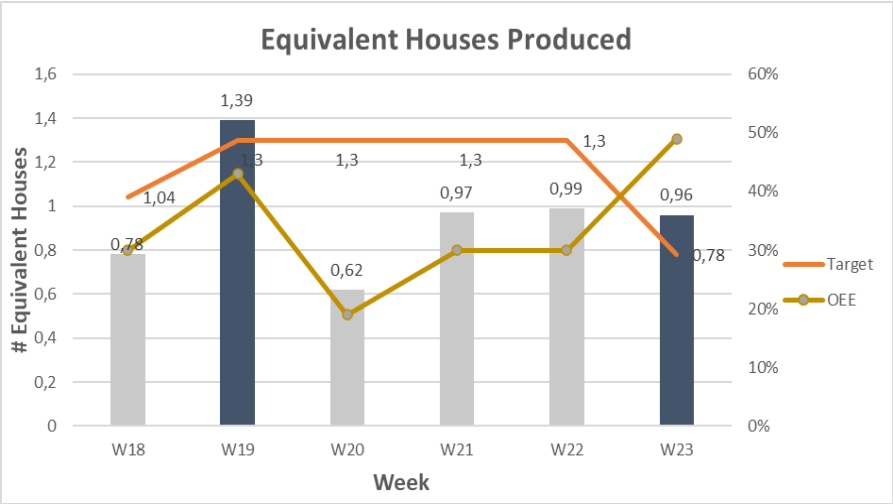


Figure 29 - Equivalent Houses Produced

It is possible to perceive some challenges in accomplishing the desired weekly production capacity. These values are the result of the problems identified above, as well as the fact that the initiatives designed have not yet all been implemented, particularly at the level of Internal Logistics with the implementation of the circuit logistics route performed by *Mizusumashi*, which doesn't allow for a full comprehensive analysis of each initiative's outcomes.

Table 9 summarizes the main problems and root causes identified with the team at weekly Value Stream meetings that did not allow achieve the desired goal, using the 3C tool.

Table 9 - Concerns and Causes related to the non-compliance of the Productive Capacity

Concern	***Cause***
Difficulty in moving panels at the end of the line	Absence of an automatic mechanism for removing panels from the line
Constraints in the storage of finished product	Reduced storage space
Displacement of operators for activities outside the line	Absence of a person responsible for Internal Logistics
Equipment breakdowns	Warranty assistance not available on time

However, when analyzing weeks 19 and 23, it is possible to perceive that the goal was overcome, reaching an OEE of 43% and 49%, respectively. This was due to the fact that there were no machine breakdowns and the displacement of operators for activities outside of production was minimized. This is a good indicator that the accomplishment of the desired production capacity is possible through the continuous improvement of the procedures and the establishment of a good management control system to avoid the occurrence of this problems and assure a continuous production flow.

6 Conclusions and Perspectives for Future Work

This chapter provides a reflection about the initiatives developed in the client's organization and the impact of the results obtained to support the answers to the research questions defined at the beginning of the project. After that, is intended to provide an understanding of the main opportunities for improvement and future initiatives that should be considered in a long-term future vision to enhance the culture of continuous improvement.

6.1 Conclusions

The Value Stream Mapping of the initial production model proved to be essential in analyzing the initial situation of the flow of materials and information and identifying potential problems for the future production model implementation.

Production Ramp-up is characterized by its high complexity and uncertainty with several influencing factors that make it difficult to meet the outlined objectives. In order to ensure a timely, high-quality and cost-effective market entry, a Ramp-up Production must consider both technical challenges and integration of individual personnel with their varied talent and requirements. Therefore, appropriate leadership is essential to support management throughout this period.

The application of Lean Management and its methodologies proved to have a positive impact in reducing disturbances. Since Lean is a concept based on value creation, the focus is on reducing or eliminating *Muda.*

Strong focus on providing a system for continuously developing people through problem solving to enhance operational excellence have been identified to be very helpful. For that, is essential to have the organization aligned in being a part of the change. Daily Kaizen provided a key role in bringing that urgently required cultural transformation since reunited personnel to work on common problems and actively developing suggestions while boosting motivation and communication.

