Creation of a Production Flow in the Mold Industry

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Master's Dissertation

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Abstract

This thesis addresses the implementation of Lean Manufacturing and Kaizen techniques in the plastic injection mold industry, aiming to improve operational efficiency and process quality at Company X. The project was motivated by the increasing demands of the automotive and consumer goods markets, which require more agile and adaptable production systems. The project was carried out in the group's first factory, which is critical in shaping the company's strategic direction and operational capabilities.

The project was divided into four main phases: initial diagnosis, solution design, implementation, and evaluation. The initial analysis identified significant issues such as prolonged lead times, high variability in production quality, and inefficiencies in resource utilization. Based on these findings, solutions were developed and implemented, including production planning, self-inspection, and the introduction of quality control interfaces using Power BI.

The results indicate significant reductions in setup time and the number of recorded non-conformities late in the process. The SMED workshop implementation resulted in a 51% reduction in setup time, while self-inspection practices contributed to a 30% decrease in non-conformities detected in the benchwork sector. Overall operational performance also improved, frequently exceeding 80%.

The project also emphasized the importance of fostering a culture of continuous improvement among employees. By engaging workers in Daily Kaizen activities and providing them with the tools and training needed to identify and address inefficiencies, the company was able to sustain and build upon the initial improvements. This collaborative approach not only enhanced the operational processes but also empowered the workforce, leading to increased job satisfaction and a more proactive approach to problem-solving. The successful application of Lean and Kaizen methodologies in this project underscores their potential to drive significant improvements in both efficiency and quality within the manufacturing industry.

Keywords: Lean Manufacturing, Kaizen, Plastic Injection Mold Industry, SMED, Self-Inspection, Continuous Improvement, Operational Efficiency, Production Planning, Quality Control, Power BI, Non-conformities

Resumo

Esta tese aborda a implementação de técnicas de Lean Manufacturing e Kaizen na indústria de moldes de injeção plástica, com o objetivo de melhorar a Eficiência Operacional e a Qualidade na Empresa X. O projeto foi motivado pela crescente procura do mercado automóvel e de bens de consumo, que exigem sistemas de produção mais ágeis e adaptáveis. O projeto foi realizado na primeira fábrica do grupo, crítica para a definição da direção estratégica e capacidades operacionais da empresa.

O projeto foi dividido em quatro fases principais: diagnóstico inicial, design de soluções, implementação e avaliação. A análise inicial identificou problemas significativos, como longos tempos de espera, alta variabilidade na qualidade da produção e ineficiências na utilização de recursos. Com base nessas descobertas, foram desenvolvidas e implementadas soluções, incluindo o planeamento da produção, auto-controlo dos moldes e a introdução de interfaces de controlo de qualidade utilizando Power BI.

Os resultados indicam reduções significativas no tempo de setup e no número de não-conformidades registadas nos ultimos setores do processo. A implementação do workshop SMED resultou em uma redução de 51% no tempo de setup, enquanto as práticas de auto-controlo contribuíram para uma diminuição de 30% nas não-conformidades detectadas na bancada de trabalho. O rendimento operacional geral também melhorou, frequentemente excedendo 80

O projeto também enfatizou a importância de fomentar uma cultura de melhoria contínua entre os funcionários. Ao envolver os trabalhadores em atividades diárias de Kaizen e fornecer-lhes as ferramentas e o treino necessários para identificar e resolver ineficiências, a empresa conseguiu sustentar e expandir as melhorias iniciais.

Palavras-Chave: Lean Manufacturing, Kaizen, Indústria de Moldes de Injeção Plástica, SMED, Auto-controlo, Melhoria Contínua, Rendimento Operacional, Planeamento de Produção, Controlo de Qualidade, Power BI, Não-conformidades

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Thank you all.

"Out of clutter, find Simplicity. From discord, find Harmony. In the middle of difficulty lies Opportunity."

Albert Einstein

Contents

Acronyms and Symbols

5S	Sort, Set in order, Shine, Standardize, Sustain
AQM	Auto-Quality Matrix
BOM	Bill Of Materials
BOP	Bill of Process
CAM	Computer-Aided Manufacturing
DT	Technical Department
FIFO	First In, First Out
JIT	Just-In-Time
KBS	Kaizen Business System
KPI	Key Performance Indicator
NC	Non-Conformities
PDCA	Plan-Do-Check-Act
PMLs	Postiços, Movimentos, and Levantadores
SMED	Single-Minute Exchange of Dies
TFM	Total Flow Management
TPS	Toyota Production System

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Chapter 1

Introduction

This dissertation project describes the implementation of disruptive improvements in the mold manufacturing industry, as a result of the agreement between Company X and Kaizen Institute (KI).

The mold manufacturing industry, closely intertwined with automotive production, presents its own set of complex challenges. In this sector, inefficiencies are often readily apparent, yet quantifying these inefficiencies can be particularly challenging due to the intricate nature of mold design and production.

Unlike simpler manufacturing processes, mold production for automotive components is affected by a wide range of factors including precision engineering requirements, material variability, and rapid technological advancements. In the precision-demanding environments of mold production facilities, inefficiencies can drastically escalate costs and affect the quality of the final products.

1.1 Project Framework and Motivation

In an era marked by rapid technological advancements and increasing global competition, mold manufacturing companies face continuous pressures to enhance operational efficiency, reduce costs, and improve product quality. Company X, one of Europe's largest manufacturer of plastic molds, is no exception. Situated in an industry characterized by stringent deadlines and precision, the need to optimize manufacturing processes becomes not only advantageous but essential. The company's commitment to maintaining its market leadership and meeting customer expectations requires continuous process improvement and waste reduction.

Based on recent industry analysis, the mold manufacturing sector is grappling with several pressing challenges that impact its competitiveness and efficiency. Key issues include pervasive skilled labor shortages and the increasing need for technological integration. Furthermore, the automotive and consumer goods industries, which are major clients for Company X, are constantly evolving and require more agile and adaptable manufacturing systems. This context highlights the importance of streamlining operations and enhancing flexibility in production lines through efficient methodologies.

The project was carried out in the first factory opened by the group, a unit critical in shaping the company's strategic direction and operational capabilities. The main focus has been on improving the value stream processes, which includes identifying bottlenecks, eliminating non-value-added activities, and ensuring that the final product meets the high standards expected by clients.

By incorporating the principles of Lean Manufacturing and Kaizen, the thesis seeks to tackle the challenges at hand. Through a thorough Value Stream Analysis, critical areas such as lead time reduction, process standardization, and quality improvement are targeted. These improvements are not only essential for cost containment but also for enhancing client satisfaction and retention, ensuring that the company maintains its position as a leader in the mold manufacturing industry.

The project timing couldn't be better with recent shifts in market demands and new regulations introduced in the plastics industry. Top manufacturers must act fast and effectively in response to these changes. By streamlining the shop floor workflow, this project directly supports the company's strategic objectives of improving efficiency and staying competitive in a demanding market.

1.2 Project Description

The group, established in 1959 in Portugal, has risen to prominence as Europe's largest producer of plastic injection molds, primarily serving the automotive industry. Its commitment to innovation and quality has positioned it as a critical supplier for major automobile manufacturers globally.

Company X was the first company in the group created to produce molds for plastic toys. The company has a total area of 15,725 m² of land, with a covered area of 12,200 m², of which 7,500 m² are allocated to the production. Currently, the main business area is the production of molds for the automotive sector, such as door panels, glove boxes and grids.

Over the years, Company X has achieved a leading position in the market and now asserts itself as one of the world leaders, with the heaviest molds produced in the company weighing 25 tons. In Figure 1.1, the parts that are produced with molds manufactured at Company X are represented.

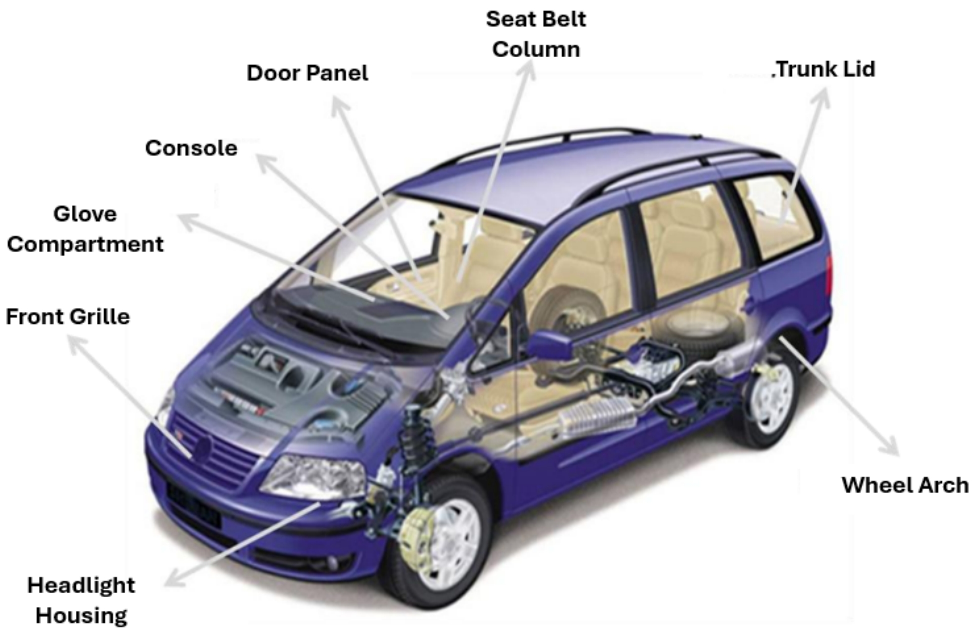


Figure 1.1: Molds produced in Company X allow series production of these plastic components.

The project described in this thesis was conducted within various departments of the company, to analyze and optimize the end-to-end process flows and enhance interdepartmental collaboration, As the automotive industry progresses, driven by technological advancements and stricter environmental regulations, Company X is facing increasing pressure to adapt its processes to meet the more rigorous requirements for precision and efficiency. In recent years, the company has identified significant operational challenges that have hindered its ability to effectively respond to these market changes. These challenges include prolonged lead times, high variability in production quality, and inefficiencies in resource utilization, which have been particularly pronounced in the tool design and fabrication stages.

The genesis of this project was rooted in the urgent need to address these operational inefficiencies. Specific problems identified included difficulty in filtering relevant budgets, low "First-Time-Right" in the first test (T1), lack of production flow and internal logistics, lack of planning, and negative sales margins. These issues not only increased operational costs but also extended the time-to-market for new molds, impacting the company's competitiveness in a fast-paced industry.

The outcome of this project is anticipated to not only improve operational efficiencies but also to contribute to Company X´s sustainability initiatives by reducing waste and optimizing resource use. This aligns with broader industry trends towards more environmentally sustainable manufacturing practices and positions the company to take a proactive stance in meeting future regulatory challenges.

1.3 Project objectives

The main purpose of this project was to reduce the Lead Time of the process and improve Quality, to ensure business continuity and company growth. To better pursue these goals, the following objectives were designed:

- 20% Reduction in the Lead Time;
- 25% Reduction in Non-Conformities detected by sector;
- 50% Reduction in Non-Conformities registered in T1;
- Operational Yield of 80% per sector;
- Introduction of Production Planning;
- Improve commitment, accountability, and feedback mechanisms of employees;

In order to achieve these objectives, the project focuses on multiple interconnected strategies. The goal of reducing the Lead Time by 20% is to streamline processes and increase efficiency, which is crucial for maintaining business continuity and fostering growth. The targeted reductions in non-conformities, 25% by sector and 50% in T1—are designed to enhance the overall quality and reliability of operations. Achieving an operational yield of 80% per sector ensures that productivity remains high, supporting these quality improvements.

Introducing Production Planning is essential for optimizing resource allocation and scheduling, thereby contributing to reduced Lead Times and higher operational yield. Enhancing employee commitment, accountability, and feedback mechanisms is vital for creating a motivated and responsible workforce, which in turn positively impacts quality and productivity.

Finally, improving communication and transparency among all stakeholders ensures that everyone is aligned with the project's goals, facilitating a cohesive and collaborative effort towards achieving the desired outcomes.

1.4 Methodology

The project was divided into four distinct phases, namely, planning, solution design, implementation, and evaluation.

The first phase of the project involved diagnosing the initial situation, which will be explained in the third chapter. This helped in identifying the main issues and opportunities for improvement. Once the current situation was fully understood, the desired future state was envisioned and solutions were designed to achieve it.

The third phase involved working with the client to implement these solutions. Finally, in the last phase, the results of the implementation were evaluated to determine if the initial goals were achieved.

1.5 Structure

This dissertation unfolds over seven comprehensive chapters. Chapter 1 sets the stage with an introduction that contextualizes the research within the broader scope of Company X and the motivating factors behind the project. Following this, Chapter 2 delves into the literature review, outlining the foundational theories and current understandings that frame the study. Chapter 3 examines the current state of affairs at Company X, defining and analyzing the problem in detail. Chapter 4 discusses the proposed solutions, describing the methodology applied to address the challenges identified. Chapter 5 details the implementation of these solutions, providing an in-depth look at the processes and strategies employed during this phase. Chapter 6 focuses on the discussion of results, critically analyzing the outcomes of the implementation and evaluating their effectiveness.

