Improving Production Capacity in a Discrete Production Industry

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"When you change your thoughts, remember to also change your world."

Norman Vincent Peale

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Abstract

Increasing production volumes in the discrete production industry is often challenging without endangering the organization's capacity to remain financially stable. This is primarily caused by increased capital utilization due to the exponential growth in inventories of finished goods and work in progress (WIP) production. Increases in output, however, are typically accompanied by significant resource investments, often at the price of not improving the productivity of already available resources.

The Kaizen Institute project with Company A, a manufacturer of hydrotherapy spas, was developed to accelerate production growth sustainably. The current dissertation focuses on the project undertaken with the primary goal of raising the factory production capacity by achieving long-term stability, using Kaizen Lean instruments like Basic Stability and Line Design. Through the creation of flow and the elimination of wastes, these methodologies seek to improve processes. Other management support tools were developed, including Material Requirement Planning (MRP), an application for tracking production data and dashboards of indications.

The period of the project in consideration is one year, from January to December of the current year. Nonetheless, the attempts undertaken between March and June are relevant to this dissertation. The indicator for the project was the number of packaged spas, which averaged nine per day in the beginning scenario and eleven per day at the project's conclusion, indicating a production increase of 22,2 percent, with some sectors experiencing more significant gains than others. Overall, the outcomes were favorable, with the administration of Company A recognizing the value of the implemented improvements. The results were sustained by promoting a culture of continuous improvement.

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Glossary

BOM – Bill of Materials

FIFO – First in, first out

FTE – Full-time equivalent

KICG – Kaizen Institute Consulting Group

KPI – Key Performance Indicator

MRP – Material Requirements Planning

MTO – Make to Order

MTS – Make to Stock

SMED – Single Minute Exchange of Die

TFM – Total Flow Management

VSM – Value Stream Mapping

WIP – Work in Progress

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1 Introduction

1.1 Context

This document is based on an optimization project implemented by Kaizen Institute Consulting Group (KICG) in a Portuguese company manufacturer of hydrotherapy products. The project aimed to increase the company's manufacturing capacity to respond to the increasing demand for their products. The project's implementation happened for four months and was implemented and supervised in the client facilities in Vila Nova de Gaia, Porto.

Company A, which will remain anonymous for confidentiality reasons, is one of KICG's clients, and it is dedicated to produce high-quality hydromassage swim spas and spa baths for indoors and outdoors.

Using a series of procedures based on the Kaizen philosophy, these actions were started to achieve incremental process improvements over time. With the assistance of natural teams, conditions were also established to allow for the long-term maintenance of accomplishments.

1.2 Kaizen Institute Global Consulting

The Kaizen Institute Global Consulting (KICG), which logo is shown in Figure 1, was founded by Masaaki Imai in 1985, is the pioneer and global leader in advancing the spirit and practice of kaizen. Its international team of experts is committed to create a world in which everyone, everywhere, and every day can improve their job and themselves. The Kaizen Institute assists firms in achieving higher levels of performance on the global market in ways that are simpler, quicker, more effective, and less expensive (Coimbra 2013).

KAIZEN™ INSTITUTE

Figure 1 - Kaizen Institute Consulting Group Logo

KICG's consulting services focus not just on diagnosing a company's problems but also on implementing the solutions. This is accomplished by utilizing the Kaizen Business System, which is the instrument that enables businesses to adopt a kaizen growth mindset. The Kaizen Institute encourages its clients to develop leaders throughout their entire organization who are capable of maintaining continuous improvement. The Kaizen Institute establishes a global community of kaizen and lean practitioners.

Porto, Lisbon, and Coimbra are the locations of offices kept open by the Kaizen Institute Portugal. It currently has x employees and has grown from one year to the next, with significant hiring of trainees and consultants in March of 2022.

1.3 Company A

Company A is a Portuguese manufacturer of high-quality hydrotherapy items, such as spa baths, as Figure 2 shows, and swim spa baths (named Swimmers). The production is highly changeable, with a total of 140 references produced last year.

Figure 2 - Example of a spa from Company A

In the year of 2021, Company A invoiced €6.5M, with a gross margin of €2.2M (33%), due to the production of a total of 1858 spas. 94% of these were exported mostly to France.

Company A contacted the Kaizen Institute so that KICG's consulting services may assist in increasing the production of spas in a sustainable manner, in response to the increased demand for spas.

1.4 Project Objectives

Company A intends to produce an average of twelve spas every day to meet customer demand. As increasing manufacturing capacity in a discrete production industry is the objective of this project, the number of spas produced per day will be the primary Key Performance Indicator (KPI) utilised and evaluated for making decisions.

The output of 8.4 units per day from spas in the final three months of 2021 will serve as the baseline for the project. To increase the quantity from 8.4 to 12 units (a 43 percent spas output increase), Company A hired the consulting services of the Kaizen Institute to improve the factory's production capacity. While some areas of the factory are prepared to produce 12 spas every day, others are not. In this project, the portions lacking this capacity will be examined in depth. Throughout the project, KICG followed its methodologies, which always start with a detailed analysis of the factory's operation.

To reach this level, the team was expected to conduct several multidisciplinary projects involving personnel of both the Kaizen Institute and Company A. Some of the initiatives that will be discussed in Chapter 4 of this study were deemed disruptive because they caused a paradigm shift in the workplace.

1.5 Dissertation Structure

The dissertation consists of five chapters. In this chapter, both companies involved are introduced along with their previously planned objectives.

As for the next chapter, a theoretical framework of the Kaizen methodology is presented, regarding the flow of information and materials and the TFM model. This information is transmitted to contextualize the concepts used and best practices for applying the referenced model.

Furthermore, in the third chapter, the company's production process is examined, along with the initial scenario and key components of the project.

The fourth chapter addresses the design and implementation of solutions, including the phases of initiative execution and the most significant difficulties and opportunities encountered during the process. In addition, the indicators and solutions identified to evaluate the influence of the execution of the ideas on the company are analysed, as well as the outcomes reported over the project's duration.

Finally, in the fifth and last chapter, conclusions are elaborated regarding the project's evolution and outcomes. In addition, there are offered some ideas and suggestions to be implemented in the near future, following the work developed until now.

2 Theoretical Background

In this chapter, the methodologies employed during the dissertation project will be discussed, as well as other methods that were not used directly but were significant to the development of the various initiatives and are therefore relevant to the document.

2.1 Kaizen Business System

The Kaizen Business System (KBS) is the foundation for all approaches used to support sustainable development and continuous improvement in organizations with whom KICG regularly collaborates.

The objectives of KBS are to increase the value of businesses by pursuing excellence in operations, excellence in changes, and excellence in growth via the following five points:

- Growth – increase in revenue, return on invested capital, increase in cash flow;
- Quality – Reduce expenses through improved quality management;
- Costs – Gross margin expansion and operations margin expansion;
- Delivery – Decrease delivery lead times;
- Quality – Reduce costs through improved quality management.

2.1.1 Toyota Production System

The Toyota Production System started from its need (Ohno 1988). After the Second World War, the market for the sale of automobiles declined significantly. The necessity of producing many types of cars in small quantities with low costs took Toyota to try to eliminate all kinds of muda (Japanese word for waste). Toyota's purpose was to step aside from the mass production paradigm introduced in the United States of America by Henry Ford and produce the vehicles that the market demanded.

In the beginning, it wasn't easy (Ohno 1988). The Toyota Production System was built around getting rid of all waste. The system needs two things to hold it up: just-in-time and autonomation, which is automation with a human touch.

The Just in Time system emerged to reduce the problems caused by stock imbalances. Generally, intermediate stocks are generated due to overproduction *muda*, considered the worst of the seven types of *muda* because it can lead to other types of waste.

Just-in-time means that, during a flow process, the right parts for assembly get to the assembly line at the right time and in the right amount. If a company sets up this flow throughout, it can get close to having no inventory (Ohno 1988).

Kaizen methodologies are based on Ohno achievements in Toyota lean processes.

2.1.2 Kaizen Fundamentals

Masaaki Imai spread the word Kaizen in his book “Kaizen: The Key to Japan's Competitive Success”. This term is composed of two Japanese words. "*Kai*" means change, and "*Zen*" means better. Together, they represent change for the better and continuous improvement (Imai 2012)

The ideology of Kaizen is built on five fundamentals. They are:

- Add Value to the Costumers;
- Waste Elimination;
- *Gemba* Orientation;
- People Involvement;
- Visual Management.

The following dissertation's subchapter will detail these Key Elements of the Kaizen Ideology.

Add Value to the Costumers

Quality First is one of the most essential Kaizen principles. Value is created when products are made with quality. This belief is almost universally accepted, in contrast to many other Kaizen ideas that are less consensual. It can be resumed in three topics (Coimbra 2013):

1. Market In – Before introducing a product, research the market. To build a product that meets market needs, you must first understand people's needs and expectations.
2. The Next Operation is the Costumer – Every organization becomes a chain of suppliers and customers with this mindset. As a result, suppliers must send the product to the next sector without defects.
3. Upstream improvement - This is the idea that every defect is caused by something higher up in the process chain and that the way to uncover the true source of the error or difficulty, the root cause, is to search upstream of the location where it was detected.

Waste Elimination

The primary premise of Pull Flow is waste elimination. Taiichi Ohno was the driving force behind the development of the Toyota Production System. He began to classify any non-value-adding activities as waste. Ohno was the first to notice the amount of *muda* in the gemba. Muda is the Japanese word for waste. He classified waste into seven types of *muda*:

1. **Defects** - Quality defects and nonconformities are not only problematic for clients, but they also necessitate expensive rework frequently.
2. **People Waiting** – Productivity drops, and lead time increases when a worker is out of work due to imbalances.
3. **People Moving** - Any movement of the body that is not directly related to adding value is *muda*.
4. **Too much processing** - Work that goes beyond what the client has requested. This occurs due to both insufficient machines and a lack of operator standards.
5. **Material and Information Waiting** – While the material is waiting to be transformed or delivered, its value remains unchanged.
6. **Material and Information Moving** – Also known as transports. Material and information movement is frequently caused by a lack of border line organization and bad layout design. It requires labor, but it is a non-value-adding activity.
7. **Overproduction** - Stocks increase when the production rate exceeds the demand or when the processes are not balanced.

Toyota tried to get rid of all muda by developing a new operations system based on eliminating the seven wastes. They then used this system in all of their supply chains. The company has done amazing things, and it's all because they have strong beliefs and do a lot of practice and reinforcement.

Muda is part of the 3M’s: *muri, mura,* and *muda*. *Muri* represents the loss of time and energy waste, and *mura* means variability. By eliminating all the 3M´s, the efficiency and flow, are easily improved.

***Gemba* Orientation**

Gemba is the Japanese word for Shop Floor. It represents the place where the adding-value activities occur. Depending on the type of business and activities, it can be the shop floor, an office, etc. *Gemba* orientation is applying Kaizen at this place. According to Taiichi Ohno, it is crucial to go to the Gemba because:

- It is where things are happening.

- Taking a close look at the real world
- Checking the real things, like tools, materials, and information makes up that reality.
- Using data that has been seen and proven to be true.

In the Gemba, it is possible to involve people (as described in the following fundamental) and implement improvement actions.

People Involvement

During implementation, it's important to get everyone in the company involved in making improvements. This will make the changes last longer.

It is not easy to change habits. “For each type of improvement or change, there is a habit to alter. For each habit, there is a group of people who will need to drop old habits and adopt better ones.” (Coimbra 2013).

Involving everyone, it becomes easier to break paradigms, change habits, reduce costs and increase client service level.

Visual Management

Visual communication is simpler than written communication. The standards in Kaizen are made with visual support. In contrast to the text-based standards and instructions we see in many *gembas*, a standard based on pictures, drawings, and creative word pictures is easy to understand and can be learned quickly.

To increase value, it is necessary to identify and reduce waste in the workplace. Visual Management is one of the effective strategies for eliminating waste; It is a Lean Tool that makes crucial information accessible to everyone. It displays the information through visual signals rather than words, making it easier for all project stakeholders to comprehend. To maximize efficiency, value, and clarity, the design should be displayed to facilitate quick comprehension and communication among stakeholders (Singh and Kumar 2021). As more information is made visible, so are the problems, making it easier to receive a reaction or a resolution. Imai (2012) emphasizes the significance of making problems evident; issues not identified in their earliest stages might significantly affect effects.

Overall, the Kaizen methodology can be performed and put into practise most effectively by following these five fundamentals.

2.1.3 Kaizen Business System Tools

Daily Kaizen

Daily Kaizen helps to inspire and integrate all corporate employees in the improvement activities, to increase process control through the definition and analysis of KPIs (Key Performance Indicators), and analyze the organization's work procedures. It also aspires to encourage all employees with an attitude of continuous improvement.

It is implemented by establishing daily meetings between the various teams at the different levels of the organizational charts. The objective is for the person leading a meeting to engage in the meeting from the level above so that all information necessary for scaling is communicated vertically and horizontally in the organizational chart.

***Gemba* Walks**

Gemba Walks consist of routine visits by leaders or managers in the area of added value that allow direct observation of reality, verification of the *Gembutsu* (materials and tools used in the production process), and the discussion of improvements based on real and valid data. Through direct contact between top management and *gemba*, the flow of information is much more accurate and frequent among all the company's employees, allowing for a more in-depth understanding of the difficulties and obstacles that production may be experiencing and allowing for more efficient and practical assistance from management members.

Structured Problem Solving - *Kobetsu* Kaizen

Kobetsu Kaizen is a structured problem-solving tool. It consists of nine steps, as shown in Figure 3, and its structure facilitates the resolution or attempted settlement of any problem. Characterizing an initial situation, which will support the investigation of the fundamental causes, is the first step in the Kaizen methodology. Solutions are then created, tested, and the outcomes are evaluated.

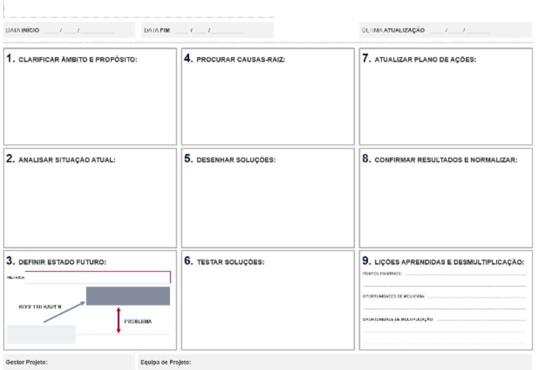

Figure 3 - Example of 9 steps Kobetsu Kaizen

Time Writing and *Muda* Hunting

"Time writing" and "*muda* hunting" are tools used to describe the initial state of a particular process. Both technologies necessitate the direct monitoring of operations at the gemba. The first tool consists of making a complete description of each operator's work and timing and documenting the duration of each one. The second tool, *muda* hunting, involves writing the process's waste and categorizing it according to the seven types of *muda*.

These tools are a part of the lean and kaizen methodologies, which argue that a complete understanding of the current state of processes is required for implementing improvements. In many organizations, administrations are disconnected from the gemba and desire to invest and make changes without understanding the current condition. These time writing and muda hunting activities should, wherever possible, be conducted in collaboration with the administration or the highest levels of the company's hierarchical structure.

2.1.1 Pull Flow

Pull and pull systems are frequently used words associated with the flow. Flow describes the condition of a material as it flows from one process to another. Pull, like flow, is a concept; the two are related but distinct. Pull regulates when the material is moved, and who determines when it happens is the client (Liker and Meier 2006). The material is pulled by the customers.

Pull flow is a way to organize your entire supply chain so that materials and information flow as smoothly as possible. To do this, it is needed to focus on getting rid of the *muda* of materials waiting (the inventory).

Pull-flow thinking isn't something that many people assume or believe in (Coimbra 2013). Most production companies today use push production. With the push system, every process makes as many units as possible and sends them to the next process, whether the following process needs them or not (Imai 2012).

Furthermore, Masaaki Imai describes the push system as a company where operators don't know and don't need to know the volume and frequency of the customer needs. With a push system, you make things in batches, which generates muda of moving and storing materials (Imai 2012). At the final assembly, operators probably put together as many products as the line can make. The finished products go to the warehouse to wait for an order.

The Toyota Production System is based on the idea of "pull flow." The Toyoda family (founder family of Toyota) and Taiichi Ohno started to think this way. After a lot of trial and error, they came up with a radical new way to organize operations that still works very well. The Toyota Production System is the name for this (Coimbra 2009).

2.1.1 *Kanban* System

Visual tools like *kanban* show when something needs to be produced or replaced. In a *kanban* system, when the replenishment level of a reference is reached, the logistics operator identifies it through a visual sign (it can be a card, an empty box, etc.). He collects information about the storage location and the amount that needs to be refilled in the next cycle (Sugimori 1977).

The most important thing about the kanban system is that it doesn't use a system of estimated replenishment. Instead, it only restocks what has been sold or used, which cuts down on inventory (Shingo and Dillon 1989). It is a way to control the Toyota Production System and get the most out of it.

Organizations have trouble adapting to this system not only when demand is high and processing times are unpredictable but also when there are long distances between workstations, automated systems, complex material flows, unreliable equipment, or many suppliers.

The *Kanban* system gives flexibility and stock control. It also ensures that customers get exactly what they order, reducing waste from having to keep small amounts of stock (Shingo and Dillon 1989). So, Lead Time can be shortened while waste is kept to a minimum in industrial activities that, because of how they work, require intermediate or final stocks to improve the level of service.

2.1.2 Materials Requirements Planning

Materials requirements can be planned using three primary categories of methods: forecasting approaches, qualitative or judgmental requirements planning, and based on known deterministic demand and known production lead times.

When requirements are planned based on known deterministic demand and known production lead times, purchase orders are generated and are precise in terms of order quantity and timing. The process accounts for the macro production planning, which is based on sales. It is possible to predict what will be produced during the next six months in a discrete production business.

The MRP tool determines gross requirements and then "explodes" the product BOM (Bill of Materials – A list of all raw materials and consumables necessary to produce a reference) to compute dependent demand, i.e., needed quantities and the determination of required dates for all associated parts and components.

This type of requirements planning is usually used in discrete production industry, which typically produces in small batches, like Company A does, or when the time it takes to make the product is shorter than the time the market wants it to be delivered.