Alongside this strategy, the harmonization of the workforce with standardized methods of performing activities demonstrated to be a valuable contribution to better manage production Ramp-up by serving as starting point for continuous evolution of processes and making them better over time. The development of a discipline of organization impacted not only the visual space of the facility as well the safety and ergonomics.

In line with literature, to develop effective supply chain capabilities, the introduction of a production model that provides a weekly vision of loading capacity combined with the application of Total Flow Management principles has demonstrated to have a great impact to overcome the inefficiencies that raised with the implementation of the new production line. The results achieved demonstrate that when there are a few variations in the process and material flows through a series of operations with constant material in continuous movement it is possible to attain the desired production capacity.

6.2 Future Work and Limitations

Although solutions designed have not yet all been implemented due to delays in the implementation of the new production line and high complexity inherent to the technology, the results reveal the importance of developing solutions that aim to reduce the constant interruptions to the production process, namely to carry out activities outside of production and the occurrence of equipment breakdowns.

It is expected that with the implementation of the Internal Logistics strategy combined with the use of help chain through operators, it is possible to perceive a minimization of work in process. By removing the responsibility of operators in the supply of consumables and wood as well as the removal of panels at the end of the line, it is expected to reduce the occurrence of activities that do not add value.

At maintenance level, future work must be developed in implementing a proper Quality Risk and Maintenance Management Plan. Maintenance is not only important to improve quality but to prevent malfunctions and disruptions, increasing the production system's reliability, availability, and maximizing output. For that, Lean methodologies suggest the implementation of a Failure Mode and Effects Analysis (FMEA) as strategy to tackle problems in advance and reduce unplanned production stop and thereby increasing the overall productivity.

Nevertheless, improvements in communication, reduction of late changes in processes and training of critical processes must be made since there are still gaps in the requirements specifications and rework is still ingrained in the organized. For this, process documentation is essential.

By embracing a proper and effective integration of these strategies with the reinforcement of an effective communication and cross-functional relations within the supply chain will contribute positively to reduce discrepancies of this phase and allow to achieve operational excellence, positioning the company for success in the competitive market landscape of modular constructions.

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APPENDIX A: Risk Matrix of Influencing Factors of Timberframe Production Model

Table 1 - Risk Matrix of Influencing Factors

Influencing Factors	***Potential Risk***	***Impact***	***Probability***	***Risk Assessment***
Degree of innovation	Lack of experience in handling new materials	4	3	12
	Additional tasks to perform is required	4	4	16
	Low maturity of processes and equipment	4	4	16
Degree of Complexity	Lack of knowledge of new operations and equipment	5	5	25
	Incapacity of not fulfilling functional requirements	5	4	20
	Internal organizational conflicts	4	3	12