The final chapter, Chapter 7, presents the conclusions drawn from the research and considers the potential directions for future work in this area.

Chapter 2

Literature Review

2.1 Kaizen Philosophy

After the conclusion of World War II, Toyoda Kiichiro, who was the president of Toyota Motor Company at the time, recognized the importance of catching up with America to ensure the survival of the automobile industry in Japan. Taiichi Ohno, a Toyota engineer, faced the challenge of building a diversified line of products with limited equipment available at Toyota's disposal. Rather than resorting to batch production, Ohno designed an integrated production system that utilized one-piece flow, which proved that there was no need to compromise quality for productivity (Netland and Powell (2016)). Together with other practices, this system came to be known as the Toyota Production System (TPS), which challenged the notion that bigger batches are synonymous with lower costs.

The Toyota Production System (TPS) strives to eliminate waste completely, and it has two main pillars - just-in-time (JIT) and autonomation. By implementing a just-in-time pull system, Toyota solved the problem of not having enough capital resources to support high inventory levels. This system means that only the necessary units are produced in the required quantities and at the right time, which enables companies to approach zero inventory. Toyota's goal with autonomation was to create an automatic checking system that would prevent defective products from being produced and increase production efficiency. When machines worked correctly, employees were freed up, allowing them to attend to multiple machines. Automation also improved the overall process by creating awareness and understanding of problems. Stopping the machine allowed Toyota to take measures to improve its process. (Ohno (1988))

Lean, based on TPS, is a methodology that accentuates customer needs, to improve quality and reduce costs through continuous improvement and employee involvement (Graban (2008)). Kaizen is a Japanese term that refers to the idea of continuous improvement. It is not the same as innovation or disruption, which can be costly. Instead, Kaizen focuses on making small and subtle improvements. This is a low-cost and low-risk process that results in incremental progress and sustainable changes in the long run.

In the early 21st century, Toyota Motor Company surpassed General Motors and became the world leader in automobile production. The company's success was largely attributed to the adoption and expansion of the Kaizen concept. Kaizen's methodology is based on five fundamental principles (Institute (2020)):

- **Create customer value**

  Value is what the customer is willing to pay for. Using a market-in approach to make informed decisions based on what the customers want and offer them in the best way possible, improving customer experience.

- **Create flow efficiency**

  Flow efficiency can be achieved by eliminating three types of waste: Muda (waste), Mura (unevenness), and Muri (overburden). Taiichi Ohno, the pioneer of Lean production philosophy, identified seven sources of Muda in the industrial context: overproduction, waiting, inventory, motion, transportation, over-processing, and defects. Any activity that does not add value to the process is considered Muda. Fujio Cho, former President of Toyota, defined waste as "anything other than the minimum amount of equipment, materials, parts, space, and worker's time, which are essential to add value to the product". Eliminating waste is the most effective way to increase productivity and decrease costs.

  Understanding all three concepts allows for a greater comprehension of Lean. Mura refers to the variation in a process that is not caused by the final customer, such as highs and lows in planned production due to the production system or irregular work rhythm. Leveling production using JIT can eliminate these irregularities, avoiding work spikes and long waiting times for workers. Muri means overburdening equipment or workers, demanding a faster rhythm for a longer period than expected. In equipment, it can cause defects and failures, while in people, it can result in safety issues.

- **Be Gemba oriented**

  Gemba is the place where value is added. It is important to identify and solve problems at their root cause. Central to Kaizen is the principle of genchi genbutsu, which means to go and see for yourself. In other words, to thoroughly observe the reality of the processes, it is necessary to go to the Gemba, the place where the action happens.

- **Empower people**

  "Respect for people" is one of the fundamental principles of the Kaizen philosophy. According to Kaizen, people are not the problem, but the processes are. The philosophy aims to improve every day, everywhere, with everyone involved in training employees and encouraging them to think and share their own ideas for improvement systematically. It is in the best interest of management to create the best possible conditions for everyone to perform at their best.

- **Be scientific and transparent**

  Knowing how to explain and substantiate findings with data is as important as identifying problems. Visual Management is a fundamental Kaizen tool that highlights issues and enables quicker responses.

KI has developed the Kaizen Business System (KBS), which is a collection of improvement principles, models, tools and processes designed to bring long-term value to all companies. The system aims to achieve growth, quality, resource and flow efficiency, all while respecting people. It consists of three different models: Growth, Change and Operations, which are applied by KI depending on the project. The figure 2.1 provides a comprehensive overview of the components of this system:

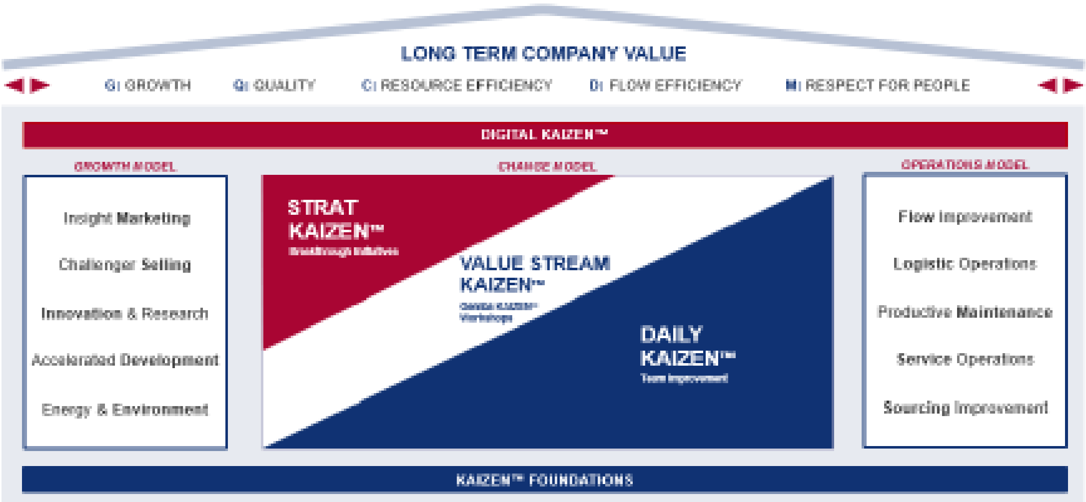


Figure 2.1: Kaizen Business System

The Growth Model focuses on earnings and revenue, paying attention to five key areas: market effectiveness, sales effectiveness, innovation, product development, and environmental impact.

The Operations Model, also known as the QCD (quality, cost, delivery) Model, aims to enhance these three dimensions by working on various areas including flow improvement, logistics operations, productive maintenance, service operations and sourcing improvement.

TFM (Total Flow Management), which is used for flow improvement across the entire supply chain, is based on pull-flow principles. This means organizing your entire supply chain to optimize material flow by eliminating unnecessary steps (known as "Muda" in Japanese).

The Change Model aims to inspire and involve individuals in fostering a culture of continuous improvement. It comprises three different capabilities: Strat, Value Stream, and Daily Kaizen. The first capability targets breakthrough initiatives, the development of top management teams, and better strategy execution. The second capability employs Kaizen Events to transform paradigms in key-value streams.

The last capability, Daily Kaizen, holds particular importance in this project. Daily Kaizen helps develop individuals to ensure the sustainability of improvements. By creating daily routines, it becomes possible to advance toward a target condition that will last in the long term. Visual Management plays a significant role in creating team boards that enable the understanding of a team's performance through Key Performance Indicators (KPIs). These boards aim to discuss the status quo and resolve day-to-day problems.

2.2 Total Flow Management

Total Flow Management (TFM) aims to enhance the flow and efficiency of processes across the supply chain (Coimbra (2009)). By eliminating waste and creating a continuous flow of activity, companies can produce and distribute products with less effort, space, tools, lead time, and costs, becoming more responsive to customer demands and more competitive in the market (Womack and Jones (1994)).

TFM focuses on three main areas: flow in production, internal logistics, and external logistics. In production, the goal is to establish a seamless, one-piece flow of materials through standardized work processes, improved operator efficiency, and minimized waste, ensuring a continuous flow from raw materials to finished products.

Internal logistics aim to create an effective logistical and information flow within the organization, linking production and logistics through a Pull system. This system begins with the customer's order, triggering orders in production and managing the supply to production lines according to scheduling and service levels proposed to the customer.

External logistics cover the movement of pallets to and from the production building, culminating in delivery to the customer. Establishing flow requires a thorough analysis and stabilization of labor, machinery, materials, and methods. Addressing labor issues such as high absenteeism rates, non-compliance with delivery deadlines, and resistance to change is essential.

Machinery must be highly available to prevent downtime and quality failures. Machines with low Overall Equipment Effectiveness (OEE) can cause high downtime, frequent breakdowns, and long setup times, hindering production. Ensuring the timely supply of materials is crucial for uninterrupted production; without it, production continuity is compromised.

Consistent, suitable, and tested working methods are necessary for effective flow. Variability in work execution can compromise product or service quality and lead to differences in team performance. To maintain stability in these four components, daily communication meetings, analysis of deviations in indicators, and structured problem resolution should be implemented. Daily Kaizen meetings play a crucial role in achieving this stability and ensuring successful TFM implementation.

This dissertation focuses on Production Flow and Internal Logistics Flow, which will be further detailed in the following sections.

2.2.1 Flow in Production

The first pillar of the Total Flow Management (TFM) model is the creation of flow in production, which involves defining the organization's value chain. In this section, we will discuss the tools for designing and laying out the production lines.

2.2.1.1 Line Designing

The first step in line design is choosing between functional and flow-based layouts. Functional layouts group machines by function, conducive to batch production but leading to high WIP and lead times. In contrast, flow-based layouts sequence operations to reduce WIP and lead time, with an ideal U-shaped design to enhance process visibility and operator flexibility.

Functional layouts isolate operators, limiting cooperation and potentially leading to batch-level quality issues. Flow-based layouts integrate multiple operations, align production speed with customer demand (takt time), and adapt more readily to changes.

Post-layout reorganization, line sizing considers either a singular, large line for efficiency or multiple smaller lines for product variety, with the latter offering better line balancing and operator flexibility.

2.2.1.2 Standard Work

After optimizing the arrangement of production lines and component placement, it is crucial to establish standardized work methods for each station. Standard work is a methodology that emphasizes the observation and simplification of tasks to improve worker engagement and resource utilization.

By measuring and observing task execution, companies can gain a better understanding of employee challenges and opportunities. Work standards ensure that tasks are performed in the most efficient, simple, and safe manner, thereby adding the highest value. According to (Imai (1997)), work standards provide a basis for sustaining improvements, setting training objectives, preventing errors, and promoting operational consistency. Identified best practices should be shared throughout the organization to simplify tasks and reduce variability.

Developing a work standard involves five stages in an iterative improvement cycle. The first step selects the process for analysis and defines improvement goals. A work study follows, with time collection, flowcharting, and identification of difficulties and opportunities for eliminating waste. The next step, work enhancement, involves focusing on value-adding activities and minimizing movements, possibly requiring line-side reorganization. Solutions are tested and results verified in this phase.

Once effective solutions are identified, they are standardized, concisely and visually documenting the new execution method. This new method is then disseminated across similar organizational areas, underpinned by adequate training plans and ensuring each employee can perform the new standard. After establishing work standards and training, employees are held accountable for adherence.

2.2.1.3 SMED

Single-Minute Exchange of Dies (SMED) is a methodology designed to reduce the time required to complete equipment changeovers. The SMED approach aims to convert as many changeover steps as possible to "external" tasks, which are performed while the equipment is running.

This system also simplifies and streamlines the remaining steps (Shingo (1985)). SMED is particularly important in manufacturing environments where reducing downtime is essential for meeting production targets and improving operational efficiency.

Developed by Shigeo Shingo for Toyota's automotive production, SMED has significantly reduced changeover times from hours to under ten minutes in many cases. The methodology's main goals are to minimize idle times and ensure that setup procedures do not impede operational flow.

By enhancing the efficiency of changeover activities, SMED not only increases machine utilization but also supports the manufacturing sector's ability to switch between products quickly, facilitating a flexible response to market demands.

The implementation of SMED involves several key phases: observing the current setup process, separating internal from external activities, converting internal to external activities where feasible, streamlining all operations, and performing continuous improvement. This structured approach allows organizations to identify wasteful procedures and unnecessary complexities within setup processes, enabling focused improvements.

2.2.1.4 Logistic Box

The Logistic Box is a vital tool in production logistics, playing a crucial role in managing the internal logistics flow and optimizing the supply chain. It is designed to streamline the movement and storage of materials, ensuring that production lines receive the necessary components in a timely manner. According to (Jacobs and Chase (2021)), the integration of smart technologies into logistics systems enhances visibility and efficiency, enabling real-time monitoring and data-driven decision-making. This approach not only improves operational efficiency but also reduces delays and bottlenecks in the production process.

2.2.1.5 Bill of Materials (BOM)

The Bill of Materials (BOM) is a comprehensive list of raw materials, components, and assemblies required to construct a product. It serves as a critical document in production planning and inventory management. BOM ensures that all necessary materials are available when needed, thus preventing production delays. According to (Stevenson (2018)), an accurate and well-maintained BOM is essential for effective production scheduling and resource allocation, contributing to the smooth flow of production operations.