Regardless of the technique, the steps are similar. First, the past consumption must be determined. Based on the objective and time period, it is chosen a forecasting approach (constant, seasonal, or trend model). This selection depends on criteria and forecasting method characteristics (last period demand, moving average, exponential, etc.). The moving average method removes accidental irregularities in time series. Also, if a current consumption value is available, the oldest consumption value of the moving interval is used. The exponential method reduces value weight as "age" increases. A weighted forecast error of the last forecast is used to correct the new forecast. Regression analysis uses a mathematical function to approximate the future.

Once the proper method is chosen, the next step is to make a forecast and evaluate it for shortcoming, reliability, quality, error sources, etc., which provides inputs for the next forecast and future planning. In qualitative or judgmental requirements planning, needs are based on subjective estimates and heuristics. This method is used when the other two cannot be used due to data availability or quality.

2.2 Total Flow Management

Kaizen Institute developed the Total Flow Management (TFM) model based on 25 years of experience implementing lean and kaizen principles. The purpose of this model is to smoothly adopt the Toyota Production System inside the production facilities and throughout the entire supply chain.

According to Kaizen principles, the objective of TFM is to eliminate waste identified in operations and build a pull value chain. Above all, TFM is focused on enhancing the flow of materials and information to construct a lean value chain that integrates production and logistical activities. In the ideal scenario, known as one-piece-flow, materials flow continuously through the system, from raw materials to the final product, with no waiting times, bringing the value-added time closer to the total crossing time of the process.

The objective of TFM is to decrease total supply chain lead time. The measure of lead time is the supply chain's inventory coverage, which can be measured in days. Reducing lead time eliminates the *muda* of waiting and implies the creation of a material flow (Imai 2012). Moreover, the Total Flow Management model stands in five pillars, as shown by the Figure 4:

- Basic reliability;
- Production Flow;
- Internal logistics flow;
- External logistics flow;
- Supply Chain Design.

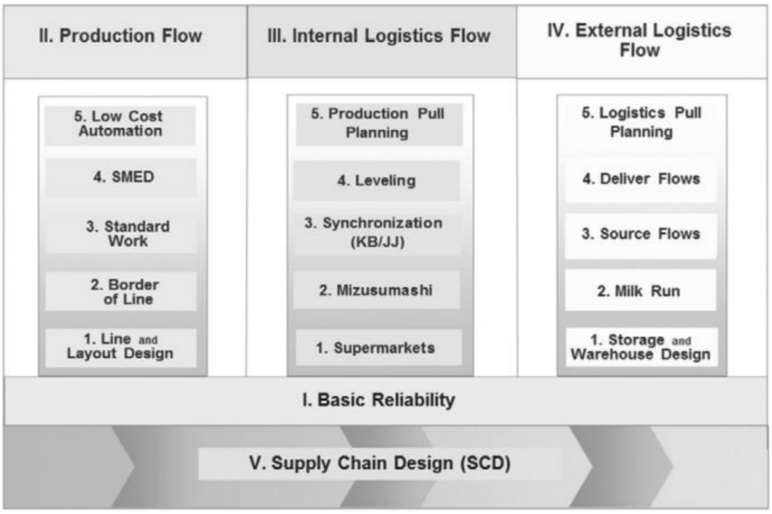

Figure 4 - Total Flow Management (TFM) model adapted from Imai (2012)

These pillars will now be explored in a more detailed way.

2.2.1 Basic Reliability

Firstly, basic reliability is related to the Toyota concept of basic stability, which says that to create flow, a certain level of basic stability is needed in the four Ms (manpower, machines, materials, and methods). The idea of stability says that it is impossible to make a balanced flow of materials when at least one of the four Ms is unreliable.

Before implementing the other flow pillars (Production flow, internal logistics flow, and external logistics flow), it is necessary to create sustainable reliability, i.e., all the processes and all the people (operators, maintenance, and suppliers) are trustable. The first thing to do is create basic reliability in the *gemba*.

2.2.2 Production Flow

The initial stage in enhancing production flow is to execute one-piece flow, establish flexibility in changeovers, provide a flexible and efficient supply of components, and increase operator productivity. The many sorts of improvement projects or events for product flow can be categorized as follows:

- Layout and line design
- Border of line
- Standard work
- Single-minute exchange of dies (SMED)
- Low-cost automation

These Production flow tools will now be explored in more detail.

Layout and line design

To guarantee the performance and adaptability of a manufacturing line, its layout and design must be optimal. As a process is a collection of processes with value-added and non-value-added activities, it is crucial to maximize the efficiency of all resources, whether they are human or mechanical. The goal is to eliminate all pauses and achieve a state of continuous motion from when the material reaches the line until the final product exits. Although it is the primary goal, integrating a unitary flow (one-piece-flow) is not always practicable due to constraints involving the production process that make its application problematic.

There are two typical types of Layouts: Functional layout and line layout. Both types will be covered in this document.

- **Functional layout** presupposes that machines are organised according to their function. This sort of layout is characterised by the use of large batches to decrease transfer between machines (typically by forklifts), as well as the existence of a significant amount of work in process (WIP). According to Coimbra (2013), it is normal for functionally organised layouts to have lead time exceeding five days.

- **Line or process layout** gives an idea of flow, with reduced WIP and lead time. But a closer look will show that some inventory has built up between the workstations. This is a sign of *muda* and may be caused by a difference in the tasks balancing at different workstations. Coimbra says it is important to always calculate the optimal WIP in each station (Coimbra 2013).

Many important machines must be duplicated when converting functional layouts to process layouts. Toyota plants have three times as many machines as functionally designed plants. Toyota built many machines for one-piece flow lines. A company can frequently recover its investment in new machines in less than a year.

O desenho de linha é uma ferramenta que ajuda a dimensionar o número de pessoas numa linha.

From lean philosophy, organizations must produce only what they expect to sell, defect-free, and when the customer requires it. Everything beyond that is considered waste. Takt time and cycle time are two concepts that help understand this equilibrium.

Takt is a German word that means beat or pace, usually associated with orchestra conductors who maintain the rhythm of the music with their baton. The need to match the demand and the production rates introduces the idea of **Takt Time**. It is calculated by dividing the available production time by the customer demand, representing the customer buying rate. For each Takt Time cycle, the customer buys one piece (Rother, Harris, and Institute 2001).

$$takt\ time = \frac{Available\ production\ time}{Customer\ demand\ per\ time\ unit}\ [time/unit]$$

Cycle time is the actual duration of producing one piece in a specific facility sector. Contrary to takt time, which is related to the demand rate, the Cycle Time is different since it is associated with the production time. Some processes in existing facilities commonly have a mismatch between cycle time and takt time.

The perfect scenario would be a match between these two concepts. Therefore, the facility would produce at the same rate as the clients are purchasing. As there are almost always unforeseen events, inevitable problems, or delays, it´s common to dimension the lines with a cycle time value slightly lower than the takt time value.

On the other hand, if the cycle time is too much undersized, people may work more slowly since they are not exerting as much effort to achieve the production target. As a result, it is necessary to keep the two timeframes close together, as this will make it easier to react to problems because they'll be recognized sooner. In several manufacturing plants, the Toyota Group provides a one- to four-hour break between shifts to allow factory workers to make up for missed output.

To determine the number of workers needed in a line, it is important to know the total amount of time it takes to make a product, from beginning to end, by summing the durations of all required operations. This duration is known as the total cycle time. Using the formula below, by dividing this cycle time by the takt time, it is possible to determine the number of people required to produce the product according to customer demand.

$$Number\ of\ workers = \frac{takt\ time}{total\ cycle\ time}$$

The next step is to balance tasks amongst the calculated number of needed operators. Figure 5 depicts the Yamazumi diagram utilised for this purpose. The purpose is to balance the workload of all operators by ensuring that they spend an equivalent amount of time on their assigned activities.

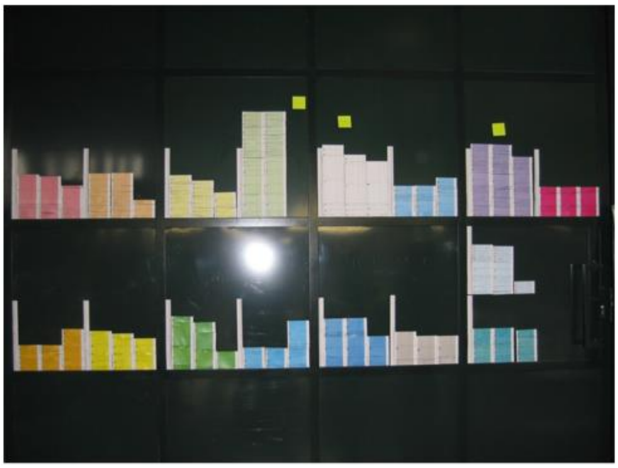

Figure 5 - Example of Yamazumi Diagram

Border of line

This concept refers to the location where all the materials and components required for the unitary flow are supplied, and it performs as the link between production and internal logistics. The major focus is on delivering the appropriate materials and components in the appropriate quantity, at the appropriate time, and at the appropriate location.

As a result, Coimbra (2013) describes four main rules that must been followed when dimensioning the border of line:

- All pieces must be placed in such a way that the line operators' picking movement is minimized.
- The positioning of components and containers must reduce the amount of time that supply logistics personnel are on the move.
- Changing parts from one product to another should take as little time as possible.
- The decision to refill or replenish should be intuitive and immediate.

Any solution developed at this phase must be compatible with the internal logistics system and meet global efficiency standards. The location of parts, the kind of containers, and the container movement in the line (full and empty) must all be carefully engineered (designed) to meet all these criteria. The central focus, however, is on reducing worker moves by putting parts as feasible as close to their place of usage.

Standard Work

Standard Work is the third part of the Production Flow topic from the Total Flow Management model. At this stage, rules are developed for various procedures in order to make them more stable, quicker, more efficient, and safer, allowing operators to devote more time to value-added tasks. The knowledge and instructions that reflect the best known way of work at the time are used to create standards (Coimbra 2013).

The aim is to complete activities in the lowest amount of time possible, lowering cycle time and lead time while maintaining high quality and avoiding *muda* and *mura*.

In Kaizen Institute implementations, standards are frequently created. These documents are posted in a visible location on the lines where operators work. They describe the tasks in a clear and concise manner, usually with images to aid comprehension. In Figure 6 it is possible to see some examples of implemented Standards.

Figure 6 - Examples of documents with Standards of Work.

Single-minute exchange of dies (SMED)

The single-minute exchange of dies (SMED) is the fourth domain of improvement in Lean production flow. This method was developed by Shigeo Shingo when he was working for the Toyota Group as a consultant. It aims to reduce the time between the changeover (setups) from one product to another. Single-minute means less than 10 minutes (9 or less) in every setup. As a result, the machine useful (and usage) time will be maximised.

“The best way to reduce setup time is stop making setups”. If there can't be no setup, the goal for SMED improvement is to have the lowest possible time.

With longer setups, companies tend to have a bigger batch production. By reducing this time, it becomes possible to produce smaller batches or even achieve unitary production. In a hypothetical scenario, if the setup of a machine from one reference to another is nearly zero, it is possible to produce more diversified orders. So, make-to-stock production can be replaced by make-to-order production.

Even though one-piece-flow seems like an obvious goal for most industrial work, the maximum efficiency paradigm keeps many organisations from agreeing with Taiichi Ohno. Organizations often dislike the unit flow in favour of batch production, which makes better use of resources (Coimbra 2013). However, producing in batches raises the inventory level (considered the muda of material waiting), which leads to the increase of intermediate and finished product stock, has some advantages and disadvantages:

Advantages of having inventory:

- Counterbalances the negative impact of setup on productivity;
- It acts as a "cushion," absorbing any potential problems;
- Quickly respond to orders that aren't diverse.

Disadvantages of having inventory:

- The rate of return on invested capital falls;
- It adds no value to the system and is thus considered waste;
- Both labour and storage space are required;
- Lengthens the Lead Time by a significant amount;
- Breaking the one-piece-flow system;
- Inventory that isn't sold gets discarded.

To understand the five SMED phases it is important to classify the changeover activities as external and internal operations. Internal operations are the ones which require the machine. On one hand, internal operations are all those that require the machine to be stopped to be performed. On the other hand, external operations are those that do not require the machine to be interrupted to be executed. The five steps of this method are (see also Figure 7):

1. **Study of the initial situation** – The initial stage is filming the operative mode in order to identify, characterize, and measure the timings of all tasks while classifying them as internal or external;
2. **Separate the internal operations and external operations** – In the second step, it is necessary to try to separate the activities based on the data gathered earlier, clearly separating and sequencing the work that can be done before the machine stops (external operations), what is done while it is stopped (internal operations), and what is done when it starts (external operations);
3. **Convert internal processes to external** – At this stage, it is considered whether, with some enhancements or a paradigm shift, operations that were previously completed with the machine stopped can now be completed with the equipment running;
4. **Reduce the internal operations** – The goal is to reduce the amount of time spent on internal procedures by implementing simple and low-cost alternatives;
5. **Reduce the external operations** – This step is similar to the previous but has a lower priority, which is why it is the final one. After decreasing the maximum amount of time possible for internal processes, the goal in this stage is to minimize the time for external tasks using the same logic as point 4.

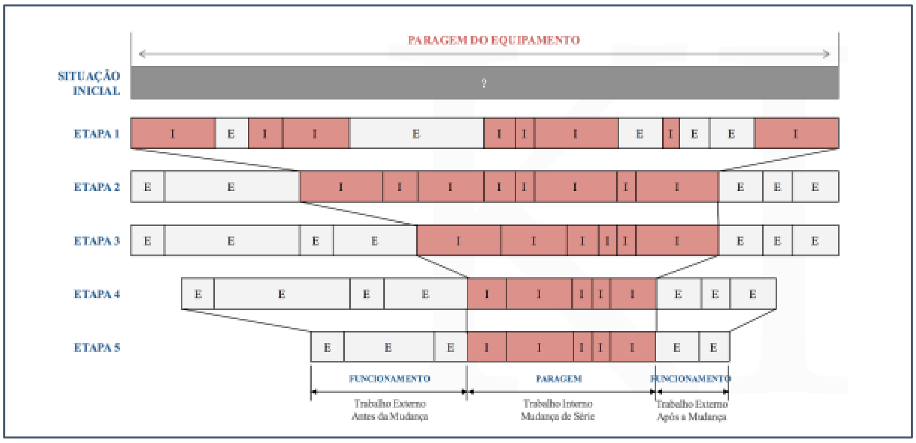

Figure 7 - The 5 steps of SMED (single-minute exchange of dies)

Therefore, this ensures not only an increase in the efficiency of the product changeover process, but also a reduction in activities performed when the machine is stopped, by maximizing the machine's value-added time.

Low-cost automation

By automating sections of the activity, it is possible to increase mechanisation and productivity. In fact, productivity is defined as an output divided by an input, with the output being the quantity of goods produced and the input being the required number of labour hours. Productivity has no limitations since the ratio becomes almost limitless as the denominator (the number of worker-hours required) is reduced.

This step of the Production flow is called low-cost automation (LCA) because it is concerned with the cost-effective mechanisation of manual operations. The distinction between low-cost automation and complete automation is that LCA focuses largely on automating simple, linear movements that are integral to the work cycle with low-cost mechanical devices.

Before automation can be implemented, the line must contain all of the production-flow features developed so far (the first four domains of production flow – line and layout design, border of line, standard work, and SMED). According to Coimbra (2009), this is the final phase in the improvement process, and if it is completed before the others, or in other words, if the *muda* is not eliminated first, it can lead to the automation of *muda*.

2.2.3 Internal Logistics Flow

Total Flow Management (TFM) model's third pillar is internal logistics flow. Creating a one-small-container flow is the challenge of internal logistics flow. It was already shown in the realm of border-of-line how to select the optimal containers to ensure the flexibility and efficiency of the lines. After this it is needed to organise internal logistics to ensure that all necessary parts are supplied in accordance with the line cycle time (which should be close to the customer's takt time). As well as Production flow pillar, this one has five sorts of improvement projects:

- Supermarkets;
- Mizusumashi;
- Synchronization (KB/JJ);
- Leveling;
- Pull planning.

These approaches will be described more briefly than the flow production methods, as the latter were more crucial to the developed work.

Supermarkets

A supermarket is a storage facility whose objective is to absorb demand fluctuations from downstream processes and shorten reaction lead time by direct distribution from stock. Each product has a set location that is easily accessible, as indicated by visual management, which streamlines the handling and replenishment of materials. This replenishment follows the FIFO (First In, First Out) principle, which states that the first item stored will be consumed first. This strategy is utilised in pull-based systems through the determination of maximum stock amounts and replenishment levels for each reference.

In resume, the rules for supermarkets design are:

- Every part number has a fixed defined position;
- It offers convenient and ergonomic picking access;
- The presence of Visual Management is essential (every time that something is picked or restocked it is needed to be visually clear);
- Follows the FIFO (First In, First Out) principle;
- It is established to facilitate the flow and management of small containers, containers on wheels (rollers), and trolleys.

Mizusumashi

Mizusumashi, also called *Mizu*, is a logistics operator with established routes for collecting, transferring, and restocking materials between supermarkets (and warehouses) and the border of line by repeating a set cycle of movements.

On the production lines, the clients are the production operators. They have a dependable logistics provider that has a fixed frequency to do the cycle, evaluates the need for additional materials, and removes empty containers and any material waste generated throughout the process (reverse logistics). The production is ensured of a constant and stable supply.

Synchronization (KB/JJ)

Synchronization is related to the information system used to signify the beginning of production or the beginning of material picking and delivery.

It can be accomplished with physical devices. It is always possible to automate the system in the future using an information system. Additionally, it is essential to establish an efficient and effective physical (visual) information system that consumers can comprehend and react promptly.

Leveling

Leveling is a series of planning procedures that transform orders into programmed batches and initiate an optimum production sequence. In other words, the objective of leveling is to plan the sequence of the lines. To do this, there are other tasks to be made:

1. Making kanban order cards (smaller batches) out of production orders;
2. Rearranging the kanban order cards to correspond to the production start dates (this levels the monthly load);
3. Mizusumashi picking cycle planning and daily load levelling (respecting daily capacity);
4. Production lines sequencing.

Leveling, in the Toyota production system, refers to the process of repeating a product in a continuous cycle of time (also called every product every interval [EPEI]). The EPEI is a number that indicates how long it will take to repeat all the product references.

