# Total Flow Management in a Power Generator Industry

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**Master's Dissertation**

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**Integrates Master's in Mechanical Engineering**

2023-06-26

*“I learned this, at least, by my experiment:*
*that if one advances confidently in the direction of his dreams,*
*and endeavours to live the life which he has imagined,*
*he will meet with a success unexpected in common hours.”*
*- Henry David Thoreau*

# Resumo

Esta dissertação explora a questão recorrente da falta de produtividade na indústria, especificamente, numa indústria de geradores elétricos que utiliza a produção em lotes. As operações da empresa estão repletas de desperdício e existe uma ausência evidente de estrutura e organização entre departamentos.

O estudo procura resolver estes problemas tendo como principal objetivo duplicar a produção semanal, bem como melhorar a eficiência operacional para conservar recursos e reduzir despesas. A estratégia de implementação centrou-se na transição para o fluxo unitário, o que foi conseguido através da aplicação de metodologias Kaizen, especificamente o modelo de *Total Flow Management* das ferramentas do *Kaizen Business System*.

O volume de produção aumentou para o dobro, e a Eficiência Global do Equipamento (OEE) da secção gargalo aumentou de 30% para 70% como consequência desta estratégia.

Os resultados demonstram a eficácia das metodologias Kaizen e da produção otimizada na transformação das operações industriais, realçando a sua capacidade de gerar ganhos de produtividade extraordinários e de reduzir o desperdício. As investigações futuras devem avaliar estas técnicas para resolver problemas de produtividade comparáveis.

## Total Flow Management in a Power Generator Industry


### Abstract

This investigation examines the prevalent issue of productivity deficiency within the power generator industry employing batch production. The company's operations are riddled with waste, and there is a conspicuous absence of structure and organization between departments.

This research seeks to address these issues with the primary objective of doubling weekly output and improving operational efficiency to conserve resources and reduce expenses. The implementation strategy centered on the transition to one-piece flow, which was accomplished through the application of holistic Kaizen methodologies, specifically the Total Flow Management model of the Kaizen Business System's tools.

The production volume increased by a factor of two, and the Overall Equipment Efficiency (OEE) of the bottleneck section increased from 30% to 70% as a consequence of this strategy.

The findings demonstrate the effectiveness of Kaizen methodologies and lean production in transforming industrial operations, emphasizing their capacity to generate extraordinary productivity gains and decrease waste. Future research and applications should evaluate these techniques to address comparable productivity issues.



### Key Words

Kaizen, Continuous Improvement, Productivity, One-piece flow

# Acknowledgements

Firstly, I want to thank my family for supporting me in every decision and for believing in my abilities, sometimes more than me. Mum, Dad, and Brother, I owe you everything and this dissertation shows that your dedication helps me to achieve my goals.

Next, I would like to acknowledge all my teachers, who have significantly influenced my personality and education.

A huge word of appreciation to my friends who played a very important role in my academic and social life. You are well aware that we will continue "O Churrasco" and “Terça às 8” for many years because we have been doing it for nearly a decade.

To my friends who understand the meaning of "grupamos" will continue to "grupar" together and host dinner parties for many years to come.

To my friends from Metal & Bio, it was with you that I started this journey, and I could not be more grateful.

To my Padel League of Clubs Team, thank you for accompanying me in the moments of decompression, you gave me the help and energy to overcome this phase of my life.

To Kaizen Institute for the vote of confidence in my work and for all the opportunities. I would like to thank "Team 10" for their extraordinary hospitality, in particular to my tutor Diogo Válter Silva for his dedication, availability, delivery, and good mood.

Lastly, I am indebted to my supervisors, Professor Carlos Bragança and Afonso Monteiro, for their availability, assistance, and guidance.

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## Acronyms

| | |
|---|---|
| OEE | Overall Equipment Efficiency |
| KBS | Kaizen Business System |
| QCD | Quality-Cost-Delivery |
| TFM | Total Flow Management |
| SMED | Single Minute Exchange of Dies |
| KCM | Kaizen Change Management |
| PDCA | Plan-Do-Check-Act |
| MCR | Mission Control Room |
| KPI | Key Performance Indicator |
| JIT | Just-in-Time |
| VSA | Value Stream Analysis |
| VSM | Value Stream Mapping |

# 1 Introduction

## 1.1 Project Framework and Motivation

In a world enduring drastic transformation, industries have increasingly pursued strategies to improve their competitiveness and performance. Against the context of an interconnected global economy, the power generation industry, a crucial sector, is on the verge of undergoing a radical transformation.

In recent years, the industry has been confronted with a variety of obstacles, including fluctuating market demands, regulatory pressures, and an ever-increasing demand for environmentally responsible solutions. Traditional business models have been further disrupted by technological advancements and digitalization, necessitating innovative approaches to optimize production and enhance operational efficiency.