APPENDIX B: Yamazumi Timberframe Production Model

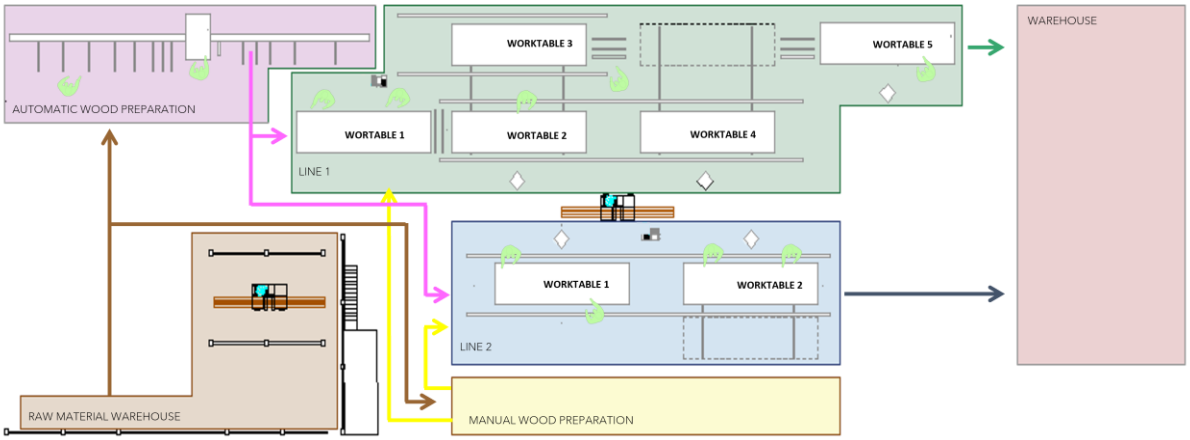


Figure 1 - Allocation of operators by worktables

LINE 1

Station	Operation	Time / Operation	Time / Station
WORKTABLE 1	Frame Assembly	01:08:00	0:41:20
	Table Movement	00:02:16	
WORKTABLE 2	Table Movement	00:02:16	1:13:40
	Canvas Placement	00:18:42	
	AGEPAN Placement	00:20:24	
	Nailing and Cutting	00:25:30	
	Table Movement	00:06:48	
WORKTABLE 3	Table Movement	00:06:48	1:17:04
	Inflating	01:08:00	
	Table Movement	00:02:16	
WORKTABLE 4	Table Movement	00:02:16	0:50:26
	OSB Placement	00:20:24	
	Nailing and Cutting	00:25:30	
	Table Movement	00:02:16	
WORTABLE 5	Table Movement	00:02:16	0:56:40
	Canvas Placement	00:18:42	
	Inner Lath Placement	00:27:12	
	Window Frame Placement	-	
	Panel Removal	00:08:30	

LINE 2

WALLS

Station	Operation	Time / Operation	Time / Station
TABLE 1	Frame Assembly	01:08:00	2:19:24
	Canvas Placement	00:18:42	
	AGEPAN Placement	00:20:24	
	Nailing and Cutting	00:25:30	
	Table Movement	00:06:48	
TABLE 2	Table Movement	00:06:48	2:55:06
	Fiberboard Placement	01:08:00	
	OSB Placement	00:20:24	
	Nailing and Cutting	00:25:30	
	Canvas Placement	00:18:42	
	Inner Lath Placement	00:27:12	
	Panel Removal	00:08:30	

ROOFS

Station	Operation	Time / Operation	Time / Station
TABLE 1	Frame Assembly	01:33:30	1:54:31
	Canvas Placement	00:20:24	
	AGEPAN Placement	00:25:30	
	Nailing and Cutting	00:18:42	
	Table Movement	00:06:48	
TABLE 2	Frame Assembly	00:07:39	2:16:21
	Canvas Placement	00:18:42	
	Fiberboard Placement	01:16:30	
	Wedge Lath Placement	00:20:24	
	OSB Placement	00:20:24	
	Nailing and Cutting	00:25:30	
	Canvas Placement	00:18:42	
	Panel Removal	00:08:30	

Figure 2 - Yamazumi Timberframe Production Model

APPENDIX C: Production Capacity Line Design

CASA MODELO	
SKY T2 142,8 m²	
Area	142,80
Metros Lineares de Parede Interior	34,00
Metros Lineares de Parede Exterior	62,90
Largura da Cobertura	105,40
Metros Lineares de Parede	96,90

Fator de Ocupação	1
# Mesas Paredes Internas	4
# Mesas Paredes Externas	7
# Mesas Coberturas	10

		# Mesas
Area Cobertura	164,90	9
Area Lage	215,90	11
Metros Lineares	119,00	11
Area	166,60	

CASA MODELO - Ocupação das Mesas		
		% Ocupação da Mesa
#Mesas Paredes	11	82%
#Mesas Coberturas	10	90%
Fator %T.Parede	0,52	

Figure 1 - Number of walls and roofs to produce of Model House

	Disponibilidade
Abertura Turno	7,5
# Dias / Semana	5
# Semana / Ano	49
# Dias / Ano	245
# Turnos	1
OEE	85%
Abertura Total	1561,875

		Tempo de Ciclo		# Mesas / Ano	# Casas Modelo	
PRODUÇÃO EXCLUSIVA	Linha 1 (Só Paredes)	01:17:04	1,28	1215,99	110,54	
	Linha 2 (Só Paredes)	02:55:06	2,92	535,19	48,65	Casas Modelo / Dia
				TOTAL	159	0,6