A BOM typically includes detailed information about each component, such as part numbers, descriptions, quantities required, and procurement sources. It can be classified into different levels of hierarchy, starting from the top-level assembly down to the smallest part. This hierarchical structure helps in understanding the relationship between various components and assemblies, facilitating better planning and execution.

In modern manufacturing, the BOM is often integrated with other systems, such as Enterprise Resource Planning (ERP) and Material Requirements Planning (MRP). This integration enables automatic updates and synchronization across different departments, ensuring that everyone is working with the most current information. The BOM also plays a crucial role in cost estimation and control, as it provides a clear breakdown of all materials required, allowing for accurate budgeting and financial planning.

2.2.1.6 Bill of Process (BOP)

The Bill of Process (BOP) outlines the specific processes and sequences involved in the manufacturing of a product. It provides detailed instructions on each step of the production process, from initial setup to final assembly. The BOP is instrumental in ensuring consistency and quality in manufacturing. According to research by (Stevenson (2018)), having a detailed BOP helps in standardizing processes, reducing variability, and improving overall production efficiency. This structured approach facilitates better planning and execution of production activities.

A well-constructed BOP includes various elements such as process descriptions, required tools and equipment, labor skills needed, and quality control measures. It may also specify the time required for each step, helping in the creation of realistic production schedules. By clearly defining the workflow, the BOP helps in identifying potential bottlenecks and areas for improvement.

The use of BOP is particularly important in industries with complex manufacturing processes, such as automotive and aerospace. For example, in the automotive industry, a BOP ensures that each component of a vehicle is assembled in the correct sequence, maintaining high standards of quality and safety. Advances in technology have further enhanced the utility of BOPs, with digital BOPs allowing for real-time updates and integration with other digital manufacturing tools.

2.2.2 Push vs Pull Planning

In the realm of production and logistics management, push and pull planning are fundamental strategies that define how inventory and production processes are controlled. These methodologies influence how resources are allocated, how production schedules are determined, and ultimately, how efficiently a manufacturing system operates. This section delves into the distinctions between push and pull planning, their respective advantages and disadvantages, and their implications on modern manufacturing practices.

2.2.2.1 Push Planning

Push planning, also known as forecast-driven planning, is a production strategy where production schedules are determined based on projected demand. This method relies heavily on historical data, market analysis, and sales forecasts to predict future demand and plan production accordingly. In push planning, the process begins with a detailed forecast of future demand. This forecast drives the entire production schedule, dictating what products to produce, in what quantities, and when to produce them. As a result, inventory levels are managed to ensure that sufficient stock is available to meet the anticipated demand, often leading to higher inventory levels as a buffer against uncertainties in demand. Production schedules in push planning are typically long-term and less flexible. Once a schedule is set based on forecasts, it can be challenging to adjust in response to real-time changes in demand.In figure 2.2 it's a simple scheme that explains how the Push strategy works.

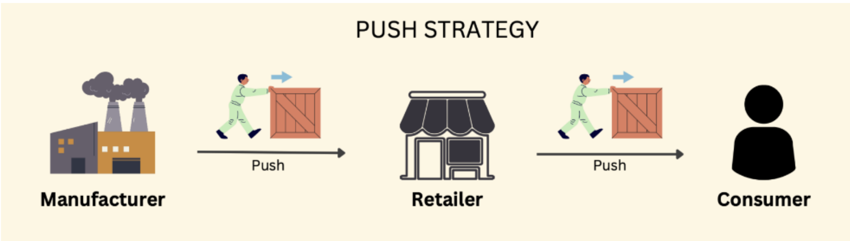


Figure 2.2: Flow of goods in a push strategy from the manufacturer to the retailer and finally to the consumer.

Push planning offers several advantages, including predictability in production schedules and resource allocation, which makes it easier to plan for long-term operations. Additionally, by producing large quantities based on forecasts, companies can benefit from economies of scale, reducing per-unit production costs. However, push planning also has notable disadvantages. Forecasting demand accurately is inherently difficult, and inaccurate forecasts can lead to overproduction or underproduction, resulting in excess inventory or stockouts. Maintaining high levels of inventory to buffer against demand variability can lead to increased storage costs and potential obsolescence of products.

2.2.2.2 Pull Planinng

Pull planning, also known as demand-driven planning, represents a fundamental shift from traditional production methods that rely heavily on forecasts and predetermined schedules. Unlike these forecast-based systems, pull planning aligns production activities directly with actual customer orders, thereby enhancing flexibility and responsiveness to real-time market demands. This method ensures that production is precisely tailored to what is required, thereby optimizing resource utilization and minimizing waste. In the Figure 2.3, it is explained the Pull Strategy, with a simple scheme:

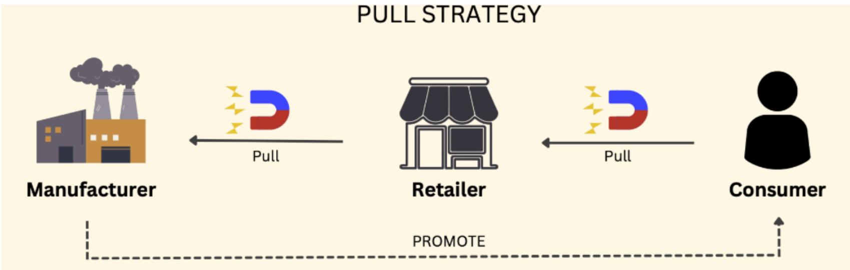


Figure 2.3: Flow of goods in Pull Strategy

At the core of pull planning is the Just-In-Time (JIT) principle, which advocates for maintaining minimal inventory levels and synchronizing production schedules closely with demand signals. In a pull system, the production process is initiated only when an actual customer order is received, which triggers a cascade of activities along the supply chain to fulfill that order. This approach starkly contrasts with push systems, where production is based on projected demand and often results in excess inventory and higher holding costs.

The implementation of pull planning necessitates a highly adaptive and flexible production schedule. Manufacturers must be capable of swiftly adjusting their production runs to accommodate fluctuations in demand. This often involves shorter production cycles, frequent reconfigurations of production lines, and a robust mechanism for continuous monitoring of demand signals. The ultimate goal is to achieve a seamless flow of materials and products through the production process, ensuring that each component arrives just in time for its use in the next stage of manufacturing.

The advantages of pull planning are multifaceted. By producing only what is needed, when it is needed, companies can significantly reduce inventory holding costs and minimize the risk of obsolescence. This lean approach not only curtails waste but also enhances the company's ability to respond swiftly to changes in customer demand, thereby improving customer satisfaction and shortening lead times. Furthermore, a well-executed pull system can lead to better cash flow management as resources are not tied up in unused inventory.

However, the successful implementation of pull planning is not without its challenges. One of the primary requirements is the establishment of a highly reliable and responsive supply chain. Any disruptions, such as delays in material deliveries or quality issues, can have immediate and detrimental effects on the production process. Therefore, strong relationships with suppliers, characterized by high levels of trust and communication, are crucial.

Additionally, transitioning to a pull system can be a complex endeavor, often requiring substantial changes to existing processes, infrastructure, and organizational culture. Companies may need to invest in advanced technologies for real-time demand tracking and production scheduling, and employees may require training to adapt to new workflows. The shift also involves reassessing and possibly redesigning the entire supply chain to ensure it is aligned with pull principles.

2.2.3 Internal Logistics Flow

2.2.3.1 Levelling

Leveling in manufacturing connects supermarket supplies to line-sides through mizusumashi and information flows, optimizing the sequence of production batches to meet customer demands more efficiently (Coimbra (2009)). This strategy reduces production batch sizes, enabling more frequent production and closer alignment of product availability to actual consumption, enhancing responsiveness to customer needs.

Pull planning transforms production quantities into scheduled orders collected by the mizusumashi for delivery to workstations, aiming for a synchronized planning system that responds dynamically to real-time shop floor events. This approach mitigates material overuse and the Bullwhip effect, a common supply chain challenge.

Key steps in the Kaizen leveling process include selecting a pacemaker line that sets the production rhythm, converting orders into Kanban cards, and organizing these cards in a logistics box that sequences daily production aligned with capacity. This setup ensures continuous material flow and efficient production scheduling, directly impacting line efficiency and reducing the need for adjustments due to process variability.

2.3 Quality

2.3.1 Auto-Quality Matrix

The Auto-Quality Matrix (AQM) is a crucial tool in Lean management, designed to improve process quality and efficiency by mapping the relationship between process steps and the detection of defects. The matrix uses the horizontal axis to represent process steps and the vertical axis to indicate where defects are detected. By identifying these intersections, companies can pinpoint the root causes of defects and implement corrective actions promptly. According to (Liker (2004)), the use of AQM helps in achieving higher quality and efficiency in production processes.

The significance of the AQM lies in its ability to minimize waste and enhance operational efficiency. Early detection of defects helps prevent compounded errors, reducing rework and scrap rates while improving product quality and customer satisfaction. The matrix supports continuous improvement initiatives by providing a structured approach to defect analysis and problem-solving, aligning with other Lean tools like the *5 Whys* and *Ishikawa* diagrams.

In summary, the AQM is vital for maintaining high-quality standards and responsiveness to customer demands, thereby supporting a company's competitive edge in the market.

2.3.2 Self Inpection

Self-inspection is a key quality management practice where operators check their work to ensure it meets set standards before moving to the next production stage. This method, integral to Lean manufacturing and Total Quality Management, involves training operators to identify defects using standardized tools and checklists (Goetsch and Davis (2014)).

The primary benefits of self-inspection include immediate defect detection and correction, which minimizes waste and reduces costs associated with rework and scrap. It also enhances operator engagement and responsibility, fostering a culture of continuous improvement and operational excellence (Imai (1986)).

Overall, self-inspection improves product quality and customer satisfaction by ensuring that only defect-free products progress through the production process, aligning with the principles of proactive quality management.

Chapter 3

Problem Description

In this chapter, the initial situation of the Company X before the implementation of the Kaizen Institute project will be presented. Only the situations that were the focus of this report will be described. Various subprojects were developed during this work, but only the most relevant ones will be detailed. This way, the initial situation of the company will be described and the root causes will be analyzed.

3.1 Operational Challenges

Company X specializes in mold production, which is divided into 5 main groups: slabs, male, cavity, PMLs (*Postiços*, *Movimentos*, and *Levantadores*), and accessories. The workflow begins with the sales team sending a quote to the customer. Upon approval, the mold enters a waiting list to be designed by the Technical Department (DT). However, a significant issue was the lack of adherence to the FIFO (First In, First Out) principle, which led to inefficiencies and delays in the production process. Molds were often left in the queue for extended periods, not being processed in the order they were received.

Instead, they advanced in the production line based on commercial pressure rather than a structured and systematic schedule. This lack of prioritization meant that some molds were expedited due to urgent customer demands or sales team pressure, while others were neglected, resulting in prolonged waiting times. This inconsistent approach disrupted the workflow, caused resource allocation issues, and ultimately affected the overall efficiency and productivity of the company.

When the DT initiated work on a mold, they produced only a preliminary drawing. This initial sketch provided a rough study of the mold, indicating its dimensions and the mechanisms to be employed for piece extraction. Following this, the purchasing team ordered the steel, which arrived at the milling center after two weeks, awaiting initial machining. One of the biggest problems was the absence of a fixed sequence task schedule for the DT team. Often, they delivered drawings much later than needed, which in turn delayed the CAM team's ability to produce machining programs promptly. Consequently, machining operations were frequently delayed, leading to idle machines and reduced operational performance.

Machining of the male and cavity components involved several stages: Roughing, Water Hole Drilling, 2D Machining, 3D Machining, Radius Reduction, Water Hole Sealing, and Erosion. After these steps, the components were sent to the benchwork sector.

The PMLs underwent a similar multi-step process, including Steel Cutting, Roughing, Water Hole Drilling, Stress Relief, Machining, Nitriding, Erosion, Polishing, and Water Hole Sealing. Accessories were machined either on a milling machine or a lathe, each with six distinct steps. When finished, both the PMLs and Accessories were sent to the benchwork sector.

In the benchwork sector, people were there to assemble all parts of the mold, polish necessary parts and make lots of adjustments to a majority of the components. After this, the mold was sent to the testing center, where plastic injection testing was conducted. If the piece had non-conformities, it was sent back to the benchwork for rework. Then it would go to the testing center again. This process was repeated until the plastic piece was free of errors. In this swimlane scheme shown in Figure 3.1 it can be seen the macroflow of information and processes within Company X.