Thus, the implementation of lean methodologies such as Kaizen has emerged as a promising solution. Kaizen refers to the philosophy or practices that emphasize the continuous improvement of manufacturing, engineering, and business management processes. Implementing one-piece flow through Kaizen methodologies streamlines operations, reduces waste, and increases overall productivity. This enables companies to maintain their competitive advantage in a market that is becoming increasingly saturated.

Moreover, market projections indicate an optimistic growth trajectory. Combined with the excess power in urbanization and industrialization in emergent economies, the rising global demand for energy presents significant growth opportunities for the sector. However, businesses must adjust to the shifting environment through innovation, efficiency, and sustainability to capitalise on this potential.

This thesis will investigate how the implementation of one-piece flow through Kaizen methodologies can play a crucial role in addressing the aforementioned challenges and capitalizing on development opportunities. This research seeks to cast light on the practical implications of these methodologies and their transformative potential in the power generation industry by analysing real-world applications and empirical data.

This study's findings and insights may assist decision-makers, planners, and industry stakeholders in developing strategic approaches that improve operational efficiency, foster innovation, and stimulate sustainable development in the power generation industry.

## 1.2 Objectives

The project in the generator manufacturing industry was motivated by a lofty but vital objective: to more than double weekly production from 44 to 100 generators. This objective demonstrates the potential for scalability in this field and the growing demand for energy solutions in an ever-expanding global economy.

To achieve this ambitious goal, the extant production process had to go through a drastic change. Although prevalent and historical, the traditional batch production model has limitations in terms of scalability, flexibility, and responsiveness to demand fluctuations. This method, which is characterized by the production of large quantities of a single product in sequential phases, frequently results in excess inventory, increased lead times, and decreased throughput, thereby reducing production efficiency and capacity.

To successfully overcome these barriers and achieve the intended level of production, the company initiated a Kaizen project.

Through Kaizen events, the organization intended to transition from batch production to a “pull” production model utilizing unit flow logic. The pull production system, as opposed to the traditional “push” system, initiates production based on actual consumer demand as opposed to forecasted demand. This significant adjustment in production logic reduces inventory levels, increases throughput, and improves market responsiveness.

In the pull production model, one-piece flow logic was implemented to process one item at a time instead of in large batches. This methodology facilitates operations, reduces waiting and transportation delays, and minimizes overproduction and excess inventory-related waste.

This project's intended outcome is not only to meet the production target, but also to establish a framework for continuous development, fostering a culture of innovation, efficiency, and adaptability that will enable the company to thrive regardless of volatile market conditions.

## 1.3 Methodology

The sequential nature of the Kaizen technique, which is widely recognized for its capacity to promote process improvement, includes discrete phases for planning and implementation. Each stage is essential to advancing the continual improvement that drives the Kaizen principles.

Value Stream Analysis (VSA), an extensive diagnostic procedure, is performed by a cross-functional team during the first phase, which can also be referred to as the planning stage. This study has two goals: to determine the procedure's present status and to identify persistent problems that reduce productivity. The team may obtain an in-depth understanding of the current processes and the areas that need improvement by carefully analysing the performance of the company and investigating process lead times.

The team changes its attention to solution creation after thoroughly analysing and mapping the present situation to reduce waste, or "Muda," and improve supply chain flow. The suggested solution includes a collection of actions specially designed to deal with problems and improve operational effectiveness.

The actual implementation of the proposed solutions takes place in the next phase - the project development or implementation stage. In this part of the process, the strategic insights gained from the VSA are transformed into practical measures intended to bring about the necessary improvements.

The methodology of structured problem solving, also known as Kobetsu Kaizen, is a systematic approach that follows a defined sequence of steps, culminating in an effective root cause analysis and the resolution of the problem at hand. The execution of Kobetsu Kaizen requires a variety of steps, including the establishment of objectives, the delineation of the current state,

the description of the ideal future state, the examination of root causes and variations, the formulation of a viable solution, the evaluation of the proposed solution, the revision of the action plan, and an accounting of valuable lessons learned from the process.

The everyday practice of Kaizen is essential to the overall Kaizen strategy. Daily Kaizen not only assures the successful implementation of improvements but also encourages participation and involvement at all levels of the business by focusing on incremental progress and creating a culture of continuous learning and development. It provides the foundation for maintaining the changes made, ensuring that the changes have a long-lasting impact on the overall efficiency of the company, contributing to the establishment of the kaizen culture (Tapping & Shuker, 2003).

## 1.4 Dissertation Structure

This master's thesis is divided into five substantial segments, each of which plays a pivotal role in the progression and comprehensive understanding of the research.