		Tempo de Ciclo		# Mesas / Ano	# Casas Modelo	
PRODUÇÃO PARALELA	Linha 1 (Só Paredes)	01:17:04	1,28	1215,99	110,54	
	Linha 2 (Só Coberturas)	02:16:21	2,27	687,27	62,48	Casas Modelo / Dia
						0,3

		Tempo de Ciclo		# Mesas / Ano	# Casas Modelo	
PRODUÇÃO DEDICADA	Linha 1 (Só Paredes)	01:17:04	1,28	1215,99	110,54	
	Linha 2 (Paredes / Coberturas)	02:55:06	2,92	280	25	
		02:16:21	2,27	327	33	Casas Modelo / Dia
				TOTAL	136	0,56

Figure 2 - Production Capacity of each production strategy

				Standard OEE
				60%
	Objetivo Semanal	# Flips / Semana	# Flips / Dia	# Flips / Dia - c/ OEE
Linha 1 (Só Paredes)	6,73	29	5	3
Linha 2 (Paredes / Coberturas)	7,86	14	2	1

Figure 3 - Number of flips to perform according to Dedicated Production strategy

APPENDIX D: Operating Model

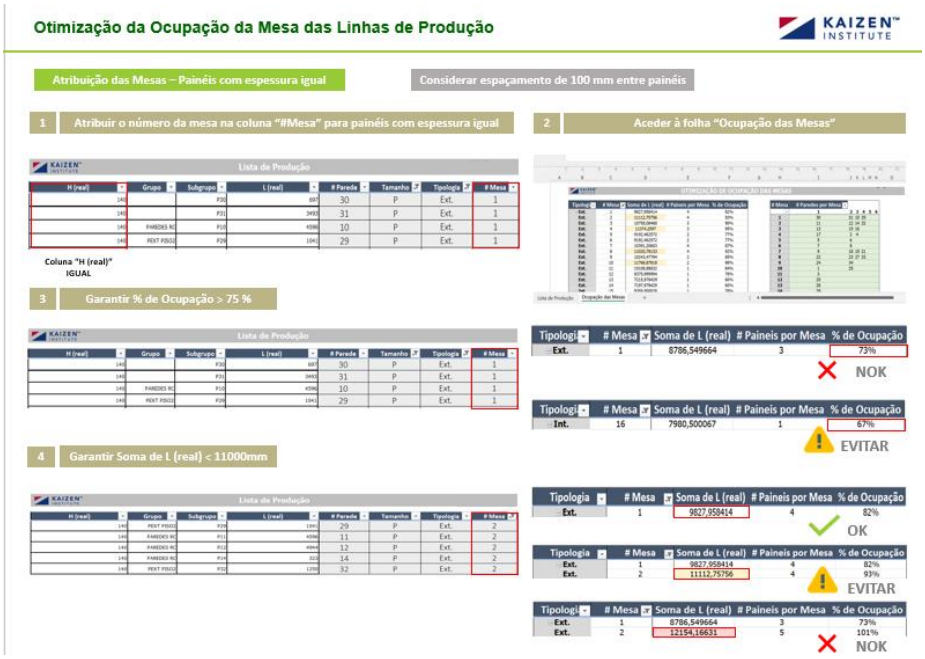


Figure 1 - Worktable Optimization Occupancy Standard

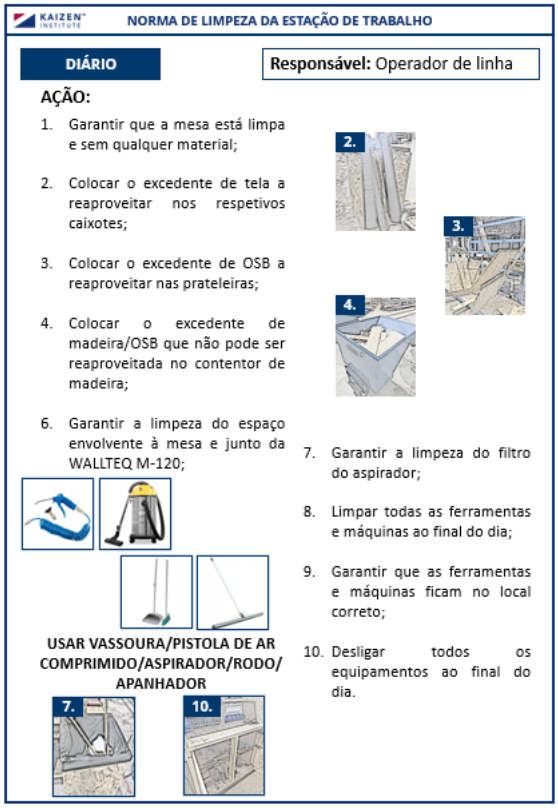


Figure 1 - Work Cleaning Standard

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STANDARD WORK LÍDER

	Início	Fim	Duração	Atividades	Cumprido
Kaizen Diário	08:00	08:15	00:15	KD Produção	
Condições de Trabalho	08:15	09:45	01:30	Gemba Walk para levantamento de necessidades e garantia de condições de trabalho por posto de cada linha de produção:	
				a. Garantir organização de cada posto de trabalho	
				b. Garantir a presença de todo o material e ferramentas necessárias para cada posto de trabalho	
Logística	09:45	10:00	00:15	**Passagem de necessidades de produção ao Armazém**	