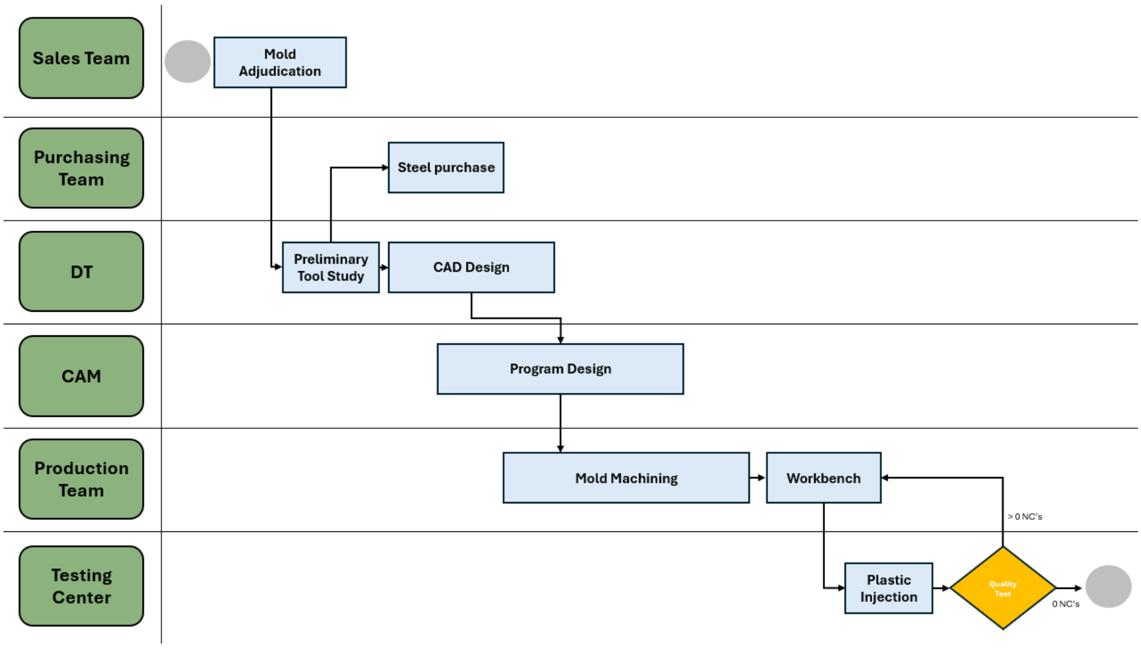


Figure 3.1: Swimlane Model of Production Process.

Despite knowing the necessary steps for machining males, cavities, PMLs, and accessories, there was no standardized sequence to follow, leading to significant inefficiencies. The sequence of operations varied from mold to mold and was largely dependent on the personal judgment and experience of the individual responsible for the process. This reliance on personal intuition rather than a structured workflow meant that components were machined based on the operator's "gut feelings" and the current machine load, rather than an optimized production schedule.

The absence of a detailed and organized planning system resulted in a lack of clear visibility into the workflow. This hindered the ability to accurately anticipate and schedule which pieces would be processed by specific machines at any given time. Consequently, the production process was subject to frequent interruptions and delays, as there was no systematic way to ensure that all necessary steps were completed in an efficient and timely manner. This lack of foresight and coordination often led to bottlenecks, with some machines being underutilized while others were overwhelmed, further exacerbating delays and reducing overall productivity.

Production faced numerous other challenges:

- There was no control over material reception.
- The milling center struggled with capacity issues.
- Stock was disorganized.
- Machines were often idle, waiting for tools.
- Stock control was nonexistent.
- Operations closure lacked routine.
- Rework was common due to mistrust in previous processes.
- Personnel frequently moved between sectors.
- Internal logistics were absent.
- Transport organization was poor.

There was a four-week work-in-progress stock, meaning that materials and partially completed components sat idle for up to a month before progressing to the next stage of production. This significant backlog caused numerous problems. The disorganized stock and lack of control over material reception compounded the delays, as it was difficult to locate necessary components promptly.

The benchwork operations also suffered from significant problems:

- Tools were far from the work area.
- A substantial amount of time was spent on rework.
- Standard components were not mapped.
- Searching for components, PMLs, and accessories was time-consuming.
- There were frequent shortages of components for assembly.
- Unmachined parts accumulated on the bench.
- Workers often retrieved materials from other sectors.
- Team specialization was lacking.

- Internal and external accessories were poorly defined.
- Material organization in the CE was deficient.

There was an eight-day work-in-progress stock. This delay was largely due to the inefficiencies and disorganization highlighted above. The distance of tools from the work area, time-consuming searches for components, and frequent shortages all contributed to these prolonged idle times. Additionally, the accumulation of unmachined parts in the benchwork sector and the need for workers to retrieve materials from other sectors further disrupted the workflow, emphasizing the critical need for better material organization and planning.

Due to all of this, the Lead Time in production was 18.2 weeks. This lengthy lead time is particularly detrimental given the highly competitive nature of the automotive industry, where time is of the essence. In this market, rapid turnaround and timely delivery are crucial for maintaining a competitive edge and meeting the stringent demands of automotive manufacturers.

The prolonged lead time not only reduces the company's ability to respond swiftly to customer orders but also impacts its reputation for reliability and efficiency. In an industry where every week counts, such delays can result in lost business opportunities and a diminished market position.

The operational performance of Company X was low, as it can be seen on Figure 3.2, primarily due to the lack of a fixed sequence of tasks and inadequate planning. Without a standardized workflow, operations were inconsistent and inefficient, leading to frequent delays and interruptions.

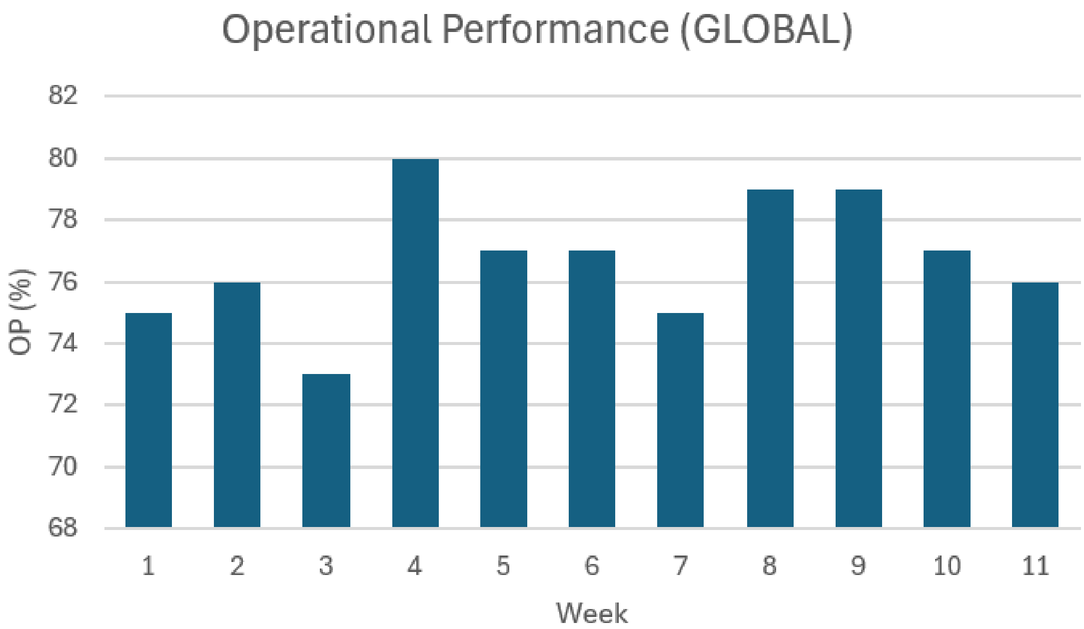


Figure 3.2: Operational Performance of all the machinery (average)

The absence of a detailed and organized planning system further exacerbated these issues, as there was no clear visibility into the workflow, causing bottlenecks and underutilization of resources. These factors combined to significantly hinder the company's overall operational efficiency.

3.2 MUDA Hunting

Muda, a Japanese term meaning "waste", is a key concept in lean manufacturing that identifies any activity or process that does not add value to the product or service. Recognizing and eliminating these non-value-adding activities is essential for improving efficiency, reducing costs, and enhancing overall quality in any production environment. In the highly competitive automotive industry, where time and precision are critical, minimizing waste is particularly crucial to maintaining a competitive edge.

At Company X, the focus on Muda hunting was applied extensively within the production process. This initiative was driven by the need to streamline operations, optimize resource utilization, and improve productivity across various sectors. Specifically, Muda hunting was conducted in several key areas: Slabs Machining, Benchwork, Roughing, Water Hole Drilling, and 2D Machining. Each of these sectors plays a vital role in the overall production workflow, and inefficiencies in any of these areas can have a significant impact on lead times, costs, and product quality.

Slabs Machining

In the machining of slabs, the Muda level was identified at 70%. The primary problems included:

- Machines were often idle, waiting for materials.
- A lack of tools was frequently observed.
- The necessity to wait for cones to cool down after tool rectification.

These issues caused significant delays and inefficiencies, highlighting the need for better resource allocation and tool management.

Benchwork

Benchwork, where Muda reached approximately 100%, faced severe inefficiencies:

- The majority of the work consisted of reworking errors from earlier stages.
- Tools were far from the work area.
- A considerable amount of time was spent searching for accessories.

These problems resulted in extensive rework and wasted time, underscoring the need for better organization and workflow improvements.

Roughing

In the roughing process, the Muda level was 70%, with key problems being:

- Lack of response capacity from the milling center.

- Tools were far from the work area.
- Difficulty in accessing stock.

These inefficiencies led to significant delays and reduced productivity, emphasizing the importance of improving stock management and tool availability.

Water Hole Drilling

Water hole drilling exhibited a Muda level of 60%, with issues including:

- Malfunctioning carousel.
- Work interruptions were common.
- Tool parameters were not clearly defined.

These problems caused frequent disruptions and inefficiencies, highlighting the need for better equipment maintenance and clearer operational guidelines.

2D Machining

In 2D machining, the Muda level was identified at 20%, with the primary issues being:

- Potentiometer utilization was below 100
- There was no planning for subsequent work.
- Tools were not suitable for the tasks at hand.
- Shared workstations led to inefficiencies.

These factors resulted in underutilized resources and operational inefficiencies, indicating the need for better planning and tool optimization.

3.3 Quality Challenges

Once the mold reached the testing center, it was subjected to plastic injection testing to identify any defects. Non-conformities detected during this phase required the mold to be returned to the benchwork sector for rework. On average, eight tests were conducted per mold to achieve the desired quality, resulting in substantial costs and delays, as resources were diverted to rework instead of progressing to other molds.

A significant issue was the lack of stringent quality control. Non-conformities were identified across various sectors, but there was no comprehensive action plan to analyze and minimize these defects. The self-quality matrix revealed that most non-conformities were detected at the benchwork and testing stages, indicating the company's failure to identify issues during earlier phases of the process. The Figure 3.3 shows the Self-Quality Matrix that was done along with the Company's Quality Department.

	Comercial	Logistics	DT	CAM	Roughing	Machining	Erosion	Benchwork	Test	Client
Comercial										
Logistics	1									
DT	1		10							
CAM										
Roughing		6			6					
Machining		5		28		92				
Erosion		3				3	18			
Benchwork				12		192	23	79		
Test						135	7	21		

Figure 3.3: Self-Quality Matrix

The quality control issues extended to the overall workflow, where defects were not systematically analyzed. This lack of a proactive approach meant that the same issues repeatedly arose without effective solutions being implemented. The inability to address quality problems early in the process not only increased costs but also delayed delivery times, impacting customer satisfaction and the company's reputation.

Another big problem was the reactive rather than proactive nature of the quality control measures in place. Instead of identifying and addressing potential causes during the initial stages, trying to eliminate some of the errors completely, by just doing the rework necessary for the correction of the error, the problems were continually being discovered during the benchwork sector, or even worse, at final testing, necessitating extensive rework.

Chapter 4

Solution Design

4.1 Pull Planning in the Production Chain

Pull Planning is a strategic approach in production management that focuses on initiating work based on actual demand rather than forecasted demand. This methodology aims to reduce waste, improve efficiency, and enhance flexibility by aligning production schedules with real-time demand signals. In the context of Company X, pull planning is instrumental in optimizing their production chain and reducing lead times.

Company X has always operated with a pull strategy, as it does not make sense to produce molds for stock. Our project merely enhanced this strategy by incorporating some tools related to pull planning.

4.1.1 Cores and Cavities

An in-depth analysis of the current factory paradigm at Company X revealed that the production lead time was approximately 18 weeks. This lead time encompassed both machining time and benchwork time. A critical finding from this analysis was the lack of a fixed machining sequence for cores and cavities, leading to inefficiencies. Previously, parts were machined based on the availability of machines, without a predetermined sequence, causing delays and unpredictability in the production schedule.

In collaboration with the production team, a study was conducted to determine the most logical sequence of machining operations. This sequence was derived from the extensive experience and expertise of the machine operators. By implementing a logical and fixed sequence of operations, Company X gained significant visibility into the production process. The factory leader could now quickly assess if the production was behind schedule relative to the customer's timeline for mold testing.

Once the production sequence was established, an average time analysis for each task per mold was conducted. This analysis highlighted that the bottleneck in the production process was the 2D machining sector, where the most time-consuming operations were performed. On average, machining a mold in this sector requires 120 hours (5 days).

The 2D machining sector housed four different machines. To address the bottleneck, three distinct production lines were created, with one machine reserved for Mura Station (a station responsible for correcting molds post-T1) and to assist in machining PML's when necessary. The constraints of each line, illustrated in Figure 4.1, facilitated the factory planner's ability to allocate molds effectively.