The first chapter “Introduction” provides context for the research. This chapter presents a global perspective on the studied sector and explores the motivation behind this endeavour. The objectives are outlined, detailing the purpose and anticipated outcomes of the research. In addition, this chapter explains the systematic approach taken to collect, analyse, and interpret data, shedding light on the methodology employed throughout the project.

The “State of the Art” section of Chapter Two is an in-depth review of extant research methodologies. This comprehensive literature review seeks to compare various techniques, casting light on their merits, flaws, and applicability in various contexts. This evaluation not only establishes the context for the study but also provides a firm theoretical foundation for the research.

Chapter Three, “Initial State”, presents a detailed depiction of the starting point of the research. It depicts the prevailing conditions, identifying and delineating the most significant issues encountered. By comprehending these issues, the chapter provides a compelling justification for the proposed solutions that follow.

The investigation is centred on Chapter Four, titled “Design of Solutions”. In this section, viable alternatives are proposed for each of the issues identified in the previous section. The effectiveness of these solutions is evaluated critically, leading to the presentation of the company's ultimate state following the proposed interventions. This chapter demonstrates the observable outcomes of the study and the efficacy of the proposed solutions.

Lastly, Chapters five and six, “Conclusions” and “Future Work”, respectively, are the concluding chapters of the thesis. It encapsulates the key findings and their implications, synthesizing the results into meaningful insights. This chapter also highlights areas for future research, acknowledging the continuous evolution of knowledge within the sector. This final chapter completes the narrative arc of the thesis, offering a reflective look at the research journey and its contributions to the field.

# 2 Literature Review

The purpose of the upcoming chapter will be to explain in depth the methodologies used. These have been carefully applied throughout the analysis of the presented problem and have also served as significant enablers in the development of the proposed solution.

This chapter provides an analysis of several essential topics about kaizen philosophy and fundaments. The focus is then directed toward the Kaizen business system. An innovative method of conducting business operations is profoundly rooted in the Kaizen philosophy and has been implemented globally.

The discussion then transitions to the idea of Overall Equipment Effectiveness (OEE). As a crucial metric, OEE enables companies to evaluate their operational efficiency and productivity, which are integral components of any extensive Kaizen implementation.

This State of Art analysis seeks to provide an overall understanding of the enumerated methodologies and procedures. The purpose of this chapter is to demonstrate their practical application and effectiveness in problem analysis and solution development as well as the theoretical details of all methodologies applied.

## 2.1 Kaizen Philosophy

The Japanese term "Kaizen" refers to a process of continuous improvement that aims to be better. The continual pursuit of improvement by all stakeholders across all aspects of a business is highlighted by this approach.

The application of Kaizen entails overcoming paradigms and obstacles of resistance, using the contributions of all organization members, and looking at the problem from multiple perspectives in an effort to find process improvements (Mendez & Vila-Alonso, 2018).

At its foundation, the Kaizen philosophy encourages a culture of continuous improvement in which every employee is urged to identify opportunities for improvement and take action to drive change. The goal is to make continuous, small-step changes to raise productivity, quality, and overall efficiency.

The lean thinking principles, which emphasize a manufacturing process that is continuously flowing, efficient, and focuses on creating value through the use of the just-in-time concept, are perfectly linked with the kaizen philosophy (Bastos, 2008). The just-in-time approach requires a company's inventory levels to be kept to a minimum while only creating the things that must be produced at the right time. The Kaizen concept enables to put this principle into practice by encouraging a continuous improvement culture that fosters waste reduction, increases productivity, and promotes innovation (K. Institute, 2018c; Ohno, 1988).

Organizations can succeed over the long term by continuously enhancing their processes and providing their clients with more valuable services through developing a Kaizen culture, which will lead to better quality, shorter lead times, and ultimately more customer satisfaction (Imai, 1986).

## 2.2 Kaizen Fundaments

The Kaizen methodology is grounded in five core principles that aim to establish a culture of continuous improvement. These principles are intended to engage all individuals within an organization and encourage collaboration and involvement in the proposed solutions to achieve the goals defined in the diagnosis phase.

### *Creating Value for the Client*

Every organization is built around the consumer, and offering a great customer experience is critical to long-term success. To reach this goal, organizations must deploy their resources wisely to value-added activities that improve the entire customer experience.

Eliminating muda (or waste) from the manufacturing process is an important first step in this approach. Organizations may enhance the performance of activities that consumers are willing to pay for by identifying and deleting activities that do not offer value to the customer. As a result, consumer happiness and loyalty may rise.

Furthermore, adopting a customer-centric strategy may have several advantages for firms, including greater brand reputation, market share, and income. Organizations may differentiate themselves by emphasizing the client experience (Imai, 1986).