Pull Planning

This TFM domain of internal logistics flow pillar contains very important planning decisions that affect the success of all other domains. There are two main types or strategies of planning: make-to-order and make-to-stock. It happens to have a combination of both, per example, some constituents are produced to stock and others to order.

In this improvement measure, the following is decided:

- Strategy for planning final product variants as well as all parts varieties (either make to stock or make to order).
- Logistics and production capacity requirements.
- Execution plan—which orders should be placed on the production pull system first.

The production pull planning follows three tasks (Coimbra 2013):

1. Deciding the planning strategy for:
    a. The finished goods – there are two strategies to plan the finished goods production:
        i. Make-to-stock (MTS) – There are not finished goods available. The customer order is the trigger for the production to start. This way, the client must wait for the final product to be ready.
        ii. Make to order (MTO) – There are finished goods available. The client does not need to wait for the final product because it will be already produced.
    b. The parts needed to make the finished goods – Another choice to be made is how to plan for the parts in the bill of materials at the level of the assembly line. Some parts may be MTS while others may be MTO.

2. Capacity planning – The requirement for capacity planning arises from the necessity of anticipating changes in market demand (including seasonality). The typical horizons for capacity planning are annually, quarterly, or monthly.
   Calculations need to be done on the takt time of the customer, and decisions about capacity need to be made to deal with the takt time that is anticipated. In this stage, decisions will be made concerning the capacity of the assembly line, the capacity of individual machines, the size of the supermarket, and the capacity of the transport system.
   The capacity plan can be calculated using the forecasts. The required resources for the following planning period (typically one month) can then be prepared ahead of time.
3. Execution planning –This must be done after the planning strategy and capacity planning to be effective. Execution planning determines what to manufacture and how much to deliver to clients.

Once they are not directly involved in the project, the fourth and fifth pillars (External Logistics Flow and Supply Chain Design) will not be discussed in detail. However, reading about them in Euclides Coimbra's book "Kaizen in Logistics and Supply Chain" is a valuable knowledge addition.

2.3 Total Quality Management (TQM)

The Kaizen approach to the word quality goes far beyond product or service quality. It also refers to the quality of the procedures and activities that result in such products or services. The former is referred to as outcome quality, whereas the latter is referred to as process quality. Quality, according to this definition, affects all aspects of a company's operations, including the processes of developing, designing, manufacturing, marketing, and servicing its products or services (Imai 1986).

Total Quality Management is a quality management system that aims to improve the quality of all products and processes. It is a long-term plan because it involves always getting better, to improve continuously. The main characteristics of TQM are:

- Focus on the customer;
- Teamwork across the entire company;
- Use facts and data to make decisions;
- Always look for problems, and their root causes to make improvements.

During the last 30 years of the 20th century, the shift from focusing on product quality to focusing on TQM was a major factor in the growth of quality management (Boaden 1997). Managers began to take quality seriously in relation to the survival of their organization as a result of increased pressure from both competitors and customers with higher expectations (Zhang, Moreira, and Sousa 2021). Quality is the key to making more money, and putting in place a good quality system in their manufacturing processes can help the company make a lot of money (Sahoo and Yadav 2020).

TQM in Japan includes things like policy implementation, building quality-assurance systems, standardization, training and education, cost management, and quality circles (Imai 2012).

2.4 Synthesis of the Chapter

This chapter explored the pertinent concepts and the theory upon which the efforts in the dissertation project's scope were based. Since it was the parent system of all others, the Toyota

Production System was discussed first. Lean production, which is rapidly being embraced and sought after by businesses in the western world, was greatly pioneered by Toyota.

Next, the Kaizen Business System and Lean Operations Management were analysed, where some of the procedures and tools adopted in the project were discussed. Finally, since they are two of the most crucial models in the kaizen methodology and also important for the work developed, the Total Flow Management and Total Quality Management models were explored.

3 Characterization of the Initial Situation

This chapter will provide a full description of the procedures as they were at the start of the project. The goal of the chapter is to analyse the processes in detail, i.e., go to the *gemba* and collect the real data on what is actually going on.

First, there will be a condensed explanation of the procedure involved in producing an SPA, breaking down each stage of the manufacturing process. Following this, the phases in which changes were done or would have the potential to be applied will be more in-depth, and the observations that were made on the ground will be presented. The key chances for improvement will be addressed at the end of this chapter, with the design of solutions to be provided in chapter 4.

3.1 Product Description

SPAs and Swimmers produced by Company A are top quality. With a total of 70 direct collaborators, which are the operators that work on *gemba*, the company sold 1858 spa units in 2021 and aims to produce 2500 spas in 2022 to accommodate the growing demand for their products.

A spa (an example is showed in Figure 8) has plenty of complexities due to the fact that it can be customized according to the request of the client. From the 42 existing molds, Company A has 145 production references according to the clients' requests. However, not all of them are now manufactured, and some of those that are, are produced in small quantities. There were a total of 93 references sold in 2021, and 32 of them accounted for eighty percent (80%) of the sales.

Figure 8 - Example of a spa produced in Company A.

The spas are constructed out of an acrylic material, which is thereafter insulated, reinforced, and subjected to the assembly of canals before being packaged and shipped. The different stages of this process will be explored in this chapter.

3.2 Production Procedure

Production Lead Time in 2021 was thirty-one (31) days. To manufacture a spa several steps are needed to complete. Fabrication and Assembly are the two main areas of Company A's factory. Each area has its own floor, and they are separated by a rigorous quality control. Fabrication regularly works with two shifts, while the Assembly works with one daily shift. The subsequent subchapter presents a process map that includes all fabrication and assembly phases.

3.2.1 Value Stream Mapping (VSM)

The value stream is a collection of *gemba* actions that contribute to the final product's value. One of the first steps to understand the manufacturing process is to map the value stream. Figure 9's Value Stream Mapping shows that the procedure consists of numerous sequential steps.

In

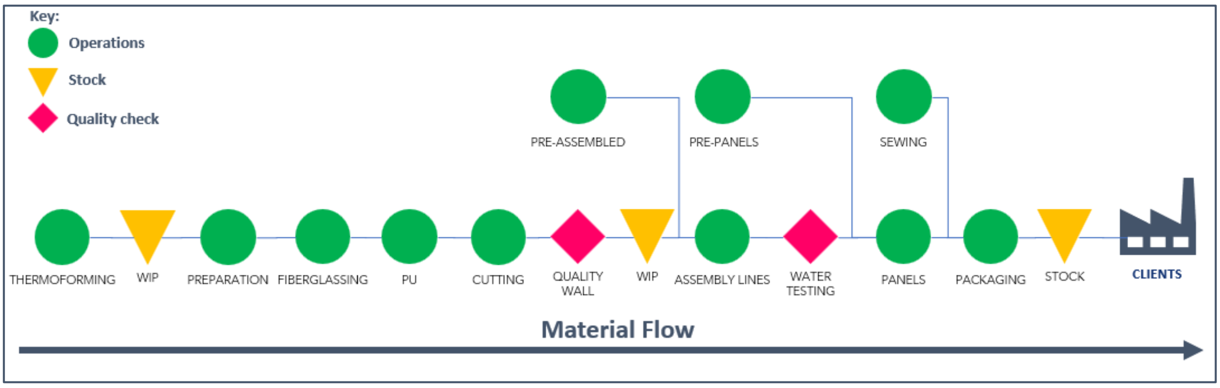

Figure 9 - Value Stream Mapping (VSM)

3.2.2 Detailed Production Procedure

In accordance with the VSM, the production operations will be described to facilitate comprehension of the process. The first five sectors (thermoforming, preparation, fiberglassing, polyurethane, and cutting) constitute fabrication, whereas the last six sectors (pre-assembled, assembly lines, pre-panels, panels, sewing, and packaging) comprise assembly.

i. Thermoforming

As the term implies, thermal energy is used to transform an acrylic sheet into a spa bath shell. The sheet is heated to temperatures between 150 and 200 degrees Celsius until it is malleable and is then subjected to a vacuum suction force that moulds the shell, with the help of a mould. The thermoforming machine is showed in Figure 10.

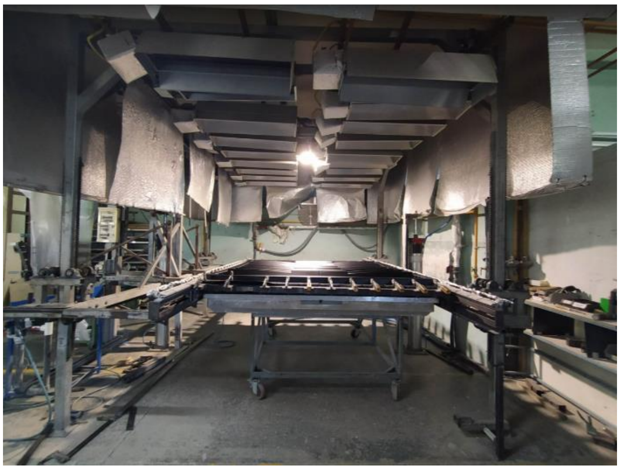

Figure 10 - Thermoforming machine with a base mold

A total of four full-time equivalents (FTE) divided into two shifts of two employees each work at this stage. Multiple operations, which may or may not be directly associated with the thermoforming equipment, must be performed. Besides operating the thermoforming machine, the two workers also have to cut and clean the acrylic sheets, to prepare them, and to change the machine's mould when shell reference change. The mould change takes longer because it is necessary to take the last mould off, put the next one on and clamp it to the machine.

The molds are wooden or epoxy resin made and are usually supplied by an external producer. However, the maintenance and verifying process before thermoforming is done by an internal operator (one FTE). This resource is sometimes working in other areas due to a lack of manpower in those sectors of the process, resulting in a failure to verify the molds entering the thermoforming machine and a consequent quality failure of the thermoformed shells. When a mold is verified, and it is OK for thermoforming, the operator turns the verification card to green; The left part of Figure 11 shows the visual management to this process, and it is noticeable that many molds are not OK for thermoforming due to this problem of a lack of manpower. The right side of the same figure shows the rack where the molds of the different references are stored.

Figure 11 - Mould verification visual management and mold rack with different references

The thermoforming sector is also responsible for producing the bases for the spa shells as well as for swimmer shells, which are made in the same way as common spas but with a different mold.

The average time for thermoforming a spa is 40 minutes, but when a mold change is needed, the step with the changeover takes about 1 hour and 40 minutes (the setup of the mold time is around one hour). When thermoforming Swimmer spas, the process is longer. It takes about one and a half hours and another two hours for the setup.

ii. Preparing

In this sector, which is referred to as the preparation process (Figure 12), an epoxy resin is applied to the shell as a primary for the fiberglass to adhere better. Because it is a step in getting ready for the fiberglassing process, it is referred to as "preparing." Preparation is a simple and fast process that also produces a small buffer for the fiberglassing sector.

Figure 12 - Spas with epoxy resin in the preparing stage.

iii. Fiberglassing

The aim of this sector is to increase the shell strength by adding fiberglass. When it comes out of the thermoforming process, the shell is fragile and can be damaged or deformed by light touches or careless handling. The shells come weighting from 10 to 20 kilograms from thermoforming, and after fiberglassing, they reach 250 to 350 kilograms.

The fiberglass is placed on with a spray gun, and then it is beaten with a brush or roller to get rid of bubbles. When these bubbles are improperly removed, quality problems typically arise. If these problems are not noticed promptly, they may cause problems farther along the value stream. When errors are discovered, the entropy necessary to correct or scrap them will be substantially higher.

In addition, wooden sticks provided by the external carpentry (Company Y) are fastened to the spa flap with fiberglass, where aluminum and wooden constructions will be screwed. These sticks are occasionally fibered incorrectly, resulting in time-consuming rework further along the value stream.

iv. Polyurethane

After fiberglassing, polyurethane is added to the shell to make spas better at keeping the heat in. The process is simple and quick, with an average cycle time of 15 minutes. Polyurethane is also put on the bases, and in this case, the cycle time is almost non-existent in the value stream.

v. Cutting

Contrary to the polyurethane process, this is longer and more complex. The SPA flap is cut here. The shell is also drilled in the locations where the water jets, air jets or led lights will be installed.

The complexity of the process comes with the number of references that lead to several cutting manual guides. The manual guides contain the information required for operators to properly drill each spa reference. As a mold can produce one or more finished product references, each thermoformed shell can be altered at this point (the 42 existing molds branch into 145 finished product references).

An electric grinding wheel is used to cut the spa flap. The difference between the flap before and after the cut is shown in Figure 13. This task has an average cycle time of 30 minutes.

Figure 13 - Spa flap before and after cutting.

Following the flap's cutting, the holes are drilled manually using a hole driller. The average number of holes per spa is 75, and the average number of various diameters used per spa is 10 out of a total of 23 diameters available in the company A’s cutting manual guides. Figure 14 shows an example of a Cutting Manual Guide. Cycle time of drilling is between 90 and 150 minutes depending on the complexity of the cut required.

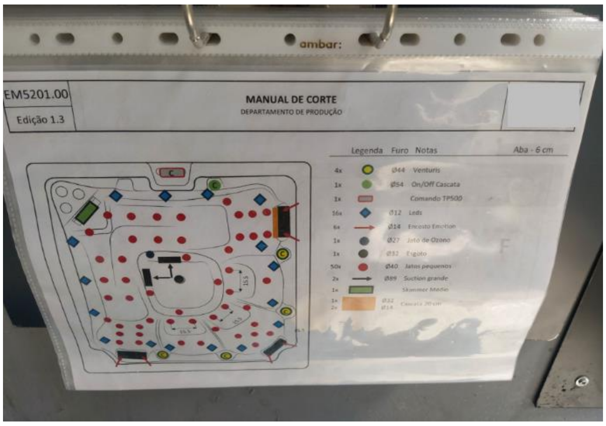

Figure 14 - Example of a Cutting Manual Guide

vi. Quality Wall

This is an important part of the factory. Here, a line between fabrication and assembly is drawn.

A rigorous and exhaustive quality check is performed here to review all problems and potential problems that may arise during the fabrication process, from thermoforming to the cutting process. These are the items screened by the quality check:

1. Examine the wood that has been fibered.
2. Look over the full tab for:
    a. Warpage
    b. Scratches
    c. Acrylic thickness + fibre thickness
3. Look for the following in the holes:
    a. The flap has holes in it.
    b. Holes in the interior (jets, sewer, LEDs)
    c. There are headrests
4. Make sure the holes are clean and free of burrs.
5. Check to see if the fibre has been properly catalysed and compressed in the spa.

After this, a round sticker with a colour code is applied in the spa as an evaluation of the quality check. If no defects are detected, the sticker is green, and the spa is validated to go to Assembly. A yellow sticker is placed on the OF paper, a paper sheet with the information of the fabrication order, in the occurrence of minor flaws that allow the spa to go up for assembly but require rework later in the value stream. A red label is put on the spa if the flaws make it impossible for it to go up to the assembly lines, if it needs to be reworked twice, or if it is scrap.

vii. Assembly Lines

Assembly follows fabrication. All motors, air canals and jets, water canals and jets, speakers and LED lights are assembled here. The factory has five assembly lines. However only four are active – line 2 is currently disabled. Line 1, line 3, line 4 and line 5 are the current active lines. Line 3 is a Swimmer spa dedicated line. It is not every day that Swimmers are produced and assembled so sometimes line 3 is working and sometimes it is stopped. Line 1, 4 and 5 have a daily objective of assembling four spas each.

Daily output of this sector is 10 assembled spas. It should be twelve (12) spas per day but there are a lot of obstacles like absenteeism and critical stockouts. Considering 3 lines, the cycle time is 120 minutes.

Placing the base and wood structure in the shell is the first operation of the lines. This operation is physically hard and requires at least two operators due to the structure's weight. If the structure is composed of aluminium, the spa structure is placed immediately on the fibering sector, and it is not an operation done in the assembly line. Named as Company Y within the scope of this project, a carpentry, is responsible for supplying the wood structures for this project. It is immediately adjacent to Company A, and both companies are owned by the same family.

The first step is the Air Canals, that involve three main tasks:

1. Application of skimmers, jets, and countersinks
2. The positioning of the air channel, as well as the connection of the jets to the collectors
3. Wire placement + structure placement + base placement

Following the installation of the air canals comes the assembling of the water canals:

4. Positioning of the engines
5. Positioning of the pre-assembled components
6. Establishing connections between the water channel jets
7. The positioning of mirrors, LEDs, and other components

After everything has been finished, the spa will proceed to the sector where water tests are performed.

viii. Water Testing

A quality check is performed in between the assembly and the panels. This check involves filling the spa first with hot water and then with cold water. The purpose of this check is to ensure that all of the components have been appropriately assembled and that there are no leaks. The test takes about twenty (20) hours with the heated water and one hour with cold water.

Following the testing, the quality team attaches a sticker with a colour code that shows whether the spa may proceed and what repairs are required, similar to what happens in the quality wall.

ix. Panels

After the spa bath has been inspected and approved by the quality control team, the next step is to assemble the side panels. Aluminium and ecowood are the two different types of raw materials that can be used to make panels at Company A. The panels are cut in the pre-panels sector (this sector will be reviewed later).

Due to the fact that the panels make up the spa's exterior sides, they play an extremely significant part in the overall appearance of the spa. Figure 15 shows a spa that has aluminium panels on the left and one that has ecowood panels on the right side. Aesthetic concerns are the driving force for the creation of longitudinal scratches in 95% of all aluminium panels. The vertical distance between these scratches is customizable per the requirements of the customers.

Figure 15 - Spas with diferent material panels (aluminium on the left; ecowood on the right).

The panels provide a vital purpose in terms of insulating against the heat in addition to the aesthetic function that they do. The installation of the panels requires also the installation of a polyethylene insulation layer as a prerequisite. Insulation is attached to the spas' structure in aluminium panels, while in ecowood panels it is attached directly to the interior of the panel itself.

x. Packaging

This is the final step in the manufacture of spas. Here, the final quality inspection occurs. The spa is then cleaned, the cover produced in the sewing sector is attached (sewing sector will be approached later), the user's manual is placed inside, and it is covered in protective film.

Three operators work in parallel (3 FTEs), and each cycle time is between 100 and 120 minutes. After this process, the spa is validated to be dispatched to the customers. Occasionally, a spa will be packaged with a missing component or material. Before the missing equipment can be replaced, the spa is stored in a tent, generating stocks, which is a *muda*.