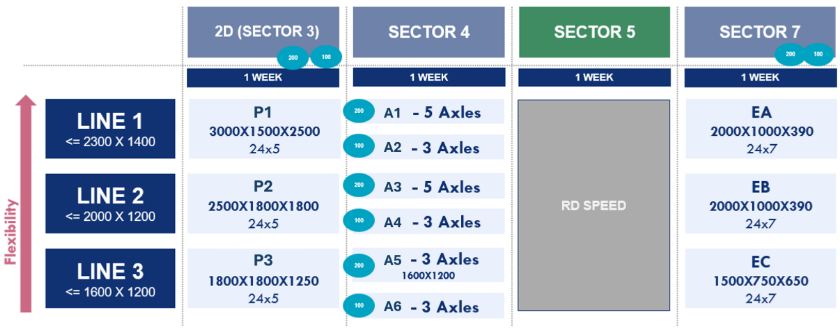


Figure 4.1: Constraints of the 3 Production Lines

Given the 5-day duration for 2D machining, the pacing of the machining line was set at 5 days. The new production process was designed to include eight machining stations, one buffer station, and four weeks of benchwork. For confidentiality reasons, the actual names of the stations have been replaced with numbers. The buffer stations were incorporated to absorb variability in the production process, ensuring that even more complex molds, which required additional time, could be accommodated without disrupting the overall flow.

In Figure 4.2, the final production flow on the Machining Sectors can be seen.

Figure 4.2: Production Flow (Core and Cavity)

The red labels below the name of the stations indicate how many weeks are left until the mold has to enter on the benchwork sector. For the benchwork, two separate lines were established: one for the core and another for the cavity. Each line consisted of fourteen distinct stations with specific responsibilities. The division into different stations followed a logical sequence, again aided by the factory director and the most experienced operators. Subsequently, operators were assigned to the stations, forming clusters of specific expertise. This approach ensured that most operators worked on tasks where they excelled, thereby enhancing overall productivity in the factory. The pacing for benchwork was set at 1 day per station, resulting in a bench lead time of 14 days.

As illustrated in Figure 4.3, Station 8 marks a point of convergence where the core and cavity undergo press fitting. Here, both components are brought to a press to ensure a perfect fit. Following this, they are separated again to be worked on independently. They come together only at the final station for the final assembly before moving to the first testing phase.

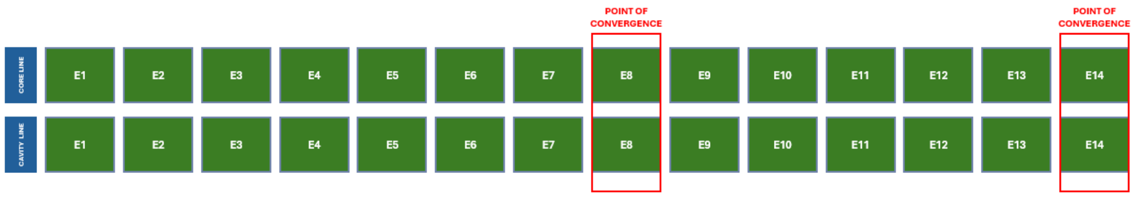


Figure 4.3: Benchwork Production Flow

4.1.2 PML's

For PML's (Postiços, Movimentos e Levantadores), a similar logical approach was followed as with the main components of the mold. The critical bottleneck in the production process was identified as the 2D/3D machining of these components. The average cycle time for machining PML's was five days, although this was occasionally insufficient for more complex tasks. In cases where the machining hours for PML's exceeded the factory's capacity, the production director, in collaboration with the sector chief, outsourced the machining of PML's. This strategic decision helped alleviate the production load and ensured adherence to the scheduled delivery times for benchwork.

The PML production flow consisted of nine distinct sectors, closely mirroring the process used for the main components. Due to professional confidentiality, the specific names of each station cannot be disclosed. The systematic approach began with the identification of a logical sequence of operations derived from the experience and expertise of the machine operators. This sequence allowed for a more predictable and efficient workflow, enhancing overall productivity.

Whenever the internal capacity was insufficient, particularly for more complex or numerous PML's, outsourcing was employed as a flexible solution to meet deadlines. This approach not only balanced the workload within the factory but also provided a buffer to manage unforeseen complexities without compromising the overall production schedule. In Figure 4.4 we can see the process that was adopted at company X:

Figure 4.4: PML's Production Flow

The implementation of a structured sequence of operations and the integration of pull planning principles for PML's have significantly enhanced the efficiency and reliability of Company X's production chain. By leveraging both internal and external machining resources, the company can better manage its production timelines and meet customer expectations.

4.1.3 Acessories

In the case of accessories, which are small but essential components for the optimal functioning of the mold, there was a significant lack of control over their machining. Often, molds would proceed to their initial testing phase without the accessories being in place, as they had not yet arrived at the benchwork stage.

To address this issue, a study was conducted to determine the most logical sequence for the production of these accessories. Following this analysis, a standardized process was established with a pacing of five days per cycle, culminating in a total duration of six weeks before the accessories reached the bench.

Figure 4.5 illustrates the process:

Figure 4.5: Acessories Production Flow

4.2 Self-Inspection

A new self-inspection dynamic was initially introduced in the 2D sector, as this area had a significant number of non-conformities (NCs) that were preventable throughout the production process. Recognizing the need for improvement, the Quality team, in collaboration with several operators, developed a form containing detailed instructions on how to conduct an effective self-inspection.

This form provided step-by-step instructions for each task and required operators to confirm whether everything was in order. The tasks included checking measurements with probes, verifying precise dimensions with calipers, ensuring that master values were in compliance, and inspecting threaded holes with a gauge, among others. After performing each task, operators had to indicate on the form whether the parameters were met satisfactorily. An example of this form can be seen on the Appendix A.

The introduction of these self-inspection tasks aimed to systematically reduce the occurrence of NCs by empowering operators to identify and rectify issues early in the production process.

In the future, the goal is to extend this self-inspection dynamic to other sectors, thereby fostering a culture of continuous improvement and quality assurance across the entire organization.

Chapter 5

Implementation

In the previous chapter, we discussed the solution design for implementing pull planning in the company, as well as the introduction of self-inspection practices across various sections. These strategies were meticulously planned to enhance production efficiency, reduce lead times, and improve overall quality control within the organization.

This chapter focuses on the practical application of the proposed theories. It provides a detailed account of the steps taken to implement these solutions on the ground, highlighting the challenges encountered and the methods employed to overcome them. The implementation phase is critical as it translates theoretical planning into tangible actions, ensuring that the designed processes are effectively integrated into the company's operations.

This chapter aims to provide a comprehensive understanding of the implementation process, from initial preparations to full-scale adoption, and to evaluate the impact of these changes on the company's performance.

5.1 Pull Planning

5.1.1 Logistics Box

The concept of the Logistics Box is integral to the pull planning methodology. This approach emphasizes producing goods based on actual demand rather than forecasts, thereby minimizing waste and improving efficiency. The Logistics Box serves as a critical tool in this system, ensuring the optimal flow of materials through various stages of production. It operates on the principle of load-capacity balancing, which is essential for managing bottlenecks and maximizing the use of installed capacity within a factory.

The primary purpose of the Logistics Box in the context of pull planning is to manage the workflow and capacity utilization efficiently. It acts as a visual and physical signal that helps maintain the balance between the demand and supply of production resources. As depicted in the slide images, the Logistics Box ensures the output of three molds per week (one mold per line), corresponding to the output of the 2D sector, which is the current bottleneck in the factory. The machining cell is structured with a pacing of one week to maintain a consistent and predictable production rhythm.

Upon the receipt of an order, the type of mold is evaluated based on its dimensions (length and width). This typology influences the allocation to a machining line. The planner fills in the mold number and its dimensions in the master table within the Logistics Box. From these dimensions, a suggested machining line is proposed, which can be adjusted based on the allocated column, as it's represented on Figure 5.1.

Semana Atual	14		PREENCHER

#MOLDE	COMPRIMENTO	LARGURA	LINHA PROPOSTA	LINHA ALOCADA
M1	1300	1300	Linha 1	Linha 2
M2	1300	1300	Linha 1	Linha 1
M3	1710	1035	Linha 2	Linha 2
M4	1000	1500	NA	Linha 2

Figure 5.1: By entering the Mold name and dimensions, the program suggests a certain line

The planner allocates molds to lines based on these characteristics and the current load on each line, ensuring allocations adhere to a First Expire First Out (FEFO) logic to meet client deadlines.

The planner must also evaluate the expected hours for each machining operation and compare them to the available hours to determine if the workload will exceed the available capacity. If the hours surpass the available time (exceeding the pacing of one week), decisions must be made to either extend available time, reallocate to another line, find internal solutions, subcontract, or accept delays. If the average hours consumed per operation consistently exceed the weekly pacing, it indicates a need to review the pacing solution as it will consistently cause delays, affecting defined buffers and process flow. A map with the relation between Load and Capacity is present on Figure 5.2.

MÉDIA DE HORAS CONSUMIDAS POR SETOR

	Soma de horas orçamentadas	Soma de horas Previstas	Média/Molde [Horas Previstas]	Média/Molde [Dias]
2D	372	360	120	5,0
ACABAMENTO	556	390	130	5,4
RR	219,1	260	87	5,4
EROSÃO	508	530	177	7,4

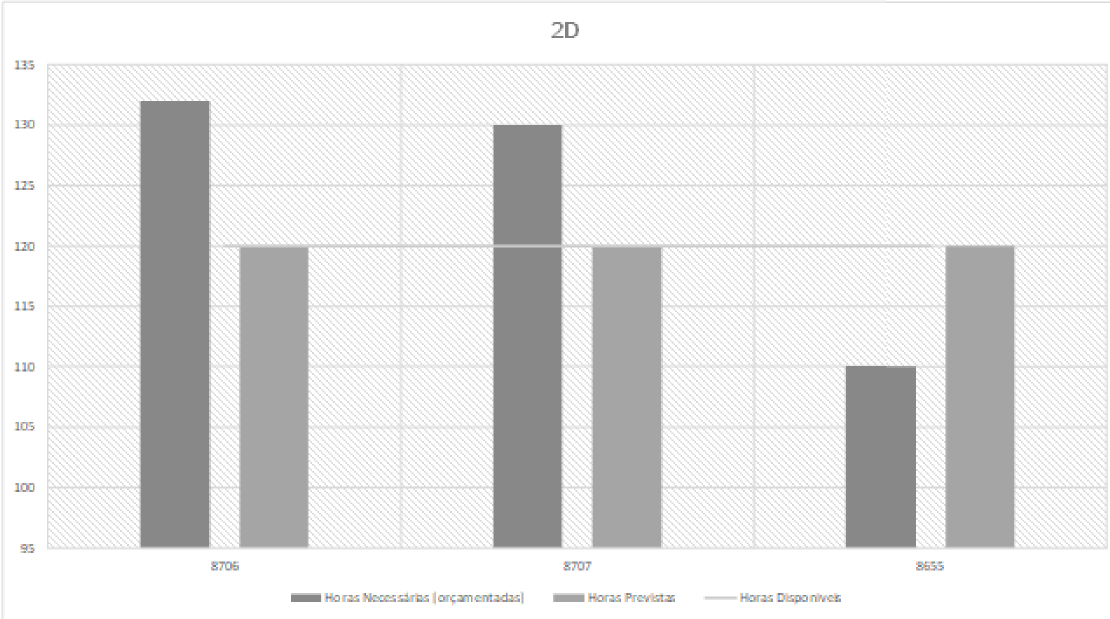


Figure 5.2: 2D Sector Load/Capacity Map

The adoption of the Logistics Box brings several significant benefits. Enhanced capacity utilization is achieved by ensuring that the bottleneck is planned to maximize the installed capacity, leading to higher efficiency and productivity. Improved workflow visibility is another major benefit, as the visual management aspect of the Logistics Box provides clear visibility of the production status, helping in quick decision-making and better planning.

Additionally, the systematic approach of evaluating mold dimensions and allocating them to appropriate lines ensures a balanced load, preventing overburdening any single line. The pacing mechanism maintains a steady and predictable production flow, reducing variability and uncertainties in the production process. Proactive delay management is facilitated by anticipating and addressing potential delays proactively, helping to maintain adherence to client deadlines and minimizing disruptions.

The implementation of the Logistics Box is based on several key assumptions:

- **Milestone Validation:**

  A one-week interval between the technical design review and client validation is planned, critical for ensuring the delivery date of the mold.

- **Calendar Weeks Consideration:**

Production weeks are considered from Monday to Friday, with specific allowances for weekends in finishing and erosion processes.

- **Blocked Delivery Weeks:**

  Certain weeks (32, 33, and 52) are blocked for deliveries due to holidays (summer and Christmas), ensuring no planned output during these periods.

- **Handling of Dual/Sandwich Molds:**

  These molds are treated as independent molds with separate entries for their cores and cavities, ensuring no increase in lead time by planning them in parallel across different lines.

- **Buffer and Stock Management:**

  Buffers are defined to absorb the variability in mold production. This setup controls the entry into the benchwork phase and maintains smooth flow.

- **Microplanning for Variability:**

  Minimum and maximum production limits are monitored to balance the line flow. This proactive approach helps in managing variances and delays effectively.

The Logistics Box, therefore, is a comprehensive tool in the pull planning methodology, enhancing the efficiency and predictability of the production process while ensuring optimal capacity utilization and proactive delay management. By adhering to these assumptions and systematically implementing the Logistics Box, the company can significantly improve its operational performance and meet client expectations consistently.