### *Flow Efficiency*

The concept of "flow efficiency" is fundamentally based on the elimination of activities that do not add value i.e., the elimination of waste (muda) (Nawras, 2017). The Kaizen methodology is dedicated to relentlessly pursuing the eradication of muda and the improvement of efficiency and is grounded on the seven muda principles.

1. Overproduction: The concept of overproduction denotes that the production of a specific item should occur solely upon receiving a customer order, as the customer is unlikely to bear the cost of surplus production.
2. Defects: defects always involve loss of resources or rework, which leads to increased production costs for the company.
3. People waiting: waiting times for people can be caused by a variety of factors such as failures, set-ups, or activity misbalancing and constitute a waste of manpower in useful time, contributing to process inefficiencies.
4. Overstocking: excess stocks of intermediate products and finished goods do not add value to any operation and cause the loss of space in the institutions.
5. Movement of people: the movement of people that arises associated with the inefficiency of the layout adds no value to production.
6. Movement of materials: as with the movement of people, the movement of materials is also wasteful in the sense that the material is not being transformed.
7. Overprocessing: the allocation of human and material resources to tasks that will not be valued by the customer represents a waste for the organization.

The detailed analysis of all activities and the mapping of added value and non-value-added tasks enables the company to act against inefficiencies with the ultimate aim of reducing lead time and optimizing the use of resources and manpower (Imai, 1986).

### *Efficiency in the Gemba*

Gemba is a Japanese term that means the place where value is added and is typically referred to as the shop floor in manufacturing settings. Gemba becomes a key driver of continuous improvement activities due to the expertise, and experience of all people of the different sectors.

The Kaizen philosophy promotes a customer-centric perspective that aligns organizational goals with the needs and expectations of end-users by emphasizing Gemba as the focal point

for improvement due to the fact that is in the Gemba that all processes occur (A. Munro, 2015; Imai, 1986).

### *Involvement of People*

The kaizen methodology leverages the expertise of every individual, from top management to Gemba workers, and uses the combined experience to introduce a culture of continuous improvement focused on both company strategy and process improvement.

For each level of the organization, tools are provided to guide managers and employees in assigning improvement-oriented responsibilities. The top management will prioritize focusing on improving the business strategy and employee motivation. Middle management is going to emphasize process improvements, and co-workers will have the opportunity to use their knowledge and experience to improve team and process performance through the use of daily kaizen (Coimbra, 2013; Imai, 1986).

### *Visual Management*

Visual management is a powerful methodology that can help organizations improve their processes and achieve their goals. This method involves presenting information as graphics or images and is typically connected to the implementation of colour-coding schemes.

The effectiveness of visual management as a communication technique is shown by the quickness and simplicity with which information can be exchanged and anomalies can be identified, making it a very effective tool for problem-solving and communication inside organizations.

The Kaizen methodology employs visual management techniques for analysing process indicators, organizing workspaces, and establishing activity standards to facilitate the comprehension and analysis of displayed information (A. Munro, 2015; Imai, 1986).

## 2.3 Kaizen Business System Model

The Kaizen Business System (KBS) is the model used to implement all the solutions discovered during the diagnosis phase. It is backed by two primary pillars, as shown in Figure 1: the growth model and the operations model, when equipped with the appropriate tools, may give an orderly and systematic approach to implementing the previously described principles.

This management framework is primarily intended to foster continuous improvement and growth across all business sectors. It aims to improve process efficiency, productivity, communication capacity, and motivation among all stakeholders.