-	10:00	10:15	00:15	Intervalo Manhã	
Gestão de Conflitos	10:15	11:00	00:45	Gemba Walk para levantamento de problemas	
	11:00	11:30	00:30	Resolução de problemas	
Atualização KD	11:30	11:45	00:15	Ponto de situação do estado de produção	
	11:45	12:00	00:15	Atualização do Plano de Trabalho	
-	12:00	13:00	01:00	Almoço	
Atualização KD	13:00	14:15	01:15	Seguimento desvios KPI's	
	14:15	15:30	01:15	Discussão e Análise dos motivos dos desvios nos KPI's	
-	15:30	15:45	00:15	Intervalo Tarde	
Condições de Trabalho	15:45	16:30	00:45	Gemba Walk para levantamento de problemas, necessidades e garantia de condições de trabalho por posto de cada linha de produção:	
				a. Garantir organização de cada posto de trabalho	
				b. Garantir a presença de todo o material e ferramentas necessárias para cada posto de trabalho	
Logística	16:30	16:45	00:15	Passagem de necessidades de produção ao Armazém	
Gestão de Conflitos	16:45	17:15	00:30	Resolução de problemas	
Preparação KD	17:15	17:19	00:04	Ponto de situação do estado da produção:	
				a. O que foi produzido	
				b. O que ficou em curso	
				c. O que não foi produzido	
	17:19	17:20	00:01	Atualizar Plano de trabalho	
	17:20	17:25	00:05	Atualizar KPI's para cada linha de produção:	
				a. Atualizar KPI Produção	
				b. Atualizar KPI Tempo Médio de Ciclo	
				c. Atualizar KPI NCF	
				d. Atualizar KPI Cumprimento do Plano	
	17:25	17:30	00:05	Ponto de situação do PDCA:	
				a. Analisar ações em curso	
				b. Levantamento de novas ações de melhoria	
				c. Discutir soluções para ações	