5.1.2 Bill of Process and Tracking Sheet

The Bill of Process (BOP) is an integral component in manufacturing, providing a detailed outline of the necessary steps, operations, and resources required to produce a product. Unlike the Bill of Materials (BOM), which lists the raw materials and components needed, the BOP focuses on the sequence and specifics of the manufacturing process. It details each operation, the order in which these operations occur, and the specific resources and equipment needed at each stage. This document is crucial for ensuring consistency, quality, and efficiency in the manufacturing process.

The BOP, as shown on Figure 5.3, includes several key components: the operation sequence, detailed descriptions of each process step, and information on the equipment, tools, and human resources, which are represented by hours, needed for each operation. By detailing these elements, the BOP allows for better coordination and scheduling, ensuring that each operation is completed just in time to meet the next stage of production. This integration within a pull planning system significantly enhances the efficiency and responsiveness of the manufacturing process.

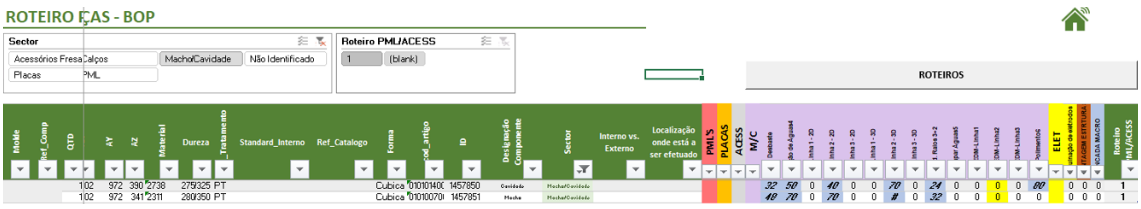


Figure 5.3: Bill of Process (BOP)

The BOP consolidates all essential data from the BOM, including mold numbers, material specifications, and dimensions. Following this, the planner must assign each reference to a specific machine and determine an appropriate time allocation. This time allocation is based on the planner's extensive experience and informed judgment, along with the help of the responsible for each sector. The BOP must be done 4 weeks before the mold enters the machining phase, and it's done in a meeting involving 6 people. Usually, it takes about 1h30m.

Moving on to the Tracking Sheet, this document plays a critical role in operational tracking and management. The Tracking Sheet is dynamically updated by the information contained in the BOP. It provides a visual representation of the hours allocated to each machine and operation, which is crucial for weekly planning and execution. This sheet serves as a practical tool for operators and managers alike.

It details the tasks to be accomplished within a specified timeframe, weekly in this case, and includes a breakdown of operations across different sectors and machines. Each task is assigned a specific duration, and the sheet is structured to reflect the sequence of operations as outlined in the BOP. Operators use this sheet to guide their daily activities, ensuring they adhere to the planned schedule.

Once a task is completed, the responsible operator marks the corresponding box on the Tracking Sheet, typically using a pen. This manual check-off system allows the sector supervisor to track progress in real time and identify any pending tasks. The ability to visually monitor task completion is invaluable for maintaining workflow efficiency and ensuring that deadlines are met. It also facilitates quick identification of any bottlenecks or delays in the production process. In the Figure 5.4 it's visible an example of a Tracking Sheet.

Legenda Tratamento Térmic

RT	Redução de tensões
T	Têmpera
N	Nitruração
RT+N	Redução Tensões + Nitruração

 # MOLDE

8775

Subcontratação	#PMLs
	2

SEQUÊNCIA PLANEADA PML FABRICO INTERNO

PMLs	24		25		26		27		28		29		30		31		31		32	
	OP.	#PMLs	OP.	#PMLs	OP.	#PMLs	OP.	#PMLs	OP.	#PMLs	OP.	#PMLs	OP.	#PMLs	OP.	#PMLs	OP.	#PMLs	OP.	#PMLs
	Corte de Aço	12	Sector 1	10	Sector 2	4	Sector 3	0 0	Maquinação 2D/3D	10 6	Sector 5	6	Sector 6	6	Sector 7	0	Sector 8	12 0	Sector 9	12

MOLDE	REF	INT/EXT	LOC.	TT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Tempo Total
					18	42	14	0	0	0	0	64	6	68	0	0	0	12	0	20	0	0	
SA8775	0300	Interno	0	NA	2	3						8						3		2			18
SA8775	0301	Interno	0	NA	2	3						8						3		2			18
SA8775	0500	Interno	ir Exte	NA	2	8	4							18				1		2			35
SA8775	0501	Interno	ir Exte	NA	2	8	4							18				1		2			35
SA8775	0800	Interno	0	NA	2	4	3							16				2		3			30
SA8775	0801	Interno	0	NA	2	4	3							16				2		3			30
SA8775	0540	Interno	0	N	1	2						8	1							1			13
SA8775	0541	Interno	0	N	1	2						8	1							1			13
SA8775	0542	Interno	0	N	1	2						8	1							1			13
SA8775	0543	Interno	0	N	1	2						8	1							1			13
SA8775	0544	Interno	0	N	1	2						8	1							1			13
SA8775	0545	Interno	0	N	1	2						8	1							1			13

Figure 5.4: Tracking Sheet

The benefits of using it are manifold. It enhances visibility into the production process, allowing for better monitoring and control. This visibility helps in maintaining the pace of production and ensures that all tasks are completed within the designated timeframes.

5.1.3 Sequencer cards

The implementation of sequencer cards is a pivotal aspect of managing and optimizing the production workflow within the factory. These cards are essential tools in ensuring that each operation is completed in the correct sequence and within the planned timeframe.

The entire process begins with the Section 1, which requires detailed information from the technical department and the factory planner. This information includes the molds planned per line over a rolling six-week period, detailing which molds enter each line, in which week, the component number, as well as the planned weeks and times for each operation. This data is made visible on the sequencing cards.

Each mold is assigned a sequencer card, which is color-coded to distinguish between cores (macho) and cavities (cavidade), as it can be seen on Figure 5.5. Darker cards are used for cores, while lighter cards are for cavities. The planner must fill out the sequencer cards, indicating the planned molds for the respective weeks. These cards are then placed in designated slots for each week, providing a visual schedule for the production line.

Once the programming phase is complete, the sequencer cards are transferred to the respective machines. This mobilization ensures that the operators know exactly what needs to be done for each mold.

The molds are then circulated through production in a First In, First Out (FIFO) manner, positioned on plates next to the machines. This systematic approach helps maintain order and

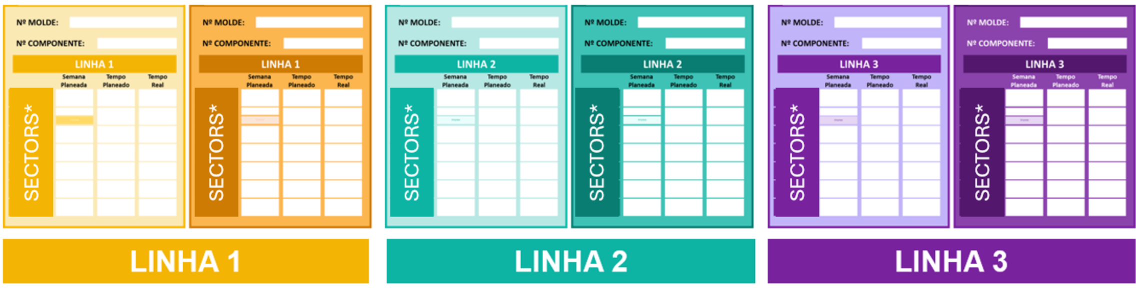


Figure 5.5: Sequencer Cards

ensures that the production schedule is followed accurately. Throughout the process, the operator responsible for each task records the actual operation times on the sequencer card. This real-time data tracking allows for accurate monitoring of the production process.

At the end of each operation, the operator takes the sequencer card to the next station, ensuring that the workflow is continuous and that all necessary steps are completed in sequence. At the end of the machining phase, the sequencer cards are collected by the factory planner. The planner analyzes the data, comparing the planned times with the actual times to identify any discrepancies or areas for improvement. Once the analysis is complete, the planner clears the data from the cards and returns them to the roughing center, ready for the next cycle.

The benefits of using sequencer cards are significant. They provide a clear and organized method for tracking the progress of molds through each stage of production. This system ensures that all necessary steps are completed in the correct order and within the planned timeframe. By providing a visual and easily accessible way to monitor production, sequencer cards help maintain workflow efficiency and identify any potential issues early on.

5.1.4 SMED

To reduce setup time, a Single-Minute Exchange of Dies (SMED) workshop was conducted on one of the 2D sector machines, specifically the P1 machine, in collaboration with its operator. During this workshop, the operator's setup process was recorded using a GoPro attached to his chest. The recording was then analyzed to break down the setup process into distinct tasks, identify which tasks could be classified as internal or external, and gather the operator's suggestions for improvement.

The analysis revealed that the setup process comprised 40 distinct tasks, with a total setup time of 1 hour and 2 seconds. The table detailing each task, its nature (internal/external), and its duration can be found in the Appendix B of this dissertation.

Upon further analysis, it was determined that 21 of the 40 tasks were external, meaning they could be performed while the machine was still running. Following this identification, several improvement proposals were made, which are summarized in the Table 5.1 below:

These improvements focus on enhancing efficiency by reducing setup times and streamlining processes. The first proposal aims to create a standardized work procedure for operators, which

Table 5.1: Potential Opportunities for Improvement and Actions for 2D Sector

Sector	Potential Opportunities for Improvement	Action
2D	Normalization of processes to reduce adjustments and task switching	Standard Work Operator
2D	Preparation of the setup process (cart ready, bridge available, eyelets)	Change setup process
2D	Greater proximity to the operator's most common tools	5S's Implementation
2D	Placing a new retention basin closer to the operator	Purchasing Dep.

helps minimize variability in the process and reduces the need for frequent adjustments and task switching.

Another significant improvement is the preparation of the setup process. The action suggested here is to change the setup process, ensuring that carts are ready, bridges are available, and eyelets are prepared in advance. This preparation can significantly reduce internal setup time by enabling operators to transition swiftly between tasks without waiting for necessary equipment or components.

The third improvement focuses on ensuring greater proximity to the operator's most common tools. The action proposed is the implementation of the 5S methodology (Sort, Set in order, Shine, Standardize, Sustain). This method enhances workplace organization, making the tools most frequently used by the operator readily accessible. Reducing the time spent searching for tools and materials cuts down setup time and improves overall efficiency.

Finally, placing a new retention basin closer to the operator is suggested. The action for this improvement is categorized under the Purchasing Department. This strategic placement minimizes unnecessary movements and enhances workflow fluidity, contributing to a reduction in setup time.

In conclusion, the SMED workshop provided valuable insights into the setup process of the 2D sector's P1 machine. By identifying and categorizing tasks as internal or external and implementing the proposed improvements, setup time can be significantly reduced. These changes not only enhance efficiency but also contribute to a more organized and streamlined production environment, fostering a culture of continuous improvement within the company. The success of this workshop will be explored in the next chapter, where the results can be seen.

5.2 Daily KAIZEN

The implementation of Daily Kaizen is crucial for introducing and maintaining a culture of continuous improvement within companies. Despite its relatively simple concepts, it presents a challenging dynamic to implement effectively. As discussed in the literature review chapter, Daily Kaizen is divided into three key components: People, Performance, and Improvement.

Initially, all factory employees underwent training on this dynamic, where they learned about the importance of several fundamental principles of Kaizen philosophy. These principles included resistance to change, paradigms, the power of visual management, and the power of standardization. The training sessions were highly successful, as they included numerous games, making the sessions more engaging and appealing to everyone.

After covering the basic concepts, we proceeded to explain how the daily dynamic functioned and what the board consisted of. The board was divided into several sections. One section was dedicated to the microplanning of the sector, where one could check which parts would be machined that week on a specific machine. The attendance and vacation map also served to control the available resources. One of the most important parts of the board was the performance indicators, which demonstrated the sector's performance. These indicators could vary from sector to sector but typically included the number of non-conformities per day, the number of self-inspections per day, and the downtime per machine.

Finally, the board included a sheet representing a PDCA (Plan-Do-Check-Act) cycle. This allowed employees to voice their concerns and report problems or improvement opportunities to their supervisor. These issues would later be reviewed and properly analyzed by a member of the corporate team. Implementing Daily Kaizen is inherently challenging due to the necessity for a significant shift in employee mentality. The success of this approach hinges on overcoming resistance to change, as individuals must adapt to new paradigms and embrace the principles of visual management and standardization. An example of a successful implementation can be seen on Figure 5.6.

Figure 5.6: Board of PML's sector (Yellow: Microplanning, Red: Performance indicators and Blue: PDCA)

This transformation requires employees to not only understand but also internalize the value of continuous improvement, which can be difficult given the entrenched habits and practices that often exist within an organization. However, fostering a culture where continuous improvement becomes second nature demands persistent effort and strong leadership. Supervisors must actively support and reinforce these principles, ensuring that employees feel empowered to identify and report issues or improvement opportunities.