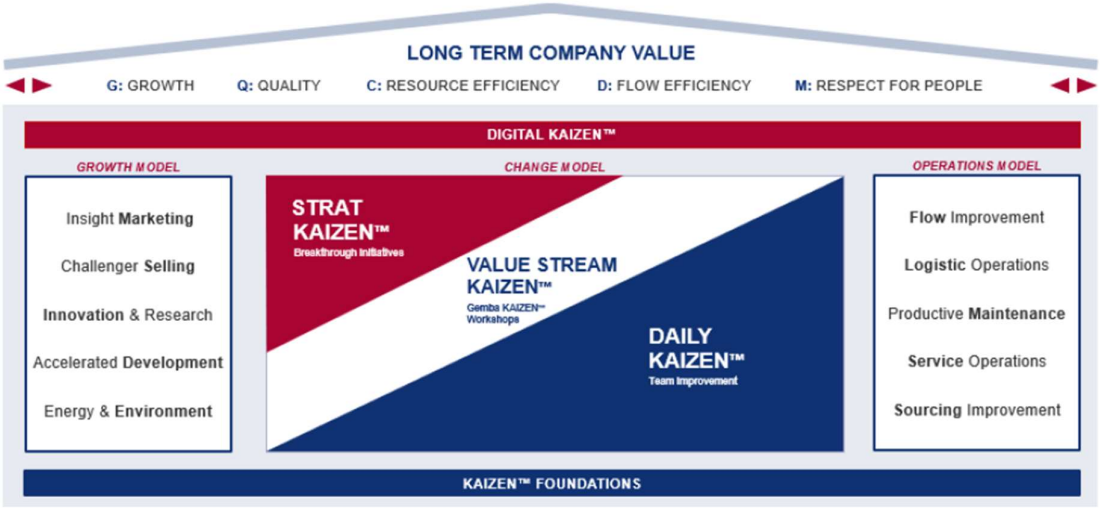



Figure 1 - Kaizen Business System Model(K. Institute, 2019)

Furthermore, the KBS plays an important role in stimulating the development of relationships between the company, its suppliers, and its customers. The KBS facilitates existing customer relationships and improves the level of service provided by improving processes and delivery times, as well as structuring working methods and increasing information transparency (K. Institute, 2019).

### 2.3.1 Growth

The growth model, as previously stated, is one of the fundamental pillars that support the KBS. This model is divided into five major growth areas (Insight Marketing, Challenger Selling, Innovation & Research, Accelerated Development, Energy & Environment) with an overall objective of improving sales performance, prioritizing innovation, and product development, all while minimizing the organization's ecological footprint (Imai, 2004; K. Institute, 2019).

### 2.3.2 Quality-Cost-Delivery (QCD)

The operating model (QCD) is applied on several fronts, including flow improvement, logistics operations, productive manufacturing, service operations, and sourcing improvement.

Each of these considerations relies on tools to improve the performance of the company. Only the tools utilized in the Total Flow Management (TFM) will be taken into account as this is the model employed in the project under consideration.

*Total Flow Management (TFM)*

Total Flow Management is an operational management concept that optimizes the flow of materials, information, and resources through the optimization of a manufacturing process. It

is a comprehensive approach that aims to improve overall system efficiency rather than focusing solely on individual parts or stages.

TFM entails analysing the entire process, from raw materials to finished goods, and identifying bottlenecks, delays, and waste. Following the identification of these areas, strategies for improving the flow of materials and information, eliminating unnecessary steps or processes, and reducing lead times are developed.

The use of real-time data to monitor and control the flow of materials and information is one of the fundamental principles of TFM. This enables businesses to make informed resource allocation, and task prioritization decisions and identify potential problems before they occur (Imai, 2004; K. Institute, 2018d).

Essentially, there are three major areas in flow implementation: production, internal logistics, and external logistics as can be visualized in Figure 2.

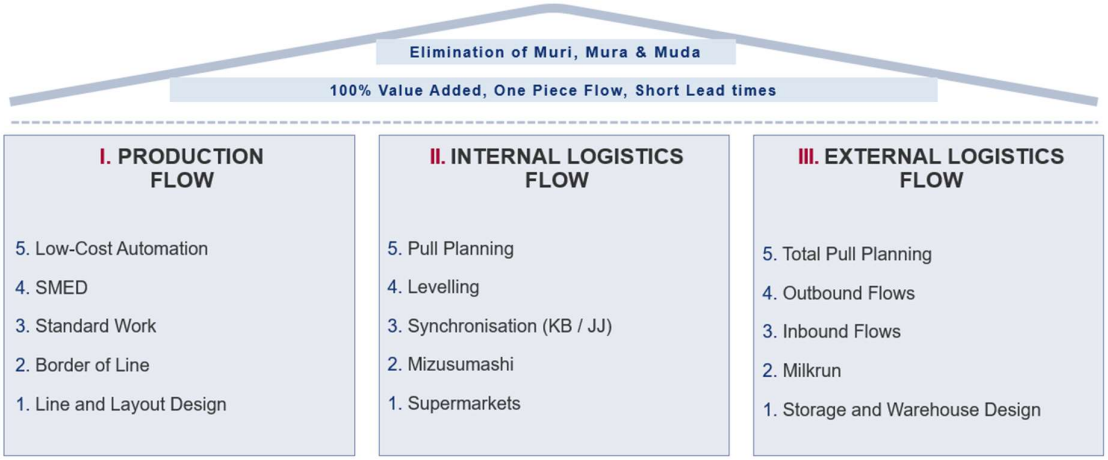



Figure 2 - Operational Model: Quality-Cost-Delivery(K. Institute, 2018d)

**Production flow**

Production flow implementation consists of small improvements and automation that provide very high gains and reduced costs. The tools used in the solution proposed for the flow improvement are described next.