Figure 1 - Standard Work of Production Team Leader

APPENDIX E: Production *Kamishibai*

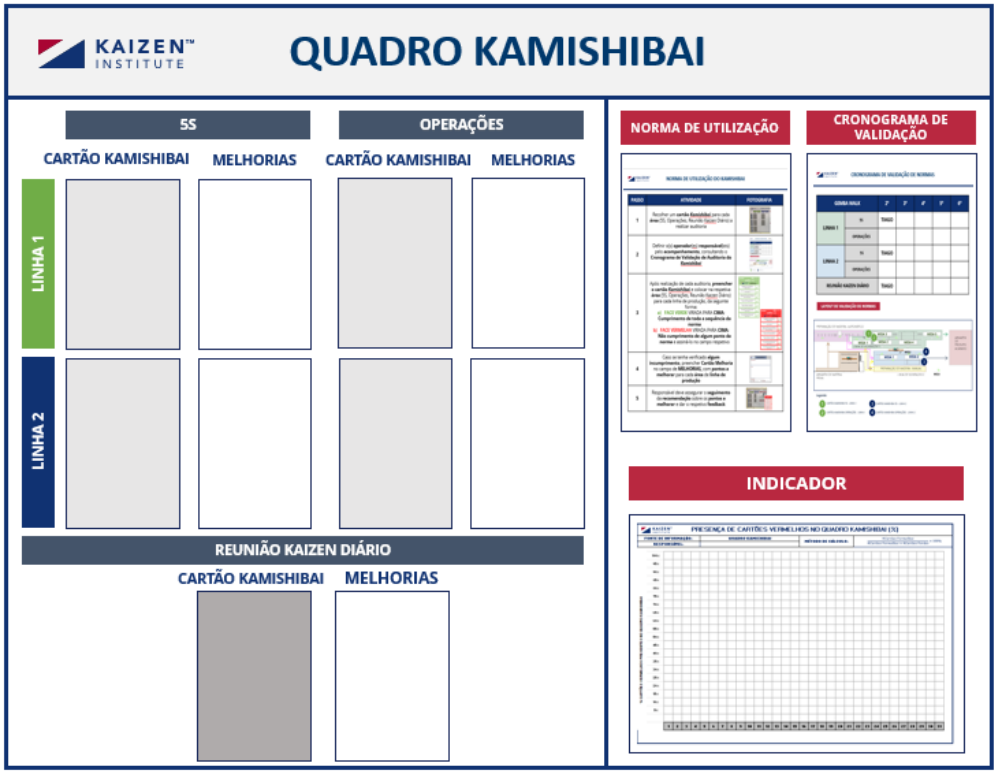


Figure 1 - *Kamishibai* Production Board

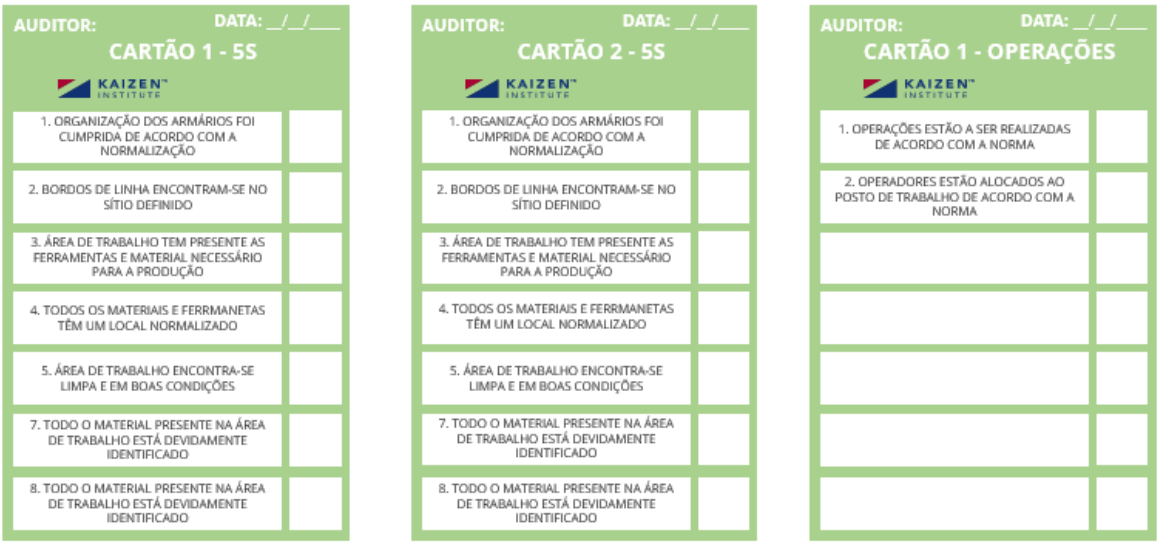


Figure 2 - *Kamishibai* Green Cards

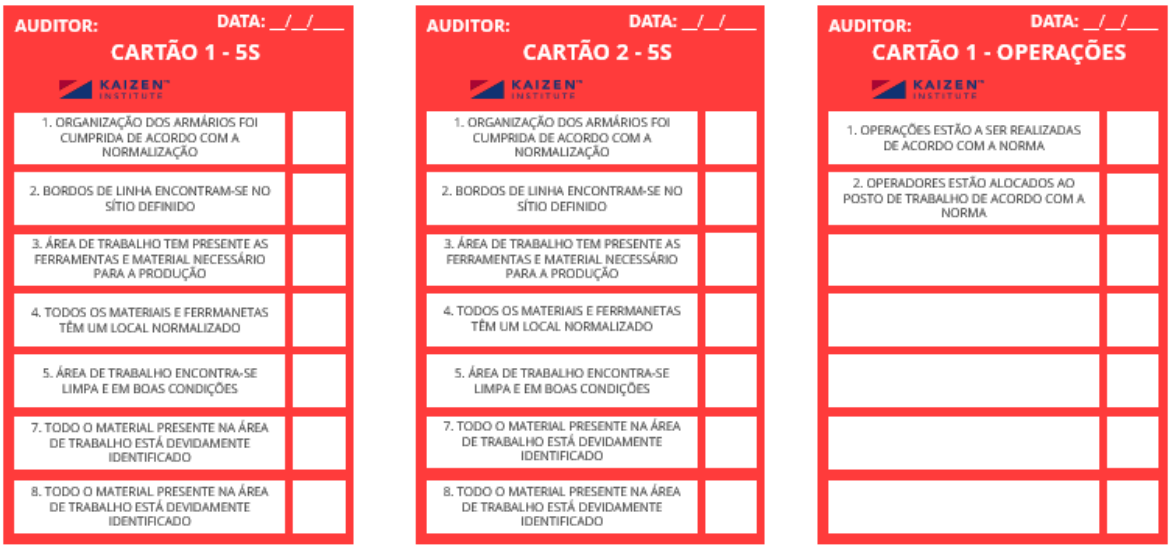


Figure 3 - *Kamishibai* Red Cards

APPENDIX F: Production Gemba Walk

Table 1 - Production Gemba Walk topics and type of action measure

ORDEM	LOCAL	TEMA	TÓPICO	TIPO DE AÇÃO	23/05/2023
1	Armazém de Matérias Primas	Processo	Todo o stock está armazenado nos racks?	Corretiva	
		Processo	As racks estão organizadas por tipologia de material e secção?	PDCA	
2	CNC	5S	Os equipamentos encontram-se limpos?	PDCA	
		5S	A área de trabalho está organizada?	Corretiva	
		Processo	A sequência de corte está a ser cumprida?	PDCA	
		Processo	As areas de armazenamento de stock intermédio estão a ser cumpridas?	Corretiva	
3	Linha 1	5S	Os equipamentos encontram-se limpos?	PDCA	
		5S	A área de trabalho da mesa 1 está organizada?	Corretiva	
		5S	A área de trabalho da mesa 2 está organizada?	Corretiva	
		5S	A área de trabalho da mesa 4 está organizada?	Corretiva	
		5S	A área de trabalho da mesa 5 está organizada?	Corretiva	
		5S	Os Bordos de Linha estão limpos e organizados?	PDCA	
		5S	Todos os materiais necessários estão abastecidos?	PDCA	
		Processo	Os operadores da linha estão nos locais definidos?	Corretiva	