Three parallel sections provide necessary items that are incorporated in products at some point of the processing line.

xi. Pre-assembled

The pre-assembled is a sector created relatively recently to supply the assembly lines. Here, carts, visible in Figure 16, are prepared with all the material that each spa will need to be assembled. Some tube and collector assemblies are also made to reduce the load on the assembly lines of some more complex models and thus level the cycle times of the entire factory.

Figure 16 – Pre-assembled carts.

Depending on the complexity of the components to be prepared, the sector's cycle time ranges between 30 and 40 minutes per spa, with two workers (2 FTE).

xii. Pre-Panels

The manufacturing of the panels takes place in this sector. When it comes to the production of aluminium panels, aluminium plates are cut with standard dimensions so that they conform to the specifications of each product reference. To do ecowood panels, ecowood slats are put together side by side, as depicted in Figure 17, and then screwed at either end to a transverse lath to maintain their stability. While aluminium panels have the insulation fixed to the spa's structure, ecowood panels use bolts to secure the polyethylene insulation directly to the panel..

Figure 17 - Ecowood slats side by side.

Because the panels are previously made with somewhat larger dimensions than what the spas will actually require, rework is necessary in this sector. The panel assemblers take then precise measurements of the distance needed for each panel before going to the pre-panels sector to have it cut to size. With two workers operating in full-time jobs (2 FTEs) the cycle time of this sector is from 30 to 40 minutes.

xiii. Sewing

Spa covers are constructed using nappa, a synthetic leather, in the sewing sector. Eight employees (8 FTEs) were employed in this sector. Four main processes describe the sewing process:

1. Nappa cutting (1.5 FTEs);
2. Machine sewing (4.5 FTEs);
3. Cover packaging (2 FTEs).

This sector contains six sewing machines, although they were never all operating at the same time, and its initial layout is seen in Figure 19.

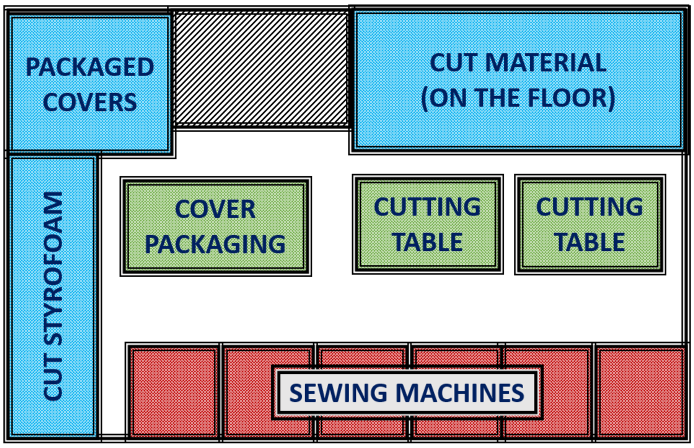

Figure 18 - Initial Layout of Sewing Sector

The sewing is a sector that is located on another floor of the factory, and which used to operate very autonomously. Raw material and inventory management was carried out by the sector head herself. The planning team delivered a sheet weekly with a two-week vision, and the sewing leader ordered replenishment based on what she expected to spend.

3.3 Production Planning

From the time a customer places an order until the acrylic goes through thermoforming, there are a series of steps that must be taken for production planning (the idea is that, after thermoforming, the spas always remain in FIFO).

The sales team take customers' orders and then, create the Fabrication Orders (OFs), which are sent to the production planning team. With Fabrication Orders in hand, the planning team defines the thermoforming schedule with four-week visibility. The subsequent objective is for the spas to follow a FIFO order down the value chain. Due to process instabilities, which will be examined later, it is not always possible to maintain the sequence, and the team must react daily to prevent production halts.

3.4 Team Description

The production supervision team was the group that worked directly on this project. Figure 19 shows a production organigram. This team is right below the production director and above the leaders of the factory sectors. So, the team includes the operations manager, his planning assistant, the director of quality, the director of maintenance, the logistics coordinator, and a member of internal logistics.

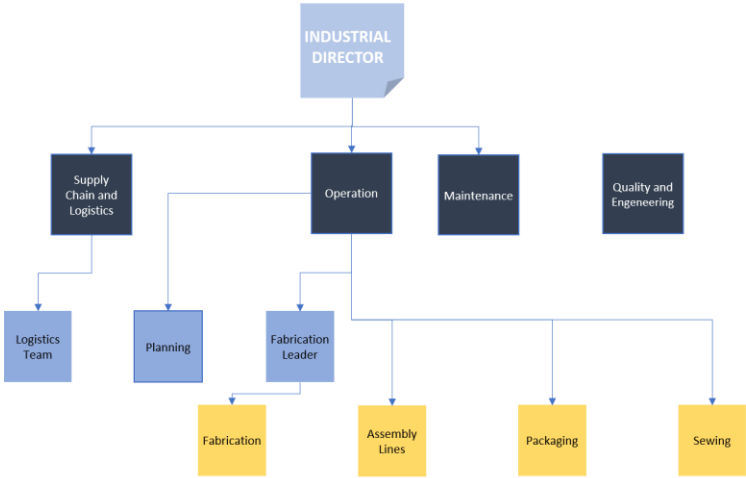

Figure 19 - Organigram of Company A.

The production is the responsibility of the supervisory team, which is also responsible for making decisions involving the various production teams and implementing improvement measures. *Gemba* diagnostic observations were made in collaboration with the members of this team.

The main difficulties that were encountered when analysing the initial situation and those that arose during the development of the work will be covered in the subsequent subchapter of this dissertation. We'll categorise these difficulties into several groups.

3.5 Main Problems and Improvement Opportunities

The main difficulties that were encountered when analysing the initial situation and those that arose during the development of the work will be covered in this subchapter. These issues, that result in considerable reductions in the factory's daily output as well as reductions in operator productivity, will be categorised into several groups.

The fabrication area of the factory, which operated in two shifts, was already prepared to increase daily production from 8.4 to 12 spas. The breakdown of raw materials was the primarily responsible for the failure to fabricate 12 spas. In the assembly area, the assembly lines were also sized to assemble 12 spas every day. This was not happening because of problems with the raw material stock and a high absenteeism rate.

3.5.1 Critical Stockouts

As previously reported, there were multiple instances of production stockouts. In 2021, there were seven stockouts per week on average. This is due to the fact that there is no reliable method for calculating consumption, as there were no bills of materials (BOMs) consumed by each produced reference (or if they did exist, the majority of them were inaccurate), and as a result, that information was not being stored, which led to a lack of awareness regarding what was available in stock and what had been used up.

Supply chain process was not structured, since there was not an analytics system of stocks, consumptions and suppliers lead times. The whole supply chain department was led by just one person.

When there are stockouts, supplies are ordered with a greater urgency, which incurs more shipping costs and necessitates a bigger financial effort from the treasury. In 2021, more than eighty thousand euros (€80k) were spent on urgent shipments than would have been appropriate under normal conditions due to the production's pressing need to replace out-of-stock materials.

Stoppages in some areas of the factory are frequently caused by the issue of stockouts. Figure 20 depicts the number of days that this problem caused manufacturing or assembly to interrupt operations between weeks 14 and 17 of this year (in April), with 4.5 average stoppages per week.

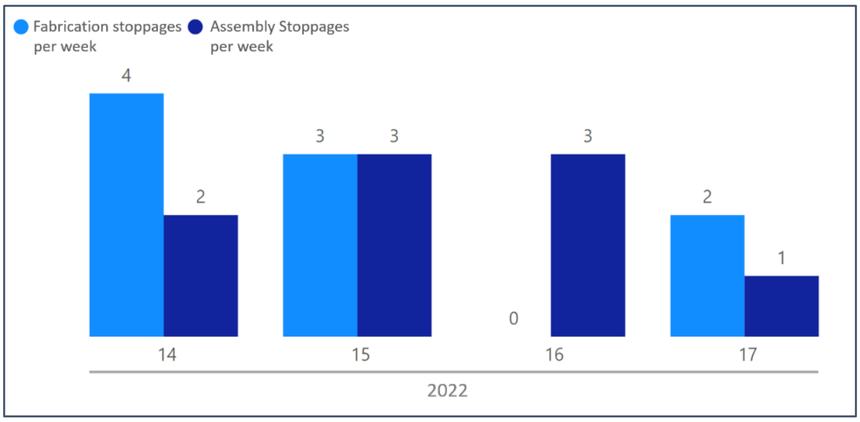

Figure 20 – April factory stoppages because of stockouts.

The issue with cash flow gets worse and worse as a result of production losses brought on by stoppages, entering a snowball loop because, if spas are not sold, no money flows into the bank account, meaning there is no revolving fund to restock the missing materials.

3.5.2 Lack of Information Flow

It was observed that there was an inadequate flow of information throughout the different departments of the company. Departments worked independently from one another; the information did not flow because they were disconnected.

Specially for some sectors that need to work in parallel, like the pre-assembled, the pre-panels, the sewing or even the external carpentry. These sectors need to be coordinated with the main value stream to deliver the supplies on time. Pre-assembled need to have the carts ready before the spas enter in the assembly line. Pre-panels need to have the panels prepared for the moment that the panels assembly would need them. Sewing need to make the spas' covers before they get packaged for shipment. And the carpentry needs to deliver the wooden structures before the spas go to the assembly lines, like the pre-assembled. Sometimes, these sectors produced the results that were expected, but to the wrong references. This caused by problems with the accuracy or quality of the information they received. This was a problem because it could stop other sectors from working since it wouldn't have the required materials.

Besides, this was a difficulty for the sectors' leaders to know what to produce when there was a lot of WIP before their lines or sectors. With the accumulation of WIP, it gets more difficult to follow the FIFO rule because, at some point, spas are stocked where the available space allows it, creating entropy and disorganisation.

This is a problem for the supervision team as well because a lot of information of the OFs, like the live sector/location in the factory of a spa, the records of the things that were done until a certain moment were out of their hands. Only going to the *gemba*, or asking the leaders of the sectors, supervision team members could know live information of the spas.

3.5.3 Supervision Follow Up

The problem that the supervision team was having with the lack of information led to the necessity of a heightened level of operations monitoring. In addition, there was a need for greater communication between the team members to analyse the production, determine the root causes of the problems and launch countermeasures to solve them, and analyse the ongoing actions of each member to promote mutual assistance and the exchange of ideas.

The team met at 10 a.m. to examine the day's production, current macro problems, and how to respond to production urgencies. This meeting lacked a set structure and did not have a visual aid of key performance indicators (KPIs) to analyse them for decision making and problem identification.

Every day at 12 p.m., the supervisory team, and the heads of the different sectors of the factory meet up. At this meeting, each leader says how many spas he previews his sector will finish by the end of the day. Even though this was useful information, it was missing something just as important: information about the problems and material stockouts in each sector. Even when these things were talked about, they were not always written down.

3.5.4 Bottleneck analysis

When figuring out how stable a factory is, it's important to look if the different processes aren't all at the same production level. By looking at the March 2022 output numbers of each sector, the supervision team could understand that the panels assembly was the bottleneck of the factory, as they were producing less than the other sector of the factory, as seen in Figure 21.

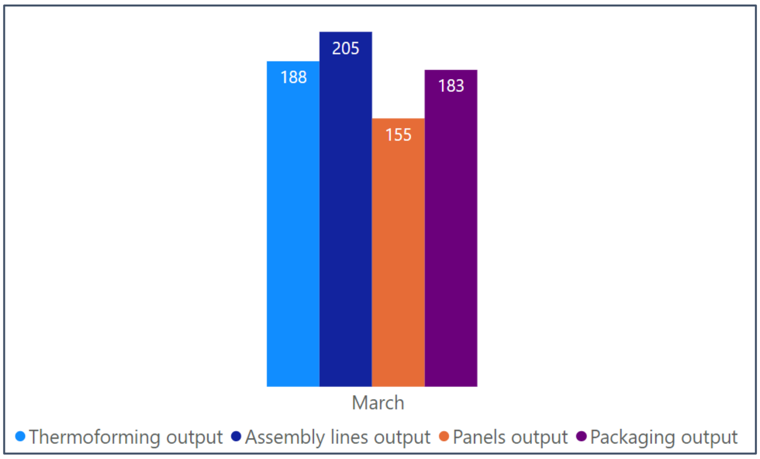

Figure 21 - Factory sectors´ total marh output.

There are 2 operators per line (2 FTEs) in the lines 1 and 5. Line 4 will not be aborded in this subchapter because it is dedicated to a different type of panel that is created in the pre-panels sector and does not require a specific operator in the panels assembly sector. Line 3 is dedicated for the swimmer spas. Line 3 won't be as well aborded in the subchapter because it produces fewer than one swimmer per day, and the characterization will instead be concentrated on lines 1 and 5.

Initially, each operator on each assembly line (lines 1 and 5) was responsible for the whole panel assembly process; so, both worked in parallel. The initial mode of operation, summarized, is descripted in Table 1:

No.	Task
1	Transport SPA from the water testing region to the panel assembly region.
2	Cut the base flap and remove protection plastic film.
3	Examine the structure using gauges.
4	Carry out the necessary rework.
5	Go to the pre-panels sector and cut and bring the polyethylene insulation.
6	Apply insulation.
7	Go to the pre-panels sector and cut and bring the corners of the panels.
8	Go to the pre-panels sector to cut and bring the panels one by one
9	Assembly of panels and corners

Table 1 - Sequence of operations of panels sector.

This sector's cycle time was significantly variable. Observations revealed intervals of 90 and of 250 minutes, with an average of 150 minutes of cycle time. With absenteeism, the average output of the panels was 8 panels per day (with lines 1 and 5 averaging 3 per day each and line 4 averaging 2 per day). The main cause of the variance was the need of reworking structures with dimensional defects (mostly wood in this case), improperly attached structures to the spas, and excess fibreglass in the fibre wood sticks that caused the spa flap to be uneven.

Observations were conducted with the intention of identifying value-added and *muda* tasks. Observations reports are available in Appendix A. A significant proportion of the time of observations, 67% was classified as being muda while 33% was recognised as added-value time (VA) as shown in Figure 22. Considering that value-added tasks are those in which the operator instals insulation or assembles corners or panels, all rework and material-gathering movements are classified as waste.

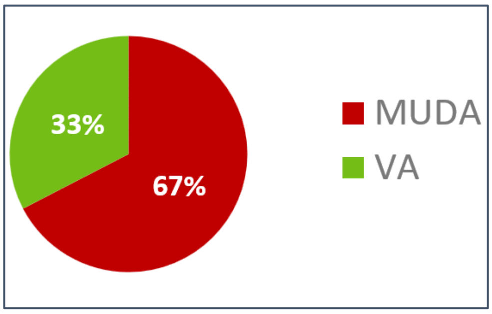

Figure 22 - Percentage of *muda* and added-value time in the observations made in the panels sector.

In addition, it was observed that the work method and the sequence of tasks performed by operators varied significantly. There were no work standards, which could lead to variations in the assembly cycle time of the panels, and the sequence of tasks in Table 1 was not followed by all the assemblers. Furthermore, the number of reworks required due to quality issues impacts the cycle time of the process.

3.5.5 Sewing Sector Problem

Even though the sewing sector wasn't a clear bottleneck, it wasn't producing as much as the rest of the factory. From March to May, the factory was making an average of 9 to 12 packaged spas per day, and only 8 covers per day were being made by sewing, as shown by Figure 23.

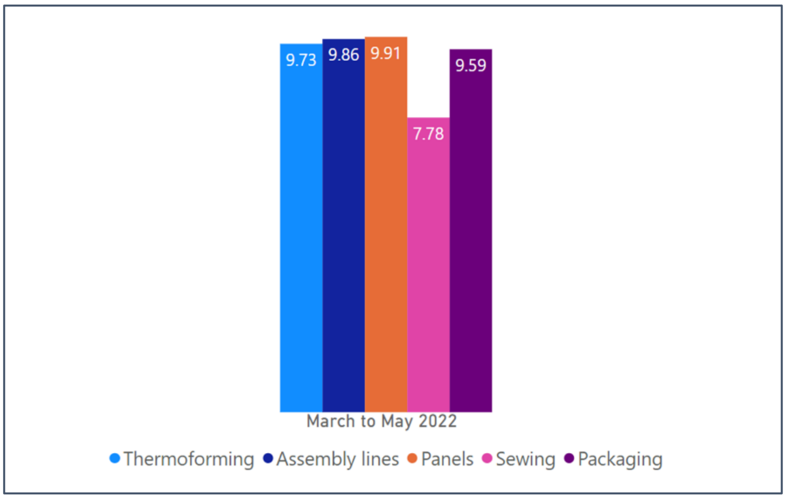

Figure 23 - Average of factory sectors' daily output between March and May.

It is possible to package a spa without a cover, but it isn't shipped until the cover is ready and attached to it. All parts of the spa must be made before it can be sold. The inability to sell the spas because they were not yet finished generated an invoicing problem, which aggravated the already existing cash flow problem.

To guarantee the objective of 12 covers per day, intervention in this sector would be necessary, which, as mentioned above, has always worked very self-sufficiently. The supervision team never have dedicated themselves to observing, monitoring, and auditing the sector, which resulted in unconcern about the sector in comparison to others in the value chain.

As mentioned before, there are three main tasks in this sector: cutting the nappa, sewing the cover with a machine, and packaging the cover. This sector's slowest part was the sewing machines, where most of the employees worked and where most of the observations were made. For two weeks, a lot of observations were made with the help of time writing and *muda* hunting tools to learn and understand the process better.

There was no standard of work of how many people should work at each sector, this number was variable. Observations showed a mean cycle time of 45 minutes per cover in normal covers, and a total of five hours production time. It happens that there are types of covers that are more difficult and can take from two to three times the time of sewing one "normal" cover. In these cases, it can take 2 hours from four sewing machines to do one cover. The observation reports can be consulted in Appendix B.

The line of the machine was very unbalanced because the sewing tasks were not distributed out in a conventional way. A seamstress could make a cover from start to finish, or they could just be making some small parts or assembling covers (joining the little parts together) all day. Besides, the flow of material was extremely inefficient, and the machine operators were forced to make a lot of material-gathering movements.

There are references of coverages that have a high degree of complexity. One of these models, referred to in this document as Quartz, is in great demand due to a commercial arrangement in which Company A agreed to sell 6 trucks (each truck transports 13 Quartz spas) every month; therefore, 78 Quartz covers must be manufactured each month, which corresponds to about 3.5 per day. The average sewing time for a Quartz cover is between four and five hours (4H30 average), compared to two to three hours for a standard complexity cover (2H30 average).