Layout reorganization

One of the most important steps in enhancing and transforming operations is the restructuring of the production layout. It is crucial to distinguish between two basic sorts of layouts: functional/traditional layout and cell layout, to understand this reorganization in greater detail.

The functional or traditional layout is characterized by processes that are broken down into discrete tasks like raw material preparation, pre-assembly, assembly, and final quality control. This division, which is often both physical and conceptual, has a substantial impact on the company's lead time and results in high intermediate stocks, extra transportation, and limited visibility of the supply chain. The main consequences of this layout are overstocking and overproduction (Rother & Harris, 2001).

The cell layout is characterized by an emphasis on process visibility and the implementation of unit-flow production. In essence, this layout encourages collaboration and cross-station support since it makes the entire process visible. Additionally, stations are sized according to the tasks being carried out, which maximizes production efficiency (Coimbra, 2013).

The adoption of the cell layout (Figure 3), which is typically implemented in either a linear or "U" shape, facilitates the reduction of stocks, movements, and lead time, thus enhancing overall

production efficiency and productivity while improving process visibility. Additionally, this layout ensures that the management of all sub-processes is simpler and easier to analyse.

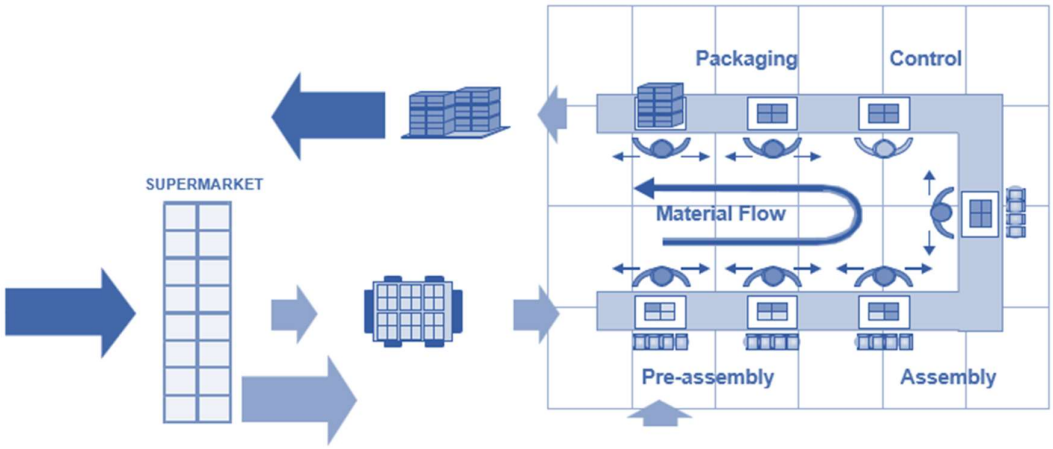



Figure 3 - Cell Layout (K. Institute, 2018d)

Line-boarding

The primary objective of the boarder of line is to act as an intermediary between production and internal logistics by furnishing operators with the requisite materials for their operations. It should therefore be designed in a way that minimizes moves and improves supply optimization.

Line side replenishment can either be continuous or sequential, with the kanban or junjo systems respectively. In the kanban system, material replenishment is triggered by material consumption, whereas in the junjo system, materials are supplied in accordance with the order of production (Coimbra, 2013).

Task standardization

Standardization of activities helps in increasing the ability to sustain the improvements applied. This advantage arises from the continuous application of the specified standards since standards are the simplest, most visual, clearest, and most accessible way to perform the task.

Standards ensure that all the information required to do a particular task is easily accessible and set the most efficient and effective approaches for conducting operations. These standards also make it easier to train new employees and reduce variability between employees (Imai, 2004; K. Institute, 2018d).

Single Minute Exchange of Dies (SMED)

SMED is a methodology that focuses on reducing the set-up time between different manufacturing processes. The purpose of SMED is to reduce or eliminate non-value-added time during a changeover process.

The SMED methodology comprises three distinct stages. Firstly, the identification of actions that can be performed during the operation of the machine (external setup) and those that require the machine to be stopped (internal setup). The objective is to minimize the non-value-added time of internal setup by completing as many activities as possible during the external setup phase. Figure 4 shows a schematic representation of this methodology.

Secondly, it is determined which of the internal task can be performed in the external phase. This may involve the design and development of fixtures or tools that can be rapidly attached and detached from the machine or the modification of the machine's design to provide easier access to the parts that need to be changed.

By implementing these two steps, the time needed for the internal setup can be greatly reduced. The third and final stage involves streamlining all aspects of the changeover process, such as organizing tools and materials to minimize search time or developing checklists to ensure that all necessary steps are completed in the correct order (K. Institute, 2018d; Shingo, 1983).