		Processo	Está a ser preenchida a checklist de qualidade?	Corretiva	
		Processo	Existem alertas de Manutenção nos Equipamentos	PDCA	
		Processo	A sequência de Montagem está a ser cumprida?	PDCA	
4	Armazém de Produto Acabado	Processo	Todas as Paredes estão armazenadas em racks?	Corretiva	
		Processo	As coberturas estão empilhadas de modo a não danificar o produto?	Corretiva	
		Processo	Está a ser preenchida a checklist de qualidade?	Corretiva	
5	Linha 2	5S	Os equipamentos encontram-se limpos?	PDCA	
		5S	A área de trabalho da mesa 1 está organizada?	Corretiva	
		5S	A área de trabalho da mesa 2 está organizada?	Corretiva	
		5S	Os Bordos de Linha estão limpos e organizados?	PDCA	
		5S	Todos os materiais necessários estão abastecidos?	PDCA	
		Processo	Os operadores da linha estão nos locais difinidos?	Corretiva	
		Processo	Está a ser preenchida a checklist de qualidade?	Corretiva	
		Processo	Existem alertas de Manutenção nos Equipamentos	PDCA	
		Processo	A sequência de Montagem está a ser cumprida?	PDCA	
6	Kaizen Diário	5S	O quadro e area estão limpos?	PDCA	
		Processo	O registo de presenças está preenchido?	Corretiva	
		Processo	Os indicadores estão atualizados?	Corretiva	
		Processo	Há evidência de que os kamishibai estão a ser realizados todos os dias?	PDCA	
		Processo	O plano de ações têm atualizações recentes (< 3 dias?)?	PDCA	