Along with the time spent moving and the imbalanced distribution of tasks on the sewing line, a lack of organisation principles was also found to be a problem. There was no culture of "always keeping the house in order", so many things that weren't being used stayed on the sewing tables. Figure 24 shows that the cut pieces were also put on the floor on a piece of cloth because there was nowhere else to put them.

Figure 24 - Cut pieces on the floor.

In addition to all of these issues, there were several material failures that made impossible the daily production goals from being met. This problem, however, was not directly related to the overall issue of factory stockouts, but rather to the fact that neither the purchasing team nor the supply chain team had visibility into the types and quantities of goods in stock. The sector leader makes material requests based on a weekly inventory and estimating the resources that would be needed, considering the two-week visibility production plan that was given every week by the panning team. This strategy was highly unreliable since many supplies were only requested when they broke or were about to break within a period shorter than the supplier's delivery lead time.

In this sector there is a table of equivalent work for each cover in which, in general, the covers have an equivalence of 1. In case the cover is more complex, it can have a higher degree of equivalence, for example 2 or 2.2, depending on the job and the number of extra pieces that need to be produced for each model. An analysis of the unit load and equivalent of the sector's planning is published in Appendix C, and it was concluded that 11.9 coverages per day were being planned, which fabrication work was equivalent, on average, to 16.9 coverages per day, as shown in Figure 25. This resulted in the conclusion that it would be essential to act in the process by increasing the team's human resources to ensure sufficient production capacity to meet demand.

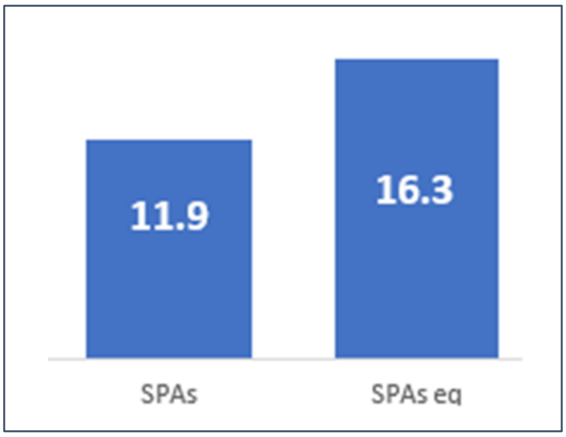

Figure 25 – Average of the unitary vs equivalent covers planned per day for sewing sector.

4 Solutions Designing and Results

4.1 Solutions designed for the main problems and improvement opurtunities

4.1.1 Material Requirement Planning (MRP)

In order to prevent stockouts, it was required to design a tool that could automatically offer information on when and how much raw materials to order, depending on a number of criteria that will be discussed later in this document. As a result, these issues will no longer be dependent on the ability of a single individual to handle all the factory's inventories, but will instead provide stock management with automatic, calculated, and trustworthy support.

Material Requirement Planning (MRP) tool creation needed the supply chain and logistics coordinators to provide the following information for each material reference:

- Material reference;
- Material name;
- Average of the internal purchasing lead time – The time from the moment that supply chain coordinator places the order until Company administration approves the purchase;
- Supplier name;
- Average supplier delivery lead time;
- Supplier delivery lead time standard deviation;
- Minimum Order Quantity (MOQ) - it is the minimum quantity that a supplier agrees to sell;
- Lot Size - the quantity to be ordered will always be a multiple of the lot size;
- Consumption history – important to have the maximum values;
- Average consumption:
    - Per day;
    - Per period of supplier delivery lead time – important avoid stockouts during the delivery time;
- Average consumption standard deviation;
- Current Stock – the warehouse stock;
- Virtual Stock – the warehouse stock plus the stock incoming stock that is currently in transit;
- Bills of Material for each spa reference.

Safety stock is necessary to withstand fluctuations in both average daily use and supplier delivery times. The safety stock is typically determined by adding the consumption standard deviation with the product of the average daily consumption with the replenishment lead time (delivery plus internal) standard deviation. Thus, the safety stock for each reference was calculated as follows:

$$SS = \sigma C + C * \sigma LT$$

SS: Safety Stock [units]
σC: Consumption Standard Deviation [units]
C: Consumption [units / day]
σLT: Lead Time Standard Deviation [days]

According to the following formula, the replenishment level is calculated by adding the safety stock to the product of the average daily consumption and the replenishment lead time (delivery plus internal).

$$RL = SS + C * LT$$

RL: Replenishment Level [units]
SS: Safety Stock [units]
C: Consumption [units / day]
LT: Lead Time [days]

The MRP tool deducts all the materials in stock that are included in the BOM of each spa produced, allowing the current stock quantity to be known. When the current stock quantity is below the replenishment level, the produced tool generates a signal identifying whar material is needed to acquire and in what quantities. The order quantity is calculated by the following formula.

$$QTO = \frac{RL - VS}{BS} \, (roundup) * BS$$

QTO: Quantity to order [units]
RL: Replenishment Level [units]
VS: Virtual Stock [units]
BS: Batch Size [units]

The development and credibility of Bills of Materials (BOMs) posed one of the major barriers to this tool's efficient functioning (MRP). As it was a time-consuming process, it was accomplished in increments, and trust was established in a very phased manner. It was crucial to include all materials and consumables in the BOM for each spa reference, with the participation of all operators and sector leaders. Otherwise, the MRP would be ineffective since the actual material amounts used in production would not be subtracted from the warehouse stock.

Results

Significant improvements have been made to the management of raw materials and consumables. Because of Resulting in critical stockouts, the facility did not totally close any of its sectors in May (which in April happened 7 times a week as seen above). The factory has only stopped the fabrication area because of the excess of WIP before assembly. Due to a shortage of financial flow, stock ruptures were not totally avoided. This will be a gradual process. However, as shown in Figure 26, the number of disruptions has dropped by 71 percent over the past three months, indicating that the introduction of MRP has produced favourable outcomes.

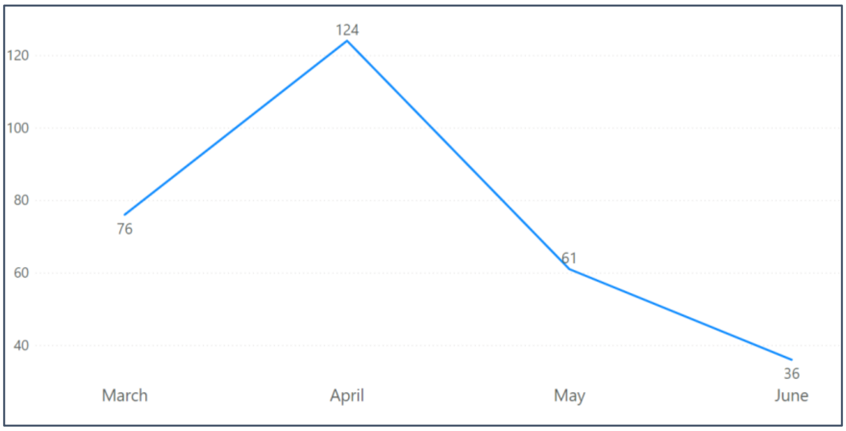

Figure 26 - Monthly Stockouts

4.1.2 Pull planning and PowerApps

Several proposals for enhancing the planning process have been made and adopted in order to simplify the planning procedure and offer the operations manager more time to focus on other issues.

An application that enables a quicker and more direct flow of information was developed to increase communication between the planning department and the multiple production sectors. The application was built with the Power Apps software, which enables the construction of this kind of tools using a simple and intuitive programming language known as Microsoft Power Fx. On the app's main page (Figure 27), users can see the different production sectors. In each one, a tablet with access to the app was set up so that that the heads of the sectors could look at the production plan and report which Fabrication Orders (OFs) were already completed.

Figure 27 - Developed application home page for production management of Company A

The information in the app comes from the spreadsheet file that the operations manager uses to set up the thermoforming production plan. The application was developed so that, from there, thermoformed spas follow in FIFO (First in, first out) in the remaining part of the process.

Each of the sectors visible in Figure 28 has a dedicated page with two columns. The left column has a list of the OFs that are planned to be produced in the sector, while the right column contains a list of the OFs that have already been completed. In sectors from the main value stream (not the parallel sectors), the left column corresponds to the right column of the previous sector, as the steps are consecutive (this does not happen in the pre-assembled, pre-panels, sewing, carpentry, etc). In Figure X shows the example of the fiberglassing page. Between the columns there are three buttons. The first is green and is used for moving produced OFs from left to right. The second, indicated by the colour red, is to execute the reverse effect if an error occurs in the application's handling and the final one is used if a spa quality issue is identified.

Figure 28 - Example of a sector's app page - fiberglassing.

As previously mentioned, information is entered into the application through the planning spreadsheet that includes the thermoforming sequencing established by the operations manager in the list of OFs to be produced in the thermoforming sector. The application then updates a query containing information about all OFs. Each line in this query represents an OF, and the dates and times at which operators complete OFs in their respective sectors are reported. In the same query, quality and rework issues, as well as stockout-related interruptions, are also documented.

By easing communication between the operations manager and the leaders of the various sectors, the Power App proved to be quite useful. Not only is it easier for sector leaders to obtain information about what to produce, but it is also easier for the operations manager to obtain information on which OFs were actually produced.

Results

The work conducted in regard to planning aimed to shorten production lead time and the amount of work in progress (WIP) by enhancing communication between the operations manager and production sectors. Figure 29 depicts the variation of production lead time throughout the course of the project, which, despite not decreasing in the progress of the project, is lower than the average baseline value for the year 2021 (which was 31 days per spa).

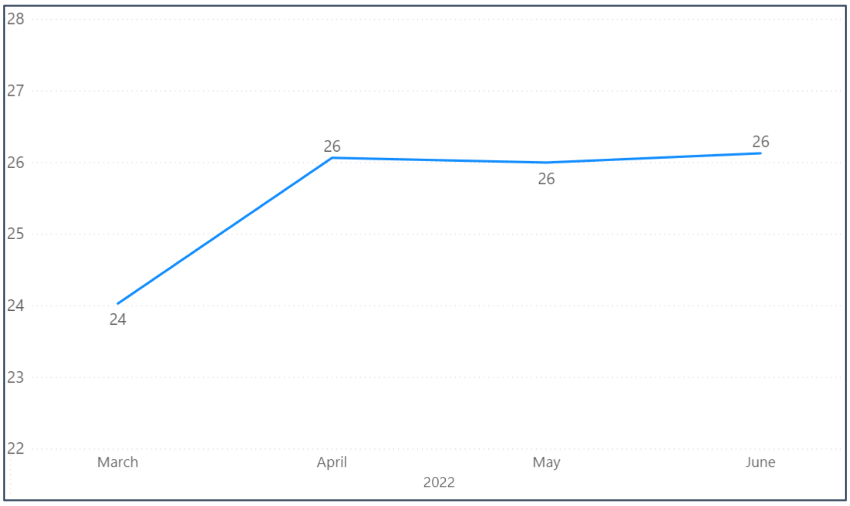

Figure 29 - Monthly production lead time.

The non-decrease is because fabrication has a greater output capacity, and the WIP between production sector frequently exceeds significant quantities, causing the Lead Time to rise.

Figure 30 shows that the average amount of WIP units in the factory had a lot of variability in the course of the project.

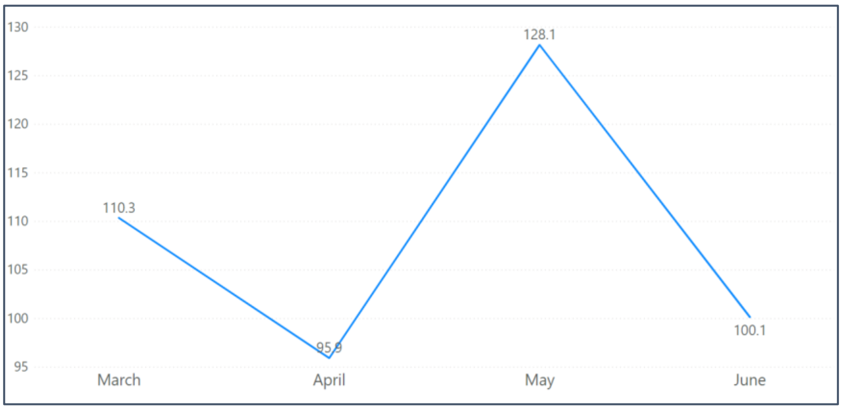

Figure 30 - Monthly WIP in the factory

4.1.3 Dashboard and Daily Kaizen

The reorganisation of the team's 10 a.m. meeting was the first improvement measure suggested and posteriorly implemented. The team reached the conclusion that it would need to examine indicators (KPIs) that could bring information on the causes of the occurring difficulties. The meeting's new structure was also discussed, and the following agenda was built:

1. Analysis of the KPIs from the previous day:
    a. Operations KPIs;
    b. Quality KPIs;
    c. Supply Chain KPIs;
2. Stockouts analysis;
3. Analysis of the actions plan.

To guarantee compliance to the meeting's agenda, certain actions were required, including the definition of KPIs for each department to be examined at the meeting, the description of the procedure for analysing material ruptures, and the manner in which the action plan would be formulated.

Table 2 shows the KPIs definition made by the supervision team:

Department	KPIs				
Operations	Daily output per sector	WIP per sector	Production Lead Time	Productivity (Hours per equivalent SPA)	Shipped spas per day
Quality	Rework time per spa	Nº of first-time quality spas	€ of no quality	Complaints received from items produced in 2022	
Supply Chain	Total stock (and per reference)	Number of daily stockouts	Prompt maintenance		

Table 2 - Defined KPIs.

A dashboard of indicators, which is a visual representation of key performance indicators (KPIs), quantifiable values used to evaluate the success or failure of achieving objectives and track the performance of operations, was created with the results of operations over the last few days. As seen in Figure X, information was provided regarding the output of each sector, the number of spas shipped per day, the amount of WIP (work in progress) in the factory, the average production lead time per month, and the productivity defined in hours worked by each spa (number of worked hours divided by the number of produced spas).

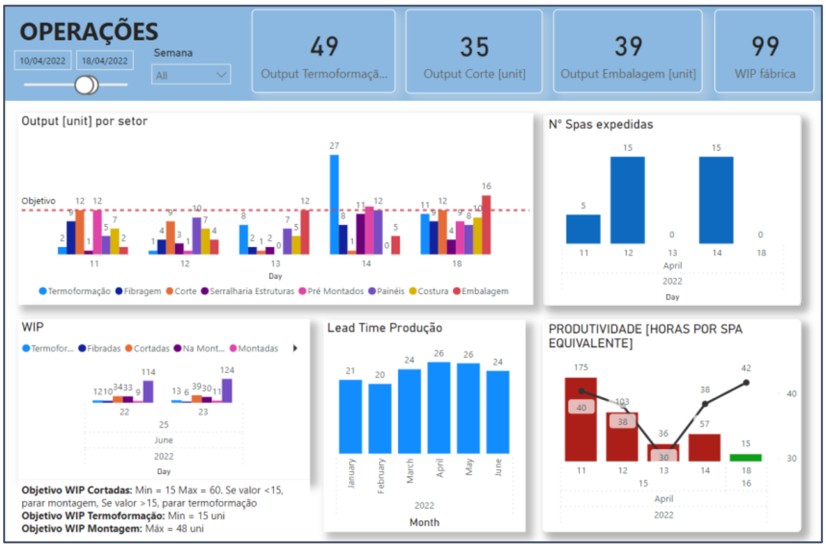

Figure 31 - Operations KPIs dashboard.

It was determined that the stockout analysis would be reviewed during the supervision meeting with the use of a two-column table (Figure 32) with the names of the materials and stock rupture on the left side and their expected arrival date on the right side. To avoid production halts in the midst of the value chain, discussing production planning and analysing the out-of-stock materials is advantageous. It was also established a reference will not be planned to produce if at least one of the materials present in the BOM is not in stock.

Figure 32 - Materials out of stock and expected arrival date.

For the meeting's final topic, an update to the action plan, As illustrated in Figure 33, a table with each column representing a weekday and each row indicating a member of the supervision was developed to note the tasks to be performed. In each cell of the table, the actions that each person had planned or that came out of this meeting would be written. The idea is that many of the actions that come out of the meetings are ways to fix the problems that identified. Because of the board, everyone on the team will know what everyone else's plans are. This table is also a good visual way to see how busy each team member is and when they will have more time to help others.

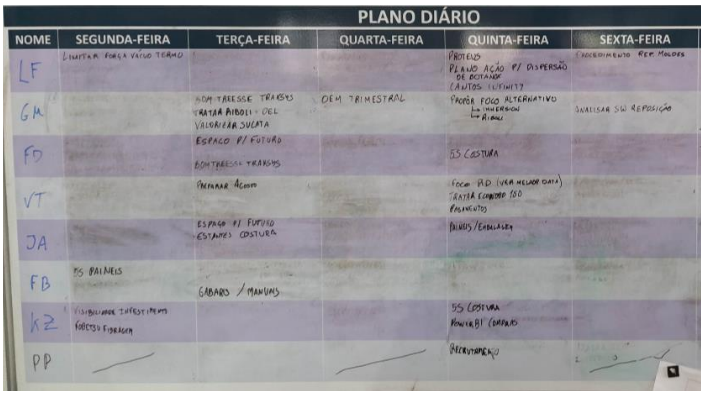

Figure 33 - Weekly actions plan.

Two key performance indicators (KPIs) were developed to track the status of ongoing and completed actions. The first indicator is the average lead time, in days, for each activity from the time it is planned to the time it is executed. The second indicator is the confidence level in the execution of the actions. Indicates the ratio of the number of closed actions to the total number of actions. During the 10 a.m. supervision meeting, the following dashboard (Figure 34) was used to monitor these indicators.