5.3 Quality Control Interface

Previously, non-conformities (NCs) were recorded in an Excel file, which documented the date of the NC, the sector of origin, the sector where it was detected (as NCs can be detected downstream in the production process), and a description of the issue. To improve the management and analysis of this data, a Power BI platform was developed, using the Excel file as its database.

On the first page of the SharePoint,as it can be seen on Figure 5.7,is displayed the number of NCs by sector over the weeks of the year, along with their descriptions. For instance, the displayed figure shows the NCs of 2024 specifically for the 2D sector.

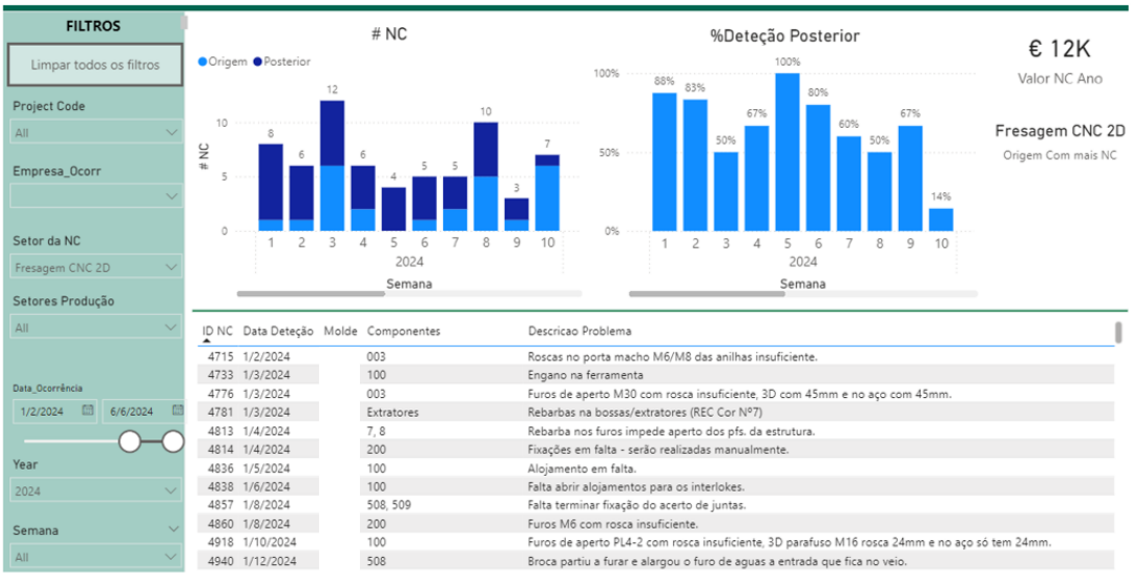


Figure 5.7: Power BI Interface for Non-Conformities analysis

The second page features a Pareto chart of the causes of NCs, allowing for a detailed analysis of the root causes, equal to the one present on Figure 5.8.

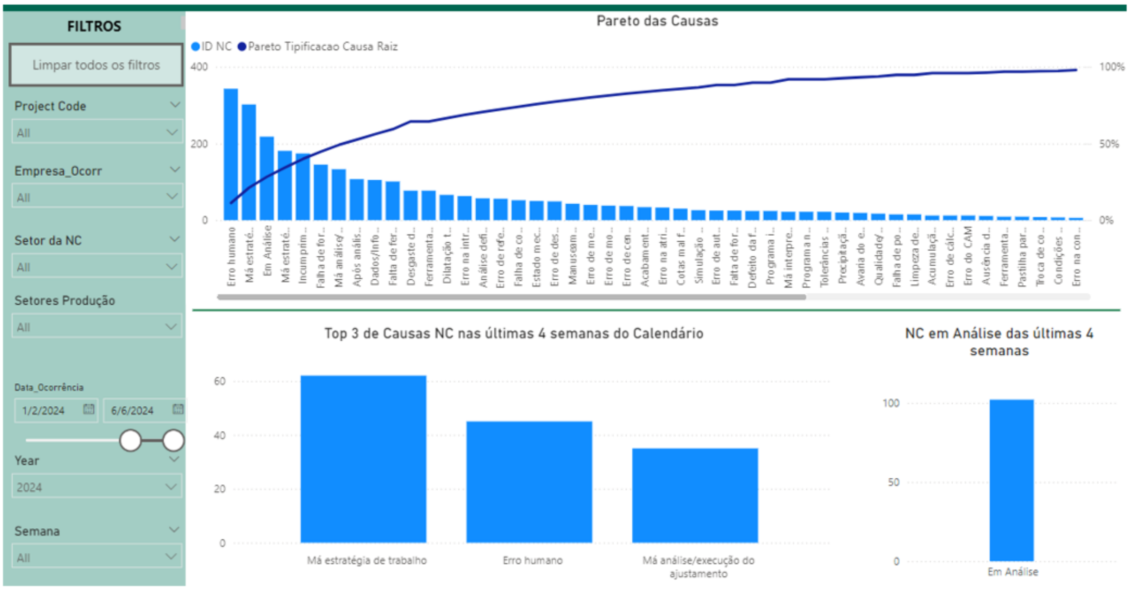


Figure 5.8: Power BI Interface with Pareto of Non-Conformities causes

The creation of this Interface was crucial as it provided comprehensive visibility into the trends and evolution of NCs. Consequently, a weekly meeting was established on Wednesdays, where the core team of the company could quickly review the current status of each sector regarding non-conformities. This meeting fostered a culture of continuous improvement, as each sector head was required to present the NCs for their sector every week. This requirement instilled a sense of competitiveness and responsibility, motivating them to reduce the number of NCs in their sectors.

This systematic approach not only enhanced transparency and accountability but also promoted proactive management of quality issues. The ability to visualize data trends and analyze root causes in real time empowered the team to address issues promptly and effectively, ultimately leading to improved operational performance and a stronger quality culture within the company.

Chapter 6

Results Discussion

This chapter will delve into the outcomes arising from the various initiatives and actions implemented in Company X, as outlined in Chapters 3 and 4. This section aims to provide a comprehensive analysis of the results and impacts of these initiatives, offering insights into their effectiveness and their contribution to the company's operational goals.

When the project commenced, the average Lead Time was approximately 18.2 weeks. The new planning process and fixed production sequence were implemented only in the first week of April. Consequently, no mold produced under the new parameters has yet reached the testing phase (T1). Therefore, it is not possible to provide a detailed analysis of this topic at this stage.

However, it is anticipated that by the last week of June, two molds will arrive at the testing center. This would result in an average Lead Time of about 14 weeks (13 weeks for production plus 1 week for testing), representing an improvement of approximately 23%.

Regarding the evolution of the number of non-conformities (NCs) recorded in the production process, an initial increase was observed, which at first glance could appear as a setback. However, this increase is attributable to the implementation of new self-monitoring dynamics within the company. These process improvements have enabled the identification of a greater number of NCs that previously went unnoticed. Thus, despite the apparent increase in the number of NCs, this phenomenon reflects greater effectiveness in detecting and ensuring the quality of the production processes. In Figure 6.1 it is possible to observe this increase:

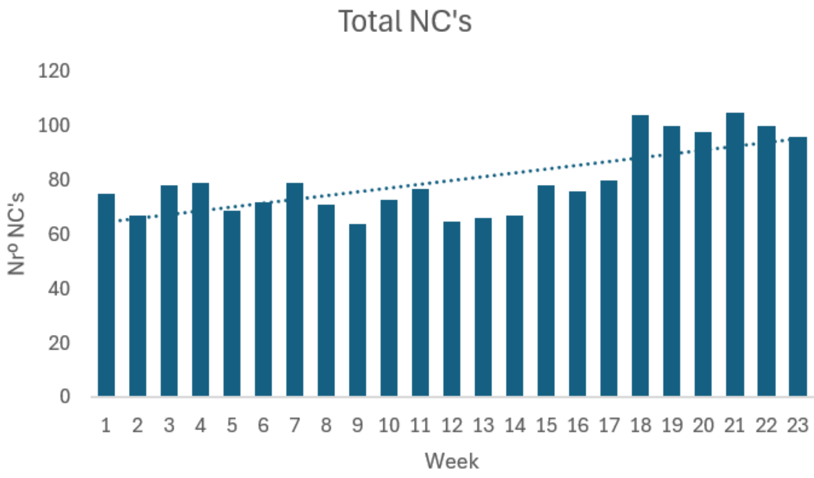


Figure 6.1: Evolution of the number of non-conformities in the company since January 2024. (Global)

One of the critical sectors in the detection of non-conformities was undoubtedly the Benchwork, as evidenced by the auto-quality matrix presented in Chapter 3. In this sector, a reduction of approximately 30% was observed over the same time intervals described above. This means that the NC's that once were detected in this sector, are now being detected much sooner in the process. This improvement is depicted in Figure 6.2.

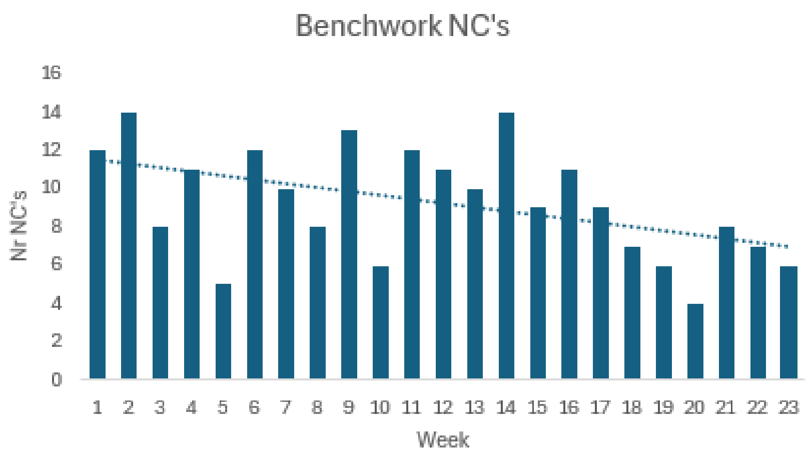


Figure 6.2: Benchwork NC's evolution since January 2024

Finally, regarding the number of non-conformities recorded during the testing phase, we only observed a 5% improvement over the previously mentioned intervals. This modest increase suggests that the self-inspection processes may not be entirely adequate, as many defects are still being passed on to the mold testing stage. This situation is unacceptable as it results in rework and consequently financial losses for the client.

Regarding the overall operational performance across all sectors, as demonstrated in Figure 6.3, there has been a significant improvement in recent weeks, allowing this value to exceed 80% on several occasions.

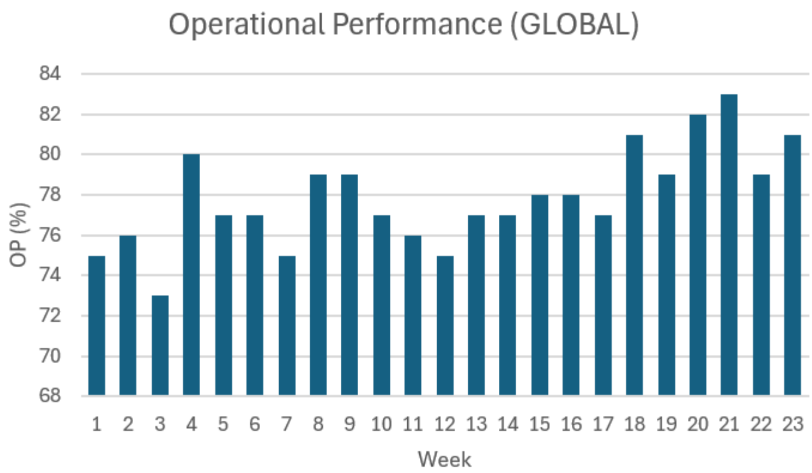


Figure 6.3: Operational Performance evolution since January 2024

It should be noted that the operational performance numbers of the machines do not exhibit consistent behavior, as they depend on various factors such as the type of molds being processed, the complexity of the tasks, machine maintenance schedules, and the availability of skilled operators.

Although it was not a direct objective of the process, the results of the SMED (Single-Minute Exchange of Dies) workshop are noteworthy. After implementing the first three proposed improvements and considering only internal operations, a significant setup time reduction of 47% was achieved. The last proposed improvement further enhanced the setup process, resulting in an additional 8% improvement.

The first three improvements focused on the normalization of processes to reduce adjustments and task switching, preparing the setup process in advance (ensuring carts are ready, bridges are available, and eyelets are prepared), and bringing the operator's most common tools closer to the workstation through the implementation of the 5S methodology (Sort, Set in order, Shine, Standardize, Sustain). These actions collectively contributed to the initial 47% reduction in setup time. By standardizing tasks, minimizing unnecessary movements, and preparing equipment in advance, the setup process became significantly more efficient.

The final point of improvement involved placing a new retention basin closer to the operator's workspace, categorized under the Purchasing Department. This strategic placement of necessary equipment reduced the time taken to fetch and return items, further streamlining the workflow and contributing an additional 8% improvement in setup time.

The Table 6.1 summarizes these results:

Table 6.1: Setup Time Improvements from SMED Workshop

	Initial	**1**	**2**
Setup Time	1:00:02	0:31:54	0:29:19
Improvement		47%	8%

In conclusion, the SMED workshop provided valuable insights and led to significant improvements in the setup process of the 2D sector's HSI machine. By meticulously analyzing and implementing targeted improvements, the setup time was drastically reduced by 51%.