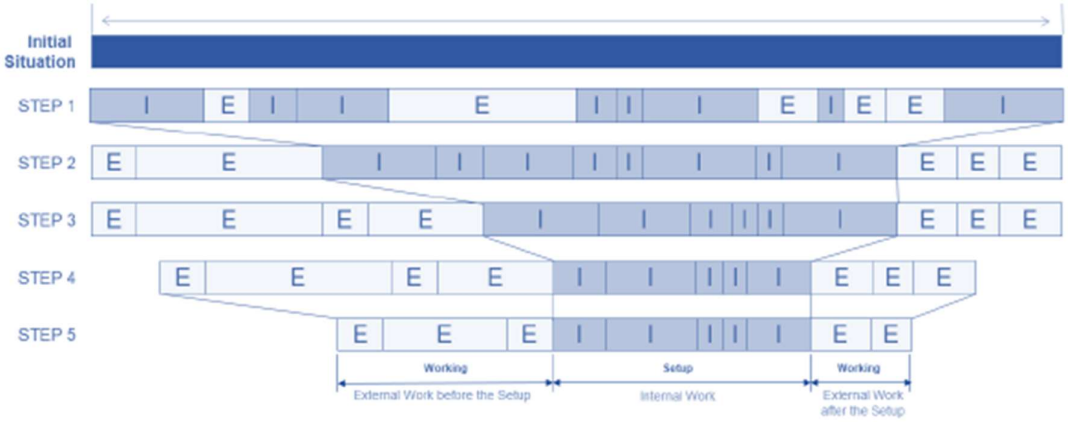



Figure 4 - Evolution of the implementation of the SMED (E: external work; I: internal work)

Low-cost automation

Low-cost automation is usually applied if there is a significant gain in this change, where the implemented effort is reduced. In other words, these automatons are usually simple mechanisms that take advantage of gravity to facilitate the movement of parts (Coimbra, 2013; K. Institute, 2018d).

**Internal Logistics**

Effective internal logistics management is critical to the success of any organization. It entails coordinating and managing the movement of materials, resources, and goods within a company. The purpose is to maximize resource utilization, reduce costs, and increase productivity. An organization can gain a competitive advantage in the market, maintain high levels of customer satisfaction, and improve overall efficiency by effectively managing these processes.

Supermarkets

The supermarket system operates on the "pull" principle, implying that materials are only replenished after consumption. Essentially a supermarket is a storage area with easy picking access and duly identified using visual management. The main goal is to reduce lead times, prevent overproduction, and enhances inventory management (Coimbra, 2013; Imai, 1986).

Mizusumashi

Mizusumashi is a logistics train that operates in multiples of takt time, and its primary function is to ensure the replenishment of various production sectors. By employing a well-designed logistics train, the flow of production can be optimized, and shortages of raw materials can be prevented (Coimbra, 2013).

Levelling and Synchronisation

In operations management, levelling is a complex procedure requiring meticulous analysis and alignment of various tasks. It is a strategic endeavour intended at optimising resources and enhance operational efficacy, which, in turn, guarantees the smooth administration of the organisation. This principle becomes especially relevant when it comes to the implementation of unitary flow.

Synchronisation in unitary flow refers to the arrangement and coordination of tasks in a manner that minimises the waiting times of the individuals and materials involved. It involves ensuring that the appropriate duties are performed at the appropriate times, by the right individuals or machinery, and in the correct sequence. This results in reduced downtime, increased output, and a more efficient process flow.

Pull Planning

Pull planning is a logistics management technique aimed at increasing the efficiency of material flows across the supply chain. This approach requires collaboration among suppliers, retailers, and manufacturers to ensure optimal inventory levels, without relying on sales forecasts or estimates. Essentially, the production volume is dictated by demand, leading to greater agility and adaptability for businesses in response to changes in demand. Pull planning enables businesses to avoid risks and expenses associated with overproduction or stockouts by monitoring inventory levels and making necessary adjustments to production and transportation schedules, thus minimizing customer dissatisfaction.

Moreover, pull planning can significantly reduce lead times by prioritizing the production and transportation of goods only when necessary. This approach eliminates the need for excess inventory and lead times (Coimbra, 2013).

### External Logistics

At the level of external logistics, having a well-defined warehouse design and selecting the most appropriate means of transportation for inbound and outbound activities, along with choosing an optimal route, are crucial. Adopting a pull planning approach that encompasses both internal and external logistics is essential for the smooth functioning of the entire organization.

### 2.3.3 Kaizen Change Management (KCM)

The implementation of process improvements is often accompanied by challenges such as resistance to change inherent in human nature and the need to break entrenched paradigms within an organization. To successfully implement disruptive ideas, a consistent change management model is essential.

The Kaizen methodology employs its change management model, known as the KCM framework. This framework is applied through three distinct methodologies, namely: Daily Kaizen, Breakthrough Kaizen, and Leader's Kaizen. Each methodology serves a specific purpose in driving continuous improvement within an organization.

*Daily Kaizen*

The Daily Kaizen methodology involves making small incremental improvements to processes daily. This methodology is focused on empowering employees to identify and implement small changes that can lead to significant improvements over time.

Daily Kaizen Level 1

The first stage focuses on improving team communication by providing transparency and a better flow of information.

Initially, the main objective is to create a work method for the team, disciplining them to have daily meetings and to communicate clearly and regularly. It is proposed to develop daily Kaizen boards with information on three major areas: people, performance, and continuous improvement.

The board allows a better organization and planning of the work (individual and collective) ensuring a good balance of workload and effective prioritization of tasks. In addition, it provides an overview of the performance and facilitates taking the initiative for improvement actions when analysing indicators.

The meeting should take place every day at a fixed time and with a short duration. The meeting agenda must adhere to be efficient and address the issues in a succinct format. It should take place discussion about the main issues of the previous day fostered by the analysis of key performance indicators. This meeting is also a moment to share ideas namely about improvements that could be done and use the PDCA cycle to act and follow the progression(K. Institute, 2018b).

Daily Kaizen Level 2

In an effort to increase productivity, the main focus of daily kaizen level two is organizing workspaces by applying visual management tools namely the 5S methodology (Imai, 1986).

A 5S methodology is a systematic approach to organizing and improving the workplace environment. The 5S stands for 5 Japanese words:

1. Seiri (Sort): The first step is to sort through all items in the workspace and remove any unnecessary items. This step helps to reduce clutter, eliminate waste, and create a more organized environment.
2. Seiton (Set in order): The second step involves logically organizing the remaining items to be easily found and accessed when needed. This includes creating a designated place for each item and labelling them appropriately.
3. Seiso (Shine): The third step is to thoroughly clean the workspace, equipment, and tools. This helps maintain a clean and safe working environment, improve equipment lifespan, and prevent accidents.

4. Seiketsu (Standardize): The fourth step involves creating standard procedures and guidelines for maintaining the first three steps. This helps to ensure that the workspace remains organized and clean over time.
5. Shitsuke (Sustain): The final step involves implementing regular checks and audits to ensure that the first four steps are being followed and maintained over time. This helps to embed the 5S methodology into the workplace culture and ensure that improvements are sustained in the long term.

The decongestion of the workplaces brings some advantages that contribute to the increase in productivity, such as reducing time spent searching for tools and materials, better use of the equipment and raw material, and increased motivation of employees (Imai, 1986, 2021).

This step also provides the ideal conditions for the next levels of daily kaizen, namely the standardization of activities, as it provides a more organized and controlled environment that facilitates the operators' tasks and subsequent standardization (K. Institute, 2018b).

Daily Kaizen Level 3

In level 3 of Daily Kaizen, the aim is to standardize by adopting the most effective methodology and make it a common practice, reducing the variability that eventually arises from different working methods.

Standardization of activities also helps in increasing the ability to sustain the improvements applied. This advantage arises from the continuous application of the specified standards since standards are the simplest, most visual, clearest, and most accessible way to perform the task.

Daily Kaizen Level 4

The fourth level focuses on problem-solving, simplification, and optimization of flows by following a structured problem-solving methodology called Kobetsu Kaizen.

In this phase, the teams should focus on eliminating any waste that can still be mitigated by, for example, improving standards. It can be expected that at this stage the teams are autonomous and can use continuous improvement tools for both processes and tasks (Imai, 1986; K. Institute, 2018b).

### *Breakthrough Kaizen*

The Breakthrough Kaizen methodology, on the other hand, is used to address larger, more complex issues that require a more in-depth analysis. This methodology involves a cross-functional team working together to identify and implement improvements.

Breakthrough Kaizen events are executed using a four-stage improvement cycle which includes Mission Control Room (MCR), Kaizen events, event closing, and value review.

The MCR is a room where Mission Control is held periodically - a meeting whose purpose is to assess the status of the project, identify difficulties and plan the next steps. This room holds several project management elements visually displayed to allow for a clear follow-up of the state of the project (K. Institute, 2018a; Schipper & Swets, 2010).

### *Leader's Kaizen*

Finally, the Leader's Kaizen methodology is focused on building a culture of continuous improvement within an organization. This involves leadership demonstrating a commitment to continuous improvement, setting clear improvement goals, and providing the necessary resources and support to enable employees to achieve these goals. By utilizing these three methodologies