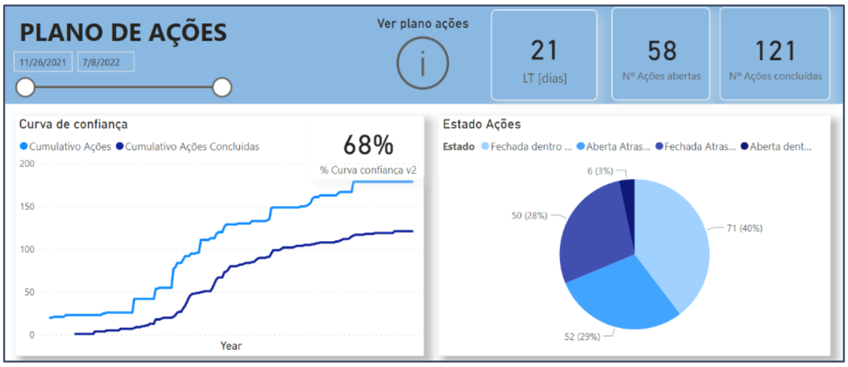

Figure 34 - Actions plan KPIs dashboard.

Although the meeting was scheduled to last 30 minutes, audits of actual sessions found that they lasted anywhere from 20 to 90 minutes. These discrepancies are unavoidably brought on by the fact that the issues that arose generated discussion and that the solutions created to tackle these issues were either more or less complex. In addition to the three topics mentioned, occasionally additional subjects also came up, such as significant announcements, client visits to the factory, audits and inspections, etc.

Later, a tool, which is a spreadsheet, was created to record the main problems detected in the factory with a possible impact on the output, to be filled in when analysing the operational KPIs, where the output of the various sectors is analysed. The data recorded in this tool visible in Appendix D, are, beyond the problem itself, the date of detection, the sector in which the problem was registered and the expected output impact for that same sector, with an additional field for recording possible additional observations. This tool makes it possible to predict, at the supervision meeting, the loss of output from each sector and the reason for this loss. Later, with a more robust database of recorded problems, it will be possible to analyse the data and understand which are the problems in the factory that most impact the production output. Because the tool was developed in the project's last phase and a sufficiently reliable database was not created, this analysis was not performed. However, this subject will be revisited in Chapter 5's subchapter on future work.

Another improvement idea that was used to make production problems clearer was to put sheets on the board of the 12 p.m. production meeting to record problems and breakdowns in each sector (meeting with the supervision team and leaders of each sector). The operations manager, who is in charge of the meeting, asks each sector leader about any problems that have come up in their sector since the meeting the day before. These problems are written down on these sheets (as shown in Figure 35), as well as the number of how many times each problem has been found. By doing this, it is possible to identify the issues that come up most frequently, which facilitates choosing the appropriate countermeasures.

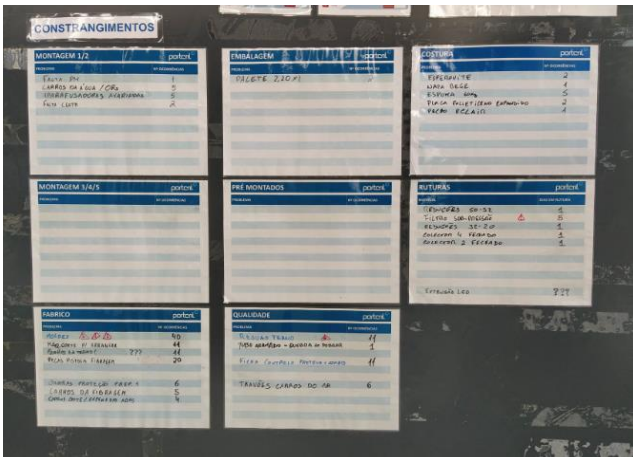

Figure 35 - Records of the sectors' problems in the production meeting board.

The last implemented improvement to give to the supervision team a better monitoring capacity of the factory was the Gemba Walks. Each of the supervisors has a different set of questions, depending on their department, to answer in an online form. There are specific questions for each department leader (operations, supply chain, quality, and maintenance). Gemba walks are typically conducted after 5 pm, when the majority of the factory has already stopped (only the second shift of fabrication is working).

Results

The indicators established for the action plan and the new structure of the supervisory team meeting contributed to more collaborative, communicative, and most importantly, effective problem-solving. Figure 36 shows the average lead time of the actions that developed during the project's oversight meeting; as can be observed, the execution time fell significantly. Also, the introduction of *gemba* walks contributed to the monitoring of existing production standards and the ongoing sustainability of implemented improvements.

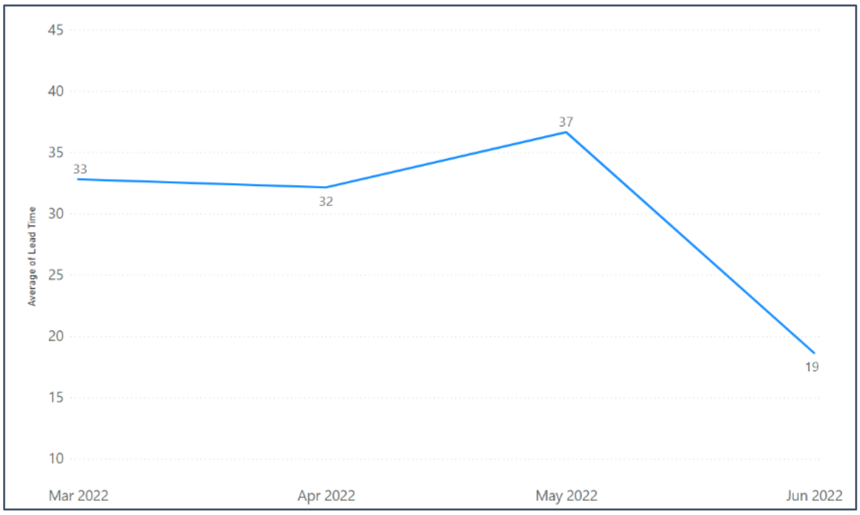

Figure 36 - Average of monthly lead time of finished actions.

4.1.4 Panels

The initial step was to assess the observations made (included in Appendix A), with an emphasis on removing the observed waste, which consisted mostly of operator movement to gather material and time spent on rework. The structured problem-solving method, Kobetsu, was followed.

After a detailed analysis of the initial situation of the panels sector, a study was conducted on the potential root causes for the problem of its assembly's excessive cycle time. The research employed the Ishikawa diagram, commonly known as a fishbone diagram. This method aims to identify the fundamental causes of problems by assessing six factors or parameters: people, environment, material, equipment, measurement, and work method. Diagrams are filled in the team sessions using data from the previous week observations. Figure 37 illustrates the diagram of the possible causes.

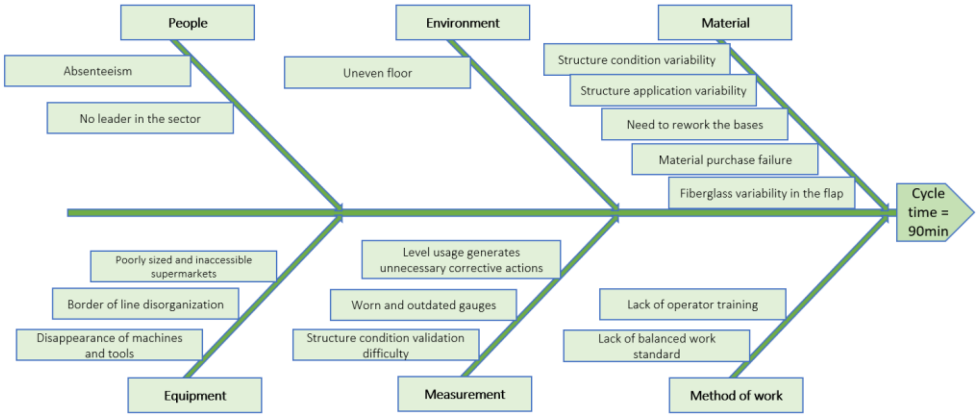

Figure 37 - Ishikawa diagram for the search of root causes of the panels problem

Two potential root causes were identified as opportunities for change that might be easily implemented as low-cost and high-impact project. They were “structure condition variability” (material category) and “lack of balanced standard work” (method of work category). For each of these causes, the proposed solution design, the tests that were carried out, and the solutions that were put into action in response to each of the challenges, will now be presented.

Issue 1 - structure condition variability

The issue of the poor conditions in which the wooden structures (in aluminium structures this issue does not exist) supplied by the carpentry (an external supplier) that make it difficult to assemble the panels correctly will be the first of the two problems to be approached. The panels are attached to the structure, and their top part fits between the spa flap and the structure. However, because of variations in the dimensions and in the structure alignment with the spa, the panels occasionally do not have enough space to fit in between them. Due to these poor conditions, reworks on the base flap and structure alignment are necessary, which might take more than an hour each spa.

The carpentry that supplies the wood structures to company A is external, but both companies are owned by the same owners. So, it was implemented a new process to validate the dimensions of assembled structures produced at the carpentry by checking the dimensions of the structures’ diagonals in its three planes (see Figure 38) used as templates. The warpages would also be examined with an aluminium bar.

Figure 38 - Example of a structure and the 3 planes to measure

It was decided that dimension validation would occur immediately following the wood structure assembly. The work standard (Figure 39), which was fixed on the wall adjacent to the assembly area of the structures, contains a table in which the operator notes the model of the built structure as well as the number of conforming structures and non-conforming structures. This provides a visual indication of which structures are regularly constructed with dimensional defects.

Figure 39 - Standard of Work of structures validation

Issue 2 - lack of balanced standard work

The solution was designed with the focus on decreasing cycle time by increasing material flow. Previously, operators worked in parallel and completed the entire process of building spa panels individually. Two stations were created in each line and the tasks of assembling the panels were divided so that both line operators can operate sequentially rather than in simultaneously. In addition, tasks such as the collection of insulation, panels, corners, and their precise cutting, which were previously performed by these operators, were transferred to the pre-panel sector. In total, three positions were defined to distribute these tasks, two in the assembly of the panels and one in the pre-panels.

The challenge of the approach was to decrease and externalise the work performed by the panel assembly operators. This was accomplished by implementing the first three steps of the SMED methodology. In this case, it is not a question of a changeover of a machine, but rather a desire to reduce the cycle time of panel assembly by externalising tasks. The first three steps of SMED correspond to:

1. Study of the initial situation;
2. Separate the internal operations and external operations;
3. Convert internal processes to external.

The first step had already been completed; all that remained was to distinguish internal from external work and externalise a part of the internal operations. Only those operations that directly involved the spa, such as cleaning the spa or assembling components in the spa, were considered internal for panel assembly. All material preparations are considered external operations. Consequently, the pre-panels sector was given responsibility for several duties (Table 3 will reveal which ones).

"Spa Preparation" and "Panels Assembly" were the names of the two workstations that were defined in panels sector. The operator who was in charge of getting the spa ready did all the tasks until the insulation fixing (including). The person who ran the assembly was in charge of assemble the panels and corners in the spa. In the pre-panels sector, the "Panels Production" workstation was set up, and cutting and transport panels were handed to this sector.

A Yamazumi chart, shown in Figure 40, was used to balance the three workstations' tasks. Based on two assumptions, the workstation for preparing the spa was bigger (80 minutes) than the one for putting together the panels (52 minutes). The first assumption is that reworking the structure won't be necessary or will take less time because the wooden structures are being tested and only those that pass the test will be put into production. The second assumption is that operators will help each other. This means that if there is a delay in this line, the operator who has already finished can take over the work of the operator who is running late, bringing the line back into balance. Lastly, the panel production station time value is smaller than the other two because it supports two lines at the same time, so the cycle time is almost twice as long as 30 minutes.

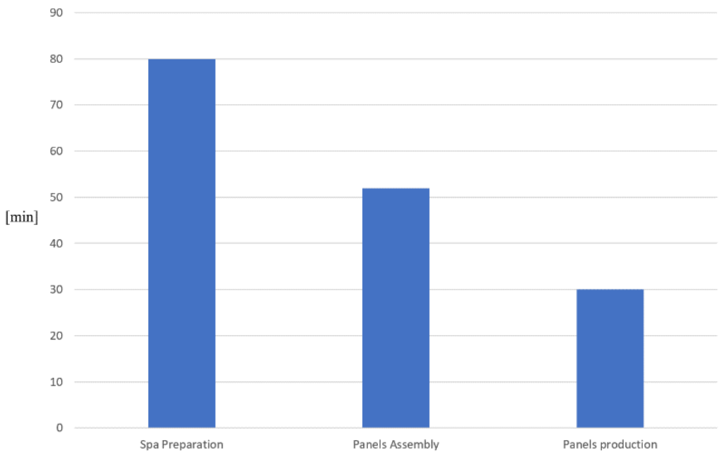

Figure 40 - Yamazumi chart for balance the tasks.

In addition to the already existing tasks documented when characterizing the initial situation, another task was created so that the designed balancing of the assembly could work. Previously, panel assembly operators measured exact dimensions at the spa to cut panels and corners that were already pre-cut to standard dimensions for each model. Now, the spa preparation operator takes a measurement on the card, visible in Figure 41, and hands it over to the panel manufacturing operator in the pre-panel sector so that he can cut them to the exact measurements needed.

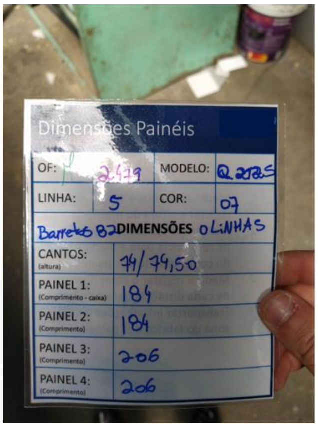

Figure 41 - Card to give the measurement information

The operator who produces the panels transports the cut panels and corners to the assembly area on a cart developed for this purpose, as displayed in Figure 42.

Figure 42 - Insulation, panels and corners transport carts

In conclusion, the balanced tasks were distributed across the three workstations as shown in Table 3:

No	Spa Preparation	Panels Assembly	Panels Production
1	Remove plastic film protection	Assemble the panels and the corners	Cut insulation, corners, and panels
2	Dimensions measurement and take the card to pre-panels	Fill in the OF paper	Sanding cutting edges of panels
3	Base flap cutting	Register spa in the daily output board	Prepare the corners to be attached to the panels.
4	Verify structure condition		Transport cart to the Panels sector
5	Structure rework		
6	Assemble insulation		

Table 3 - Balanced tasks of panels sector.

Results

The efforts to improve the bottleneck area also had positive results, as the cycle time in lines 1 and 5 of panel assembly decreased. Figure 43 shows how the output of the panels evolved over the period of the project. The supervision team considered the bottleneck fixed as the sector was able to make 12 spas per day under normal circumstances. Despite this, problems in this sector are now caused by a high rate of absenteeism and material breaks that make it hard for the sector to reach its goals in a steady way.

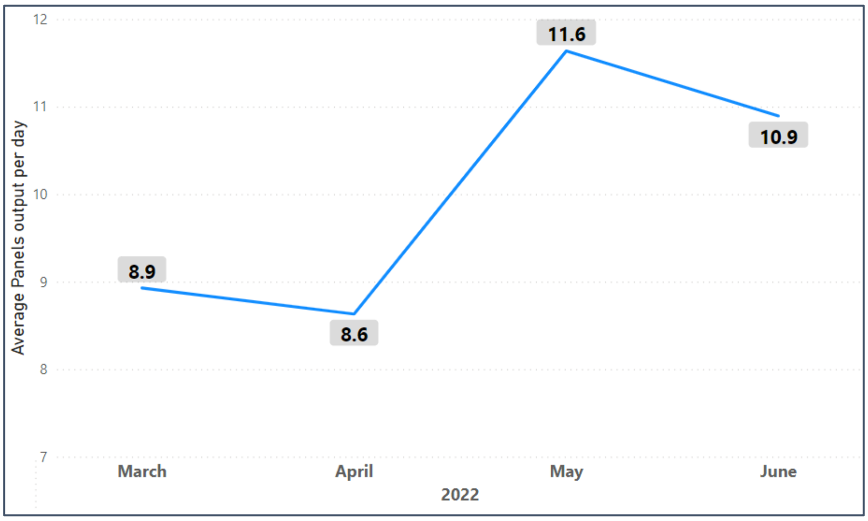

Figure 43 - Average of panels daily output per month.

4.1.5 Sewing

Although this sector was also a bottleneck in the plant, it was never considered to be as problematic as the panels sector because it did not involve production in the spa shell directly. However, spas without coverage are not shipped, and their sale is therefore not completed. Company A already had a big problem with cash flow, so it had to ship spas quickly and use the money to buy back out-of-stock materials. Therefore, they had to make more covers every day. By increasing the sales of spas and consequently the cash flow in a self-sustained rehabilitation process (without the use of external investments) is a lengthy process which target is attainable if the results are constant.

Covers are sold together with the spas produced but can also be sold separately, in after-sales services for covers that have been damaged by customers or even for spas whose customers did not order cover in advance. So, there is a chance to increase revenue by making more than 12 covers per day. As these items will be in demand and sold, they will not generate internal inventory. The cash flow issue could be reduced by making 14 or 16 covers per day. In short, the demand for coverage is greater than the demand for spas; hence, it was decided to increase production capacity to 16 coverages per day in this area.

This sector's low output was traced back to its root causes using the same method as the panel sector. Figure 44 depicts the Ishikawa diagram developed with the Company A supervisory team in response to the *gemba* observations.

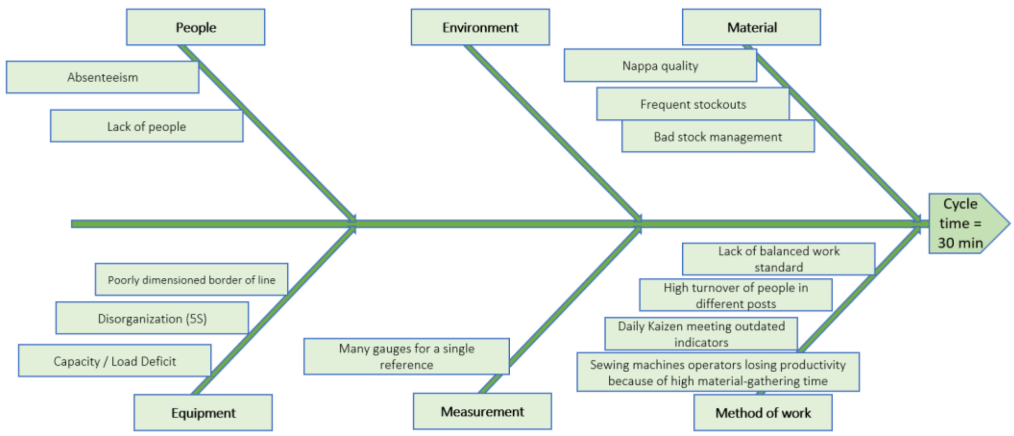

Figure 44 - Ishikawa diagram for the search of root causes of the sewing problem

Of the possible problems found, four of them were identified as root causes that make impossible the growth of the sewing's productive capacity to 16 covers per day as follows:

- High level of material-gathering movements done by machine operators;
- Lack of workers to match the 16-cover demand;
- Lack of balanced standard work;
- Area disorganizations;
- Poor stock management.