Chapter 7

Conclusions and Future work

The implementation of Lean Manufacturing and Kaizen methodologies in Company X, particularly within the plastic injection mold industry, has yielded significant operational improvements. This thesis has demonstrated that systematic approaches to identifying and addressing inefficiencies can lead to substantial gains in productivity and quality. Through detailed analysis and targeted interventions, such as the SMED workshop and the introduction of self-inspection practices, Company X has achieved remarkable results.

A pivotal aspect of this project was the introduction of a fixed production scheme and tools related to pull planning. These measures were essential in transforming the chaotic and unpredictable production environment into a streamlined and efficient system. The development of a logical and fixed sequence of machining operations for cores, cavities, PMLs, and accessories provided much-needed visibility into the production process. By establishing a clear sequence, the factory leader could quickly assess if the production was behind schedule relative to the customer's timeline for mold testing, thereby enhancing overall productivity and reducing lead times.

The implementation of the Logistics Box was another key achievement. This tool ensured the optimal flow of materials through various stages of production, maintaining a balance between demand and supply of production resources. The Logistics Box allowed for a systematic evaluation of mold dimensions and their allocation to appropriate machining lines, thus preventing overburdening of any single line and maintaining a steady production rhythm.

The SMED workshop, which focused on reducing setup times for the 2D sector's HSI machine, was notably successful. By analyzing and reclassifying setup tasks as internal or external and implementing strategic improvements, the setup time was reduced by 51%. This included the normalization of processes to reduce adjustments and task switching, preparation of setup processes in advance, and the strategic placement of tools and equipment closer to the operator's workspace. These changes not only streamlined the setup process but also fostered a more organized production environment, aligning with the principles of continuous improvement intrinsic to the Kaizen philosophy.

Moreover, the introduction of self-inspection practices, particularly in the 2D sector, significantly reduced the number of non-conformities detected lat in the project. This proactive quality control measure empowered operators to detect and rectify issues early in the production process, contributing to a 30% decrease in non-conformities in the benchwork sector. The creation of a Power BI interface for non-conformity analysis further enhanced the company's ability to monitor and address quality issues in real-time, fostering a culture of accountability and continuous improvement.

Despite these successes, the project also highlighted areas for future work to sustain and build upon the initial improvements. One key area is the further integration of technology and automation in the production processes. The development and implementation of advanced data analytics and real-time monitoring systems could provide deeper insights into production inefficiencies and potential areas for improvement. Additionally, expanding the self-inspection practices to other sectors within the company could further enhance overall quality and operational efficiency.

Future work should also focus on addressing the challenges associated with workforce engagement and training. Ensuring that all employees are fully trained and committed to the principles of Lean and Kaizen is crucial for maintaining a culture of continuous improvement. This involves not only initial training sessions but also ongoing support and reinforcement of these principles through regular workshops and performance reviews.

In conclusion, this thesis has demonstrated the effectiveness of Lean Manufacturing and Kaizen methodologies in improving operational efficiency and quality within the plastic injection mold industry. The significant improvements in setup times and non-conformities, along with the enhanced operational performance, underscore the potential of these approaches to drive continuous improvement. However, to sustain these gains and further enhance productivity, future work should focus on integrating advanced technologies, expanding self-inspection practices, and fostering a culture of continuous improvement through ongoing training and engagement of the workforce. By addressing these areas, Company X can continue to lead in the competitive plastic injection mold industry, meeting the evolving demands of the automotive and consumer goods markets.

Bibliography

Coimbra, E. A. (2009). *Total Flow Management: Achieving Excellence with Kaizen and Lean Supply Chains*. Kaizen Institute.

Goetsch, D. L. and Davis, S. B. (2014). *Quality Management for Organizational Excellence: Introduction to Total Quality*. Pearson.

Graban, M. (2008). *Lean Hospitals: Improving Quality, Patient Safety, and Employee Engagement*. CRC Press.

Imai, M. (1986). *Kaizen: The Key to Japan's Competitive Success*. McGraw-Hill.

Imai, M. (1997). *Gemba Kaizen: A Commonsense, Low-Cost Approach to Management*. McGraw-Hill.

Institute, K. (2020). *The KAIZEN™ Way*. Kaizen Institute.

Jacobs, F. R. and Chase, R. B. (2021). *Operations and Supply Chain Management*. McGraw-Hill Education, 16th edition.

Liker, J. K. (2004). *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. McGraw-Hill.

Netland, T. H. and Powell, D. J. (2016). *The Routledge Companion to Lean Management*. Routledge.

Ohno, T. (1988). *Toyota Production System: Beyond Large-Scale Production*. Productivity Press.

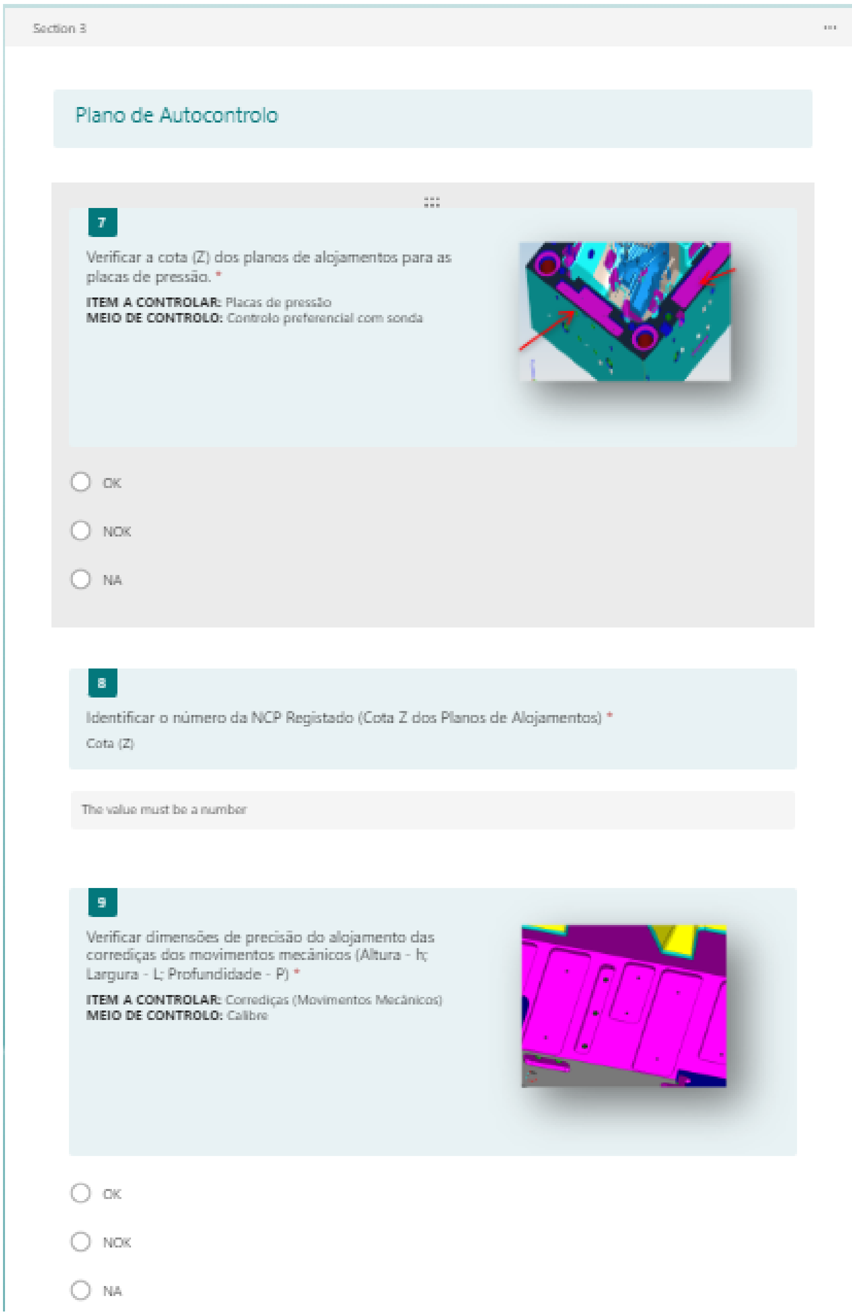
Shingo, S. (1985). *A Revolution in Manufacturing: The SMED System*. Productivity Press.

Stevenson, W. J. (2018). *Operations Management*. McGraw-Hill Education, 13th edition.

Womack, J. P. and Jones, D. T. (1994). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. Simon & Schuster.

Appendix A

Self-Inspection FORM (Section 3)



Section 3

Plano de Autocontrolo

7

Verificar a cota (Z) dos planos de alojamentos para as placas de pressão. *

ITEM A CONTROLAR: Placas de pressão
MEIO DE CONTROLO: Controlo preferencial com sonda

OK

NOK

NA

8

Identificar o número da NCP Registado (Cota Z dos Planos de Alojamentos) *

Cota (Z)

The value must be a number

9

Verificar dimensões de precisão do alojamento das corrediças dos movimentos mecânicos (Altura - h; Largura - L; Profundidade - P) *

ITEM A CONTROLAR: Corrediças (Movimentos Mecânicos)
MEIO DE CONTROLO: Calibre

OK

NOK

NA

Figure A.1: Self-Inspection Form (Section 3)

Appendix B

Internal/External Operations

ZÉ								
Nº	Operação	I / E	T. Parcial	T. Total	VA/MUDA	NOTA	Ferramenta	✓
1	Desapertar molde	I	0:00:52	0:00:52	MUDA			
2	Buscar ponte	E	0:01:00	0:01:52	MUDA			
3	Prender olhais	I	0:00:26	0:02:18	MUDA			
4	Içar molde (1ª tentativa)	I	0:00:28	0:02:46	MUDA	Operador teve de ajustar a posição dos olhais		
5	Trocar dois olhais	I	0:00:12	0:02:58	MUDA			
6	Içar molde (2ª tentativa)	I	0:00:58	0:03:56	MUDA			
7	Buscar aparafusadora	E	0:00:42	0:04:38	MUDA			
8	Retirar chupetas	E	0:00:52	0:05:30	MUDA			
9	Deslocar molde para a bacia de retenção	I	0:01:39	0:07:09	MUDA	OPORTUNIDADE: Bacia Mais Próxima, só limpar depois como placas		
10	Virar molde	E	0:02:20	0:09:29	MUDA			
11	Limpar molde (molde inclinado)	E	0:05:46	0:15:15	MUDA			
12	Deitar molde	E	0:00:21	0:15:36	MUDA			
13	Prender ponte	E	0:00:59	0:16:35	MUDA			
14	Içar molde	E	0:00:33	0:17:08	MUDA			
15	Limpar molde (molde na horizontal)	E	0:03:02	0:20:10	MUDA			
16	Deslocar molde até ao corredor	E	0:02:00	0:22:10	MUDA			
17	Ir buscar carrinho	E	0:01:10	0:23:20	MUDA			
18	Pousar molde no carrinho	E	0:01:15	0:24:35	MUDA			
19	Deslocar carrinho	E	0:00:12	0:24:47	MUDA			
20	Deslocar ponte até novo molde	E	0:01:58	0:26:45	MUDA			
21	Buscar berbequim e olhal	E	0:02:00	0:28:45	MUDA			

Figure B.1: Detailed Tasks on P1 machine (Part 1)

22	Prender olhal	I	0:00:13	0:28:58	MUDA			
23	Prender ponte + Içar novo molde + Deslocar molde	I	0:03:49	0:32:47	MUDA			
24	Pousar berbequim	E	0:00:11	0:32:58	MUDA			
25	Limpar mesa	I	0:01:22	0:34:20	MUDA			
26	Buscar aparafusadora e remover Fast Mill	I	0:01:37	0:35:57	MUDA			
27	Limpar mesa com sopro	I	0:04:07	0:40:04	MUDA			
28	Limpar Fast Mill com pano	I	0:00:54	0:40:58	MUDA	Inclui interrupção do operador a falar com colega		
29	Colocar novo molde na mesa	I	0:03:32	0:44:30	MUDA	Inclui deslocação da mesa para colocação do molde		
30	Desprender ponte	I	0:00:47	0:45:17	MUDA			
31	Remover ponte do caminho	E	0:00:57	0:46:14	MUDA	Inclui interrupção do operador a falar comigo		
32	Buscar aparafusadora	E	0:00:13	0:46:27	MUDA			
33	Aparafusar molde	I	0:00:36	0:47:03	MUDA			
34	Buscar material	E	0:02:04	0:49:07	MUDA			
35	Colocar parafuso na mesa	I	0:01:30	0:50:37	MUDA	Incluir interrupção por chegada do colega do turno seguinte		
36	Arrumar material	E	0:00:10	0:50:47	MUDA			
37	Soprar abaixo dos olhais	I	0:00:39	0:51:26	MUDA			
38	Buscar material (berbequim + ponta)	E	0:00:23	0:51:49	MUDA			
39	Remover olhais	I	0:00:43	0:52:32	MUDA			
40	Deslocar mesa + comparação + centrar	I	0:07:30	1:00:02	MUDA			
	Tempo Total (minutos)			1:00:02				

Figure B.2: Detailed Tasks on P1 machine (Part 2)