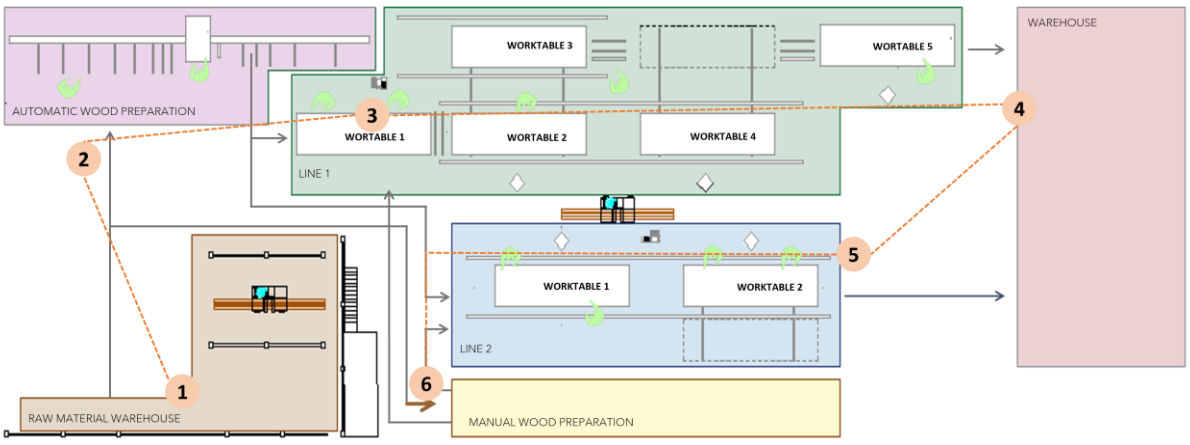


Figure 1 - Gemba Walk Route

APPENDIX G: Daily Kaizen Production Board



Figure 2 - Daily Kaizen Production Board

APPENDIX H: Skills Matrix

MATRIZ DE COMPETÊNCIAS

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Legenda:

○	O operador não está treinado
◔	O operador teve treino
◑	O operador executa a tarefa com supervisão
◕	O operador executa a tarefa autonomamente
●	O operador sabe dar formação

		NORMAS DE OPERAÇÕES													
ÁREA	OPERADOR	Data	COMP	DATA	COMP	DATA	COMP	DATA	COMP	DATA	COMP	DATA	COMP	DATA	COMP
	Operator A		●		●		●		●		●		●		
	Operator B		●		●		●		●		●		●		●
	Operator C		●		●		●		●		●		●		
	Operator D		◕		◑		◕		◕		◑		●		
	Operator E		◕		◕		◕		◕		◕		●		
	Operator F		◕		◕		●		●		◑		●		
	Operator G		●		●		●		●		◕		●		
	Operator H		●		●		●		●		◕		●		
	Operator I		◑		◕		●		○		◑		●		

Figure 3 - Production Skills Matrix