The excessive number of seamstress motions was the first of these constraints to be addressed. Since machine sewing is the sector's bottleneck, the usage of machines must be prioritised. As a result, two individuals were permanently assigned to the nappa cutting, with the responsibility of feeding the machines with materials so that operators did not have to get up to gather them.

The last problem (poor stock management) was the second to approach because it did not need a large or expensive intervention. The materials required to manufacture the cover were included in the bills of materials (BOMs) for the various spa references. This list already existed, but it was not digitized since the management of materials and inventory was handled by the sector leader; it was just necessary to provide this information to the corresponding BOMs. The materials were included in the consumptions and used by the previously developed MRP tool, where orders needs will be automatically calculated. Concerning the other issues, it was determined to tackle them simultaneously, as they would be interdependent in the event of more disruptive changes.

With a need for 78 Quartz covers every month, or 3.5 per day, it was at first considered necessary to dedicate a sewing line to this reference. Based on takt time, the required number of personnel for this line has been calculated as presented below. It should be noted that the total sewing time is 5h and the number of demanded covers per day was rounded from 3.5 covers per day to 4 covers per day so that trainee seamstresses can also reach their daily objectives. The number of people calculated was 3.

$$Occupation\ Hours = 5\ [h] * 4\ \left[\frac{units}{day}\right] = 20\ [\frac{h}{day}]$$

$$Workers/day = \frac{20\ [h/day]}{7\ [hours/worker]} = 2.85\ [workers/day]$$

It was also necessary to dimension another line to produce 12 covers of regular complexity, each of which requires a total sewing time of 2H30. With the previous line being dedicated to producing 4 covers every day, the total will be 16. The calculations are presented in the same manner below returning 4 necessary operators for this line.

$$Occupation\ Hours = 2.5\ [h] * 12\ \left[\frac{units}{day}\right] = 30\ [\frac{h}{day}]$$

$$Workers/day = \frac{30\ [h/day]}{7\ [hours/worker]} = 4.2\ [workers/day]$$

Using Yamazumi charts once more (which can be consulted in Appendix E), the supervision team and the leader of the sewing sector balanced the jobs for each of the two lines after this dimensioning of the number of workers for the sewing machines. This process was similar to the one used in the assembly of the panels.

It was realized that the Quartz dedicated line had many tasks in common with the regular complexity line, and that only one of the three workers on the Quartz dedicated line would be producing the parts that made the Quartz covers more complex than the others (these parts are called elevations). These parts are fully independent from the rest of the coverage during its manufacture and are only applied to the cover in the packaging process. The two additional line members would perform jobs that were identical to those on the regular complexity line. This analysis led to the realisation that these two machines might be losing potential productive capacity because they would be performing the same tasks but with more dimensioning slack time than the regular complexity line, which was dimensioned with a smaller time off.

Therefore, the previously drawn lines were reformulated, and six machines were assigned to a line that would do tasks of average difficulty with a workstation was created to produce elevations (with the objective of producing elevations for 4 covers per day). The line, then comprised of six individuals, would aim for 16 coverages per day. In addition to these seven machines, an extra workstation has been developed for the sector leader in sewing to dedicate to after-sales service (ASSs) and help in the event of unforeseen delays on the production line.

$$Occupation\ Hours = 2.5\ [h] * 16\ \left[\frac{units}{day}\right] = 40\ [\frac{h}{day}]$$

$$Workers/day = \frac{40\ [h/day]}{7\ [hours/worker]} = 5.7\ [workers/day]$$

Regarding the disorganisation of the sector, a rack for cut materials and a smaller one for consumables such as threads, zip fasteners, etc. were constructed in the carpentry. Due to the purchase of two machines, the packaging ran out of space to operate in this room. As a result, it was relocated to a room on the ground floor, next to where the styrofoam is cut, improving the flow so that the styrofoam does not have to be transported to this floor and then back down again. The final layout of the sewing sector is shown in Figure 45.

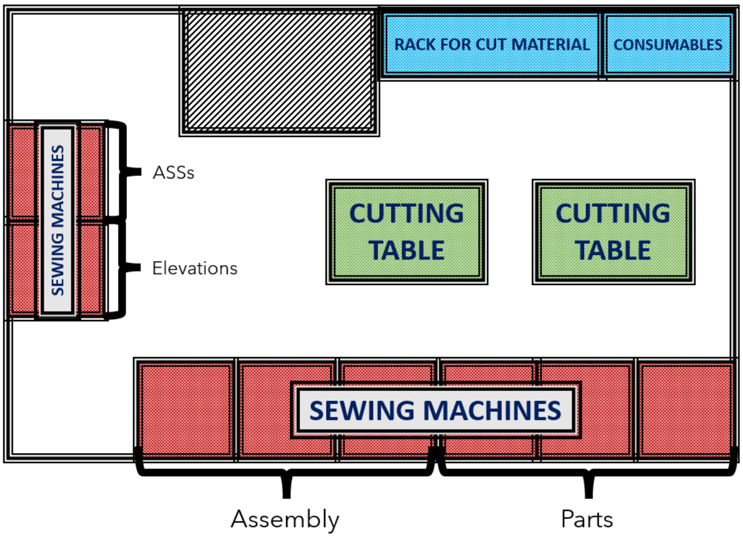

Figure 45 - Designed and implemented sewing sector layout.

Results

Positive results were also seen in the sewing sector of the project, though they were less stable than those seen in the panel sector because the proposed solution was only put into place a few weeks before the project ended. Now, audits and *gemba* walks will be used to keep a close eye on things and make sure that the line design and standards are being met. Figure 46 shows that the average output of the last month of the project was 55% than the baseline value that had been set before. However, it is now necessary to stabilise to guarantee a total increase of 100%, which has only been achieved on a few days so far.

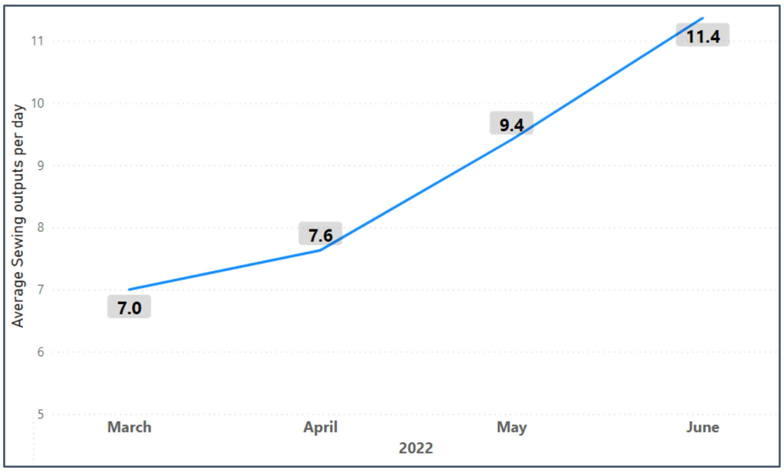

Figure 46 - Average of sewing daily output per month

4.2 Overall Results

The factory generally had positive benefits from the project, with the average output rising from 8.4 to 12 and projections indicating that the numbers will keep growing following the boost in demand. Packaging (located at the end of the assembly area and the factory's final sector) had increased in output, as shown by the graph in Figure 47.

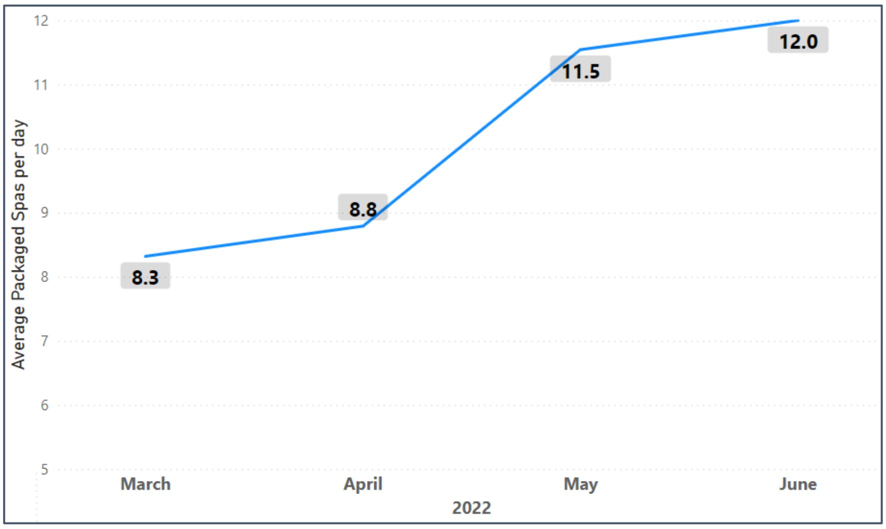

Figure 47 – Average of packaging daily output per month.

Overall, production gained more stability, reducing the number of highs and lows, being constant at a higher level. The general conclusions about the work and the project will now be addressed in the following chapter.

5 Conclusions and Future Work

This project developed within the scope of the Master's Dissertation had the main objective of increasing the productive capacity of company X. For this, several tools were used that helped to overcome arose constraints. Kaizen methodology was present in the various initiatives, following one of its most essential principles: the involvement of all people, in all areas and every day.

In all projects performed, the initial situations' characterization phases and the design and implementation of solutions and improvements were carried out collaboratively. In cooperation with teams from the various sectors where implementations were carried out, the supervision team participated in all actions. As mentioned in the discussion of results, redesigning the supervision meeting facilitated better collaboration in completing tasks. Also, when executing a project and some actions belonged to different people, they pushed each other to complete their tasks before the deadline.

Companies do not always accept changes in work culture and paradigms. Still, in this instance, the Company X team demonstrated a strong commitment, from the outset of the project to the proposed actions and initiatives, to the project's sustainability, and to the implementation of audits and *gemba* walks, which in many organizations fall out of use due to a lack of commitment, motivation, or because people do not see the value in the implemented improvements.

Noting that the factory's production capacity increases as stockouts reduce, even if they are not critical, underlines the concept that stability, regularity, and consistency are essential to the success of a factory and any business.

As explained at the beginning of this document, creating a production flow brings significant productivity and lead time gains. During this project, the production flow from the beginning of the factory, in thermoforming, to the end, in packaging, did not increase due to the growth of WIP and the presence of stockouts. However, the flow was created in sectors such as panel assembly and sewing, with the production capacity of these sectors increasing significantly and their lead time decreasing. Improvements in the flow of information were also implemented, such as the card to record the dimensions of the panels to be cut and the Power Apps developed.

The importance of working according to the takt time was also one of the project's central themes. Depending on whether the cycle time is shorter or longer than the takt time, failure to level the load of a production unit with the capacity at which it can sell to the customer can result in either the *muda* of overproduction, which generates stock accumulations, or sales losses as a result of not maximizing the production potential.

The implementations were facilitated by the fact that management recognized the initiatives' value and outcomes. In addition to being receptive to future improvement recommendations, they also desired to participate. It is anticipated that the Kaizen Institute will continue to provide advisory services to Company X following the completion of this project. In the following subchapter, we will discuss some prospective projects and future efforts to preserve and strengthen the previously completed initiatives.

5.1 Future Work

The developed improvements require post-implementation monitoring to guarantee that the efforts continue to be done. Changes should be preserved through audits. In this chapter, some potential areas for improved implementation will be discussed.

5.1.1 Future monitoring of implemented improvements

In this subchapter, we will discuss ways to enhance some of the efforts performed during the project. It is vital to have talks about the problems to develop improvement ideas and actions better. All of them can be continually improved if the resources are available.

Similar to the validation of the dimensions of the wooden structures implemented in the carpentry, a validation could be implemented in Company A's assembly lines, providing a double confirmation, increasing the level of confidence in the structures with the double validation, and decreasing rework time in the panels' sector.

The balancing performed in the panel sector was limited to two lines and might be expanded to the other lines in the future. It will be required to follow the same line design approach, determining the assembly demand for each line and allocating workers appropriately. One of the assembly lines has been stopped for the time being, but if output grows in the future, this line may reopen, and it will be necessary to scale the number of workers there, both in assembly and in the panels.

As for sewing, this will need to be regularly observed, as the target was not yet met after the experiment. A daily audit system is viable for ensuring that the layout and line design are followed. Even after the objectives have been achieved, audits must continue to be guaranteed that the implemented changes are sustainable.

5.1.2 Sustainable Growth

Company A hopes to achieve the factory's average daily output of 14 spas by the end of 2022. It turns out that to reach 14 spas each day, a progressive transition is required. Many of the earlier stockouts were caused by the rise in daily production from 8 to 12 spas, and the purchasing capacity did not increase as quickly as production capacity.

To successfully complete this transition, it is vital to obtain cash flow in a gradual and sustainable manner. To accomplish an instantaneous transition, an external funding request would be required.

The averages of production over the last few weeks were examined, and the reasons for the lack of basic stability were tried to find. The conclusion is that absenteeism greatly affected the results, along with stockouts, which hurt productivity and output. This is because when the human resources for each sector were dimensioned, a possible absenteeism factor or the employee's vacation factor were not considered.

A dimensioning of production's direct human resources was developed for when the factory achieves stability for a more extended period than now. This dimensioning considered the absenteeism rates of each sector, which were obtained from the human resources department, and the vacation absence rate. The absence rate for the assembly was 8 percent, and fabrication was 7, while the holiday absence rate was also 8 percent. These figures are extremely high; if we do not account for them, we will be short 16 percent of assembly personnel and 15 percent of fabrication personnel. Appendix F can be consulted to see the work already done.

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Appendix A – Panels Observations Report

MODO OPERATÓRIO PAINÉIS

Lista Tarefas					
No.	Operação	Duração	Tipo	E ou I	Posto Trabalho
1	Trazer SPA da zona de testes até zona de painéis	02:00	Muda	I	Preparar SPA
2	Trazer SPA da zona de testes até zona de painéis	02:00	Muda	I	Montar Painéis
3	Cortar aba da base	06:00	Muda	I	Preparar SPA
4	Lixar aba da base	03:00	Muda	I	Preparar SPA
5	Verificar estrutura com régua, nível e gabaris	05:00	Muda	I	Preparar SPA
6	Retrabalhar estrutra	30:00	Muda	I	Preparar SPA
7	Aplicar enchimento para fixação dos painéis	10:00	Muda	I	Preparar SPA
8	Limpeza com pistola de ar comprimido	03:00	Muda	I	Preparar SPA
9	Pintar zonas de retrabalho e zonas sem tinta (madeira)	04:19	Muda	NA	Preparar SPA
10	Recolher e cortar isolamento	07:24	Muda	E	Fazer Painéis
11	Colocar isolamento	10:00	VA	I	Preparar SPA
12	Transportar SPA e trazer seguinte para o posto	02:00	Muda	I	Montar Painéis
13	Transportar SPA e trazer seguinte para o posto	02:00	Muda	I	Preparar SPA
14	Recolher cantos	03:00	Muda	E	Fazer Painéis
15	Recolher bites	01:45	Muda	E	Fazer Painéis
16	Medir cantos	01:06	Muda	E	Preparar SPA
17	Medir bites	01:06	Muda	E	Preparar SPA
18	Cortar cantos	03:33	Muda	E	Fazer Painéis
19	Cortar bites	01:30	Muda	E	Fazer Painéis
20	Montar cantos	11:00	VA	I	Montar Painéis
21	Medir distância para painel	00:30	Muda	I	Preparar SPA
22	Cortar e recolher painel	02:00	Muda	E	Fazer Painéis
23	Lixar zona de corte do painel	01:00	Muda	E	Fazer Painéis
24	Retirar cola painéis	01:00	Muda	E	Fazer Painéis
25	Fazer montagem dos bites nos cantos (algumas referencias)	02:36	Muda	E	Fazer Painéis
26	Montar painel	00:48	VA	I	Montar Painéis
27	Furar painel	01:01	VA	I	Montar Painéis
28	Aparafusar painel	02:22	VA	I	Montar Painéis
29	Medir distância para painel	00:30	Muda	I	Preparar SPA
30	Cortar e recolher painel	02:00	Muda	E	Fazer Painéis
31	Lixar zona de corte do painel	01:00	Muda	E	Fazer Painéis
32	Retirar cola painéis	01:00	Muda	E	Fazer Painéis
33	Fazer montagem dos bites nos cantos (algumas referencias)	02:36	Muda	E	Fazer Painéis
34	Montar painel	00:48	VA	I	Montar Painéis
35	Furar painel	01:01	VA	I	Montar Painéis
36	Aparafusar painel	02:22	VA	I	Montar Painéis

37	Medir distância para painel	00:30	Muda	I	Preparar SPA
38	Cortar e recolher painel	02:00	Muda	E	Fazer Painéis
39	Lixar zona de corte do painel	01:00	Muda	E	Fazer Painéis
40	Retirar cola painéis	01:00	Muda	E	Fazer Painéis
41	Fazer montagem dos bites nos cantos (algumas referencias)	02:36	Muda	E	Fazer Painéis
42	Montar painel	00:48	VA	I	Montar Painéis
43	Furar painel	01:01	VA	I	Montar Painéis
44	Aparafusar painel	02:22	VA	I	Montar Painéis
45	Medir distância para painel	00:30	Muda	I	Preparar SPA
46	Cortar e recolher painel	02:00	Muda	E	Fazer Painéis
47	Lixar zona de corte do painel	01:00	Muda	E	Fazer Painéis
48	Retirar cola painéis	01:00	Muda	E	Fazer Painéis
49	Fazer montagem dos bites nos cantos (algumas referencias)	02:36	Muda	E	Fazer Painéis
50	Montar painel	00:48	VA	I	Montar Painéis
51	Furar painel	01:01	VA	I	Montar Painéis
52	Aparafusar painel	02:22	VA	I	Montar Painéis
53	Retirar 1 painel	00:49	Muda	I	Montar Painéis
54	Preencher papel da OF	01:40	Muda	E	Montar Painéis
55	Registar a SPA no quadro de output diário	00:20	Muda	E	Montar Painéis
56	Cortar e recolher barrotes	01:50	Muda	E	Montar Painéis
57	Furar barrotes	02:00	Muda	E	Montar Painéis
58	Aparafusar barrotes na SPA	02:00	Muda	I	Montar Painéis
59	Transportar SPA e trazer seguinte para o posto	01:30	Muda	I	Fazer Painéis
60	Transportar SPA e trazer seguinte para o posto	01:30	Muda	I	Montar Painéis

Appendix B – Sewing Obsertvaions Report

Sewing Machines

MODO OPERATÓRIO COSTURA				
Lista Tarefas				
No.	Ação	Operação	Duração	Posto Trabalho
		Fazer Tiras de União	00:08:00	1
		Fazer Faixas laterais	00:21:00	2
		Fazer zona do fecho	00:12:00	3
		Fazer Folhos	00:14:00	1
		Coser Fecho à zona do fecho	00:10:00	3
		Colocar etiqueta e chave nos fechos tuc	00:01:00	2
		Tranportar material para a mesa	00:03:00	
		Coser Tira de União	00:02:00	
		Fazer Tampo 1	00:32:00	
		Fazer Tampo 2	00:32:00	
		Unir tampos	00:05:00	
Total			**02:20:00**	

Styrofoam

MODO OPERATÓRIO COSTURA									
Lista Tarefas									
No.	Ação	Operação	T inici	Duraçã	Tipo	I/E	Posto Trabalho	Notas (Ferramenta, etc..)	Type of
	Fazer Placa de Esferovite	Recolher placas	00:00:00	00:02:16	Muda		Esferovite	E5	
	Fazer Placa de Esferovite	Recolher cunhas	00:02:16	00:01:09	Muda		Esferovite	No caso de as placas serem mais curtas do que a cobertura. (placas têm apenas 2 m de largura)	
		Aplicar Cola na lateral	00:03:25	00:01:35	VA		Esferovite	E5	
		Colar cunhas nas laterais	00:05:00	00:02:00	VA		Esferovite	E5	
		Lixar zona de colagem	00:07:00	00:02:50	VA		Esferovite	E5	
		Recolher placas	00:09:50	00:01:54	Muda		Esferovite	E5	
		Recolher cunhas	00:11:44	00:01:16	Muda		Esferovite	E5	
		Aplicar Cola na lateral	00:13:00	00:01:00	VA		Esferovite	E5	
		Colar cunhas nas laterais	00:14:00	00:02:00	VA		Esferovite	E5	
		Lixar zona de colagem	00:16:00	00:02:00	VA		Esferovite	E5	
		Recolher placas	00:18:00	00:02:50	Muda		Esferovite	AM6 - um dos modelos mais demorados	
		Colar cunhas, lixar, recortar largura	00:20:50	00:17:40	VA		Esferovite	AM6 - um dos modelos mais demorados	
			00:38:30					AM6 - um dos modelos mais demorados	
		Colocar calhas nas 5 esferovites		00:25:00	VA			AM6 - um dos modelos mais demorados	
		Transportar 5 esferovite		00:07:30	Muda			AM6 - um dos modelos mais demorados	

Packaging

MODO OPERATÓRIO COSTURA

Lista Tarefas

No.	Operação	Duração	Tipo	Posto Trabalho	Notas (Ferramenta, etc..)
1	Plastificação do esferovite	00:07:30	VA	Embalagem	
2	Perguntar a Sónia que cobertura embalar	00:00:30	Muda	Embalagem	AM6
3	Reorganizar coberturas já feitas para retirar a que está por baixo	00:01:00	Muda	Embalagem	
4	Recolher isolamento esferovite	00:01:00	Muda	Embalagem	Mais uma vez necessitaram de reorganizar o espaço onde estava o esferovite para retirar o isolamento da AM6 que não estava acessível
5	Colocar isolamento 1 na cobertura e fechar o fecho	00:03:00	VA	Embalagem	
6	Colocar isolamento 2 na cobertura e fechar o fecho	00:03:00	VA	Embalagem	
7	Preencher Folha de Qualidade	00:01:30	Muda	Embalagem	
8	Ajeitar e assentar cobertura	00:04:00	VA	6	
9	Efetuar medições e registar no caderno	00:01:30	Muda	Embalagem	
10	Conferir medidas limite da cobertura (máx desvio = 2 cm)	00:00:30	Muda	Embalagem	
11	Mover cobertura para suporte de cavaletes	00:00:15	Muda	Embalagem	
12	Colocar plástico proteção bolha sobre a mesa e cobertura sobre o plástico	00:01:00	VA	Embalagem	
13	Fechar plástico proteção	00:00:30	VA	Embalagem	
14	Selar com fita-cola	00:01:30	VA	Embalagem	
15	Colar etiqueta com info da cobertura	00:00:30	VA	Embalagem	
16	Colocar filme aderente	00:04:00	VA	Embalagem	
17	Colocar cobertura no buffer output	00:00:45	Muda	Embalagem	

Cutting

MODO OPERATÓRIO COSTURA

Lista Tarefas

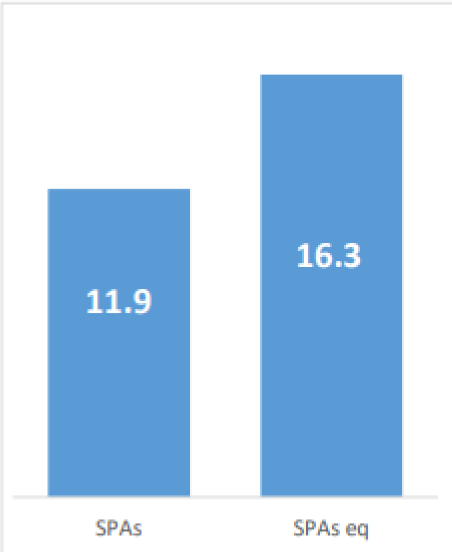
I	Ação	Operação	Duração	Posto Trabalho	Notas (Ferramenta, etc..)
	Corte	Desenrolar rolo para cima da mesa e fixar 5/6 vezes	00:05:00	1	Cortam-se aos lotes de 6 para ser mais rápido.
	Corte	Marcar Linhas de Corte	00:05:00	1	
	Corte	Cortar Tampos e peças + pequenas	00:05:00	1	
	Corte	Marcar Pontos de Costura	00:05:00	1	
	Corte	Com sobras de pano fazer mais peças pequenas	00:05:00	1	
	Corte	Ajudar as colegas a movimentar as coberturas	00:10:00		

Appendix C – Sewing Load Capacity Analysis

OF Nº	Modelo	Cliente	Código	Data Prevista	Spas equivalentes
21/1850	Double 520 Deluxe 2.0	Balness	DB5206	23/05/2022	1
21/1257	Emotion 5	Kersyal	EM5101	23/05/2022	1
21/1260	Sense S (Double 320 Eco)	Kersyal	DB3201	23/05/2022	1
21/1579	Prestige 2	Mondial	MON203	23/05/2022	1
21/2627	Torino Luxe	Riboli	GRS501	23/05/2022	1
21/2628	Torino Luxe	Riboli	GRS501	23/05/2022	1
21/2629	Torino Luxe	Riboli	GRS501	23/05/2022	1
21/2630	Torino Luxe	Riboli	GRS501	23/05/2022	1
21/1436	Emotion 5.2 (Premium 520/EVO260)	DEL	EM5205	24/05/2022	1
21/2293	Emotion 5.2 (Premium 520/EVO260)	DEL	EM5205	24/05/2022	1
21/2294	Emotion 5.2 (Premium 520/EVO260)	DEL	EM5205	24/05/2022	1
21/2295	Emotion 5.2 (Premium 520/EVO260)	DEL	EM5205	24/05/2022	1
21/2296	Emotion 5.2 (Premium 520/EVO260)	DEL	EM5205	24/05/2022	1
21/2297	Emotion 5.2 (Premium 520/EVO260)	DEL	EM5205	24/05/2022	1
21/2299	Emotion 6 (Premium610/EVO 160)	DEL	EM6105	24/05/2022	1
21/2300	Emotion 6 (Premium610/EVO 160)	DEL	EM6105	24/05/2022	1
21/2351	Emotion 5.2 (Premium 520/EVO260)	DEL	EM5205	24/05/2022	1
21/2352	Emotion 5.2 (Premium 520/EVO260)	DEL	EM5205	24/05/2022	1
21/2353	Emotion 5.2 (Premium 520/EVO260)	DEL	EM5205	24/05/2022	1
21/2354	Emotion 5.2 (Premium 520/EVO260)	DEL	EM5205	24/05/2022	1
21/1739	Sense L (Double 620 Eco)	Ecocompósitos	DB6201	25/05/2022	1
21/1740	Sense L (Double 620 Eco)	Ecocompósitos	DB6201	25/05/2022	1
21/1741	Sense L (Double 620 Eco)	Ecocompósitos	DB6201	25/05/2022	1
21/2556	Sense M (Double 520 Eco)	KERSYAL	DB5201	25/05/2022	1
21/2513	Double 320 Deluxe 2.0	SARL NST ENVIRONNEMENT	DB3206	25/05/2022	1
21/0810	Emotion 5.2	Aqua Vita	EM5201	26/05/2022	1
21/2310	EMOTION 5	Aquilus	EM5103	26/05/2022	1
21/2720	Roma Luxe	Riboli	GRS602	26/05/2022	1
21/2375	Lounge Concept III Design	Blue & Green SRL	LC3001	26/05/2022	5
21/2374	Lounge Concept III Design	Blue & Green SRL	LC3001	26/05/2022	5
21/2487	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2488	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2489	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2490	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2491	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2492	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2493	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2494	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2495	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2496	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2497	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2498	Quarz 212 Slim	GRUPPO TREESSE	TRE103	27/05/2022	2.21
21/2499	Quarz 212 Slim TOP	GRUPPO TREESSE	TRE104	27/05/2022	2.21
21/2065	Lux (Velvet)	Balness	LUX002	28/05/2022	3
21/2066	Lux (Velvet)	Balness	LUX002	28/05/2022	3
21/2070	Lux (Velvet)	Balness	LUX002	28/05/2022	3
21/2265	Lux (Velvet)	BALNESS	LUX002	28/05/2022	3
21/2064	Lux (Velvet)	Balness	LUX002	28/05/2022	3
21/2067	Lux (Velvet)	Balness	LUX002	28/05/2022	3
21/2619	Torino Luxe	Riboli	GRS501	30/05/2022	1
21/2620	Torino Luxe	Riboli	GRS501	30/05/2022	1
21/2621	Torino Luxe	Riboli	GRS501	30/05/2022	1
21/2622	Torino Luxe	Riboli	GRS501	30/05/2022	1
21/2623	Torino Luxe	Riboli	GRS501	30/05/2022	1
21/2624	Torino Luxe	Riboli	GRS501	30/05/2022	1
21/2625	Torino Luxe	Riboli	GRS501	30/05/2022	1
21/2626	Torino Luxe	Riboli	GRS501	30/05/2022	1
21/2632	Roma	Riboli	GRS301	30/05/2022	1
21/2634	Roma	Riboli	GRS301	30/05/2022	1
21/2392	Power 12 iTech	SAS SUD OUES	SW1204	30/05/2022	2
21/1629	Power 15 iTech	SudOuest	SW1504	30/05/2022	2
21/1631	Power 15 iTech	SudOuest	SW1504	30/05/2022	2
21/1950	Double 620 Deluxe	Java Group	DB6203	31/05/2022	1
21/1275	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1276	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1277	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1278	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1279	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1280	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1281	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1282	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1283	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1284	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1285	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1286	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1
21/1287	Zeta 2.0 (NV 130)	Zyke	ZT2002	31/05/2022	1

21/2500	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2501	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2502	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2503	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2504	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2505	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2506	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2507	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2508	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2509	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2510	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2511	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/2512	Quarz 212 Slim	GRUPPO TREESSE	TRE103	31/05/2022	2.21
21/0667	Emotion 5	Le Nid La Coccinelles	EM5101	31/05/2022	1
21/2284	Emotion 5	BALNESPA TECH	EM5101	31/05/2022	1
21/2077	Lounge Concept III Supreme	Balness	LC3002	31/05/2022	5
21/1830	Emotion 3	Etablissements Dorn	EM3101	31/05/2022	1
21/1831	Emotion 3	Etablissements Dorn	EM3101	31/05/2022	1
21/1832	Emotion 3	Etablissements Dorn	EM3101	31/05/2022	1
21/1833	Emotion 3	Etablissements Dorn	EM3101	31/05/2022	1
21/1834	Emotion 3	Etablissements Dorn	EM3101	31/05/2022	1
21/1835	Emotion 5.2	Etablissements Dorn	EM5201	31/05/2022	1
21/1836	Emotion 5.2	Etablissements Dorn	EM5201	31/05/2022	1
21/1837	Emotion 5.2	Etablissements Dorn	EM5201	31/05/2022	1
21/1838	Emotion 5.2	Etablissements Dorn	EM5201	31/05/2022	1
21/1839	Emotion 5.2	Etablissements Dorn	EM5201	31/05/2022	1
21/1840	Emotion 5.2	Etablissements Dorn	EM5201	31/05/2022	1
21/1841	Emotion 5.2	Etablissements Dorn	EM5201	31/05/2022	1
21/2263	Power 15 iTech	AQUADETENTE	SW1504	31/05/2022	2
21/2665	Quarz 212 Basic	Treesse	TRE101	31/05/2022	2.21
21/2666	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2667	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2668	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2669	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2670	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2671	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2672	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2673	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2674	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2675	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2676	Quarz 212 Slim	Treesse	TRE103	31/05/2022	2.21
21/2677	Quarz 212 SlimTop	Treesse	TRE104	31/05/2022	2.21
21/1923	Double 620 Deluxe	Balness	DB6203	31/05/2022	1

Total SPAS	Equivalentes	Carga/Dia		Carga/Dia
119	194.19	11.9	SPAs	11.9
		16.318487	SPAs eq	16.318487



Appendix D - Problems Report Tool

Constrangimentos na Produção

Data	Setor	Problema	Impacto de Output Estimado	Observações
27/06/2022	Termoformação	snível Pinças	2	Sucata
27/06/2022	Termoformação	Muitas Trocas de Moldes	4	
27/06/2022	Corte	Colocar Depósitos no telhado	6	
27/06/2022	Fibragem	Falta 2 Pessoas	6	
20/06/2022	Termoformação	Bomba de Vácuo avariada		Não é possível tirar SW nem SPAs de moldes que tenham fugas
28/06/2022	Embalagem	Falta de Paletes	2	
28/06/2022	Fibragem	Falta 1 Pessoas	4	

Appendix E - Sewing Yamazumi Charts

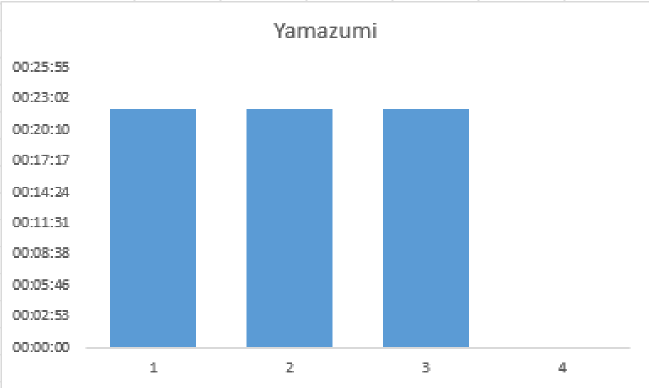
MODO OPERATÓRIO COSTURA

Lista Tarefas

No.	Ação	Operação	Duração	Posto Trabalho	Notas (Ferramenta, etc..)
		Fazer Tiras de União	00:08:00	1	
		Fazer Faixas laterais	00:21:00	2	Fazer faixas 8min + fazer as pegas ???min + fechos tuc aqui contabilizados
		Fazer zona do fecho	00:12:00	3	
		Fazer Folhos	00:14:00	1	e fechos tuck
		Coser Fecho à zona do fecho	00:10:00	3	
		Colocar etiqueta e chave nos fechos tuc	00:01:00	2	
		Tranportar material para a mesa	00:03:00		
		Coser Tira de União	00:02:00		
		Fazer Tampo 1	00:32:00		
		Fazer Tampo 2	00:32:00		
		Unir tampos	00:05:00		
Total			**02:20:00**		

Tempo de abertura (Horas/Dia)	Procura (Unidades / Dia)	Takt time (minutos)	Takt time (hh/mm/ss)	Tempo total de 1 unidade (minutos)	Nº de pessoas calculado	Nº de pessoas
7.5	12	37.5	00:37:00	140	3.73	4

Posto	Tempo
1	00:22:00
2	00:22:00
3	00:22:00
4	00:00:00



Appendix F – Human Resources Dimensioning – 14 daily spas

PLANO DIMENSIONAMENTO FÁBRICA

Objetivo output	14
Tx Absentismo Escritório	0%
Tx Absentismo Montagem	8%
Tx Absentismo Fabrico	7%
Tx Absentismo Costura	4%
Tx Absentismo Logistica	3%
Férias	8%

	Line Des	Necessida	Atua	Contra	Novos ou IE
Moldes	2	2.4	2	0	
Termoformação	4	4.7	4	1	IEFP
Preparação	2	2.4	2	1	IEFP
Fibragem	7	8.2	5	3	Novos
PU	1	1.2	1	0	
Pintura	2	2.4	1	1	Novos
Corte	6	7.1	6	1	IEFP
Serralharia	5	5.9	5	1	IEFP
Pré Montados	3	3.6	3	0	
Linha 1	9	10.7	10	1	IEFP
Linha 2	0	0.0	0	0	
Linha 3	4	4.8	2	3	IEFP
Linha 4	9	10.7	7	4	Novos
Linha 5	9	10.7	6	5	Novos
Preparação Paineis	4	4.8	4	1	IEFP
Embalagem	4	4.8	4	1	IEFP

Costura	11	12.5	9	3	Novos
Logística Interna	9	10.1	7	2	IEFP
Qualidade	6	6.5	6	1	Novos
Manutenção	4	4.3	3	1	Novos

Total Fabrico	29	34.1	26	8
Total Montagem	42	50	36	15

Total Fábrica	101	117.6	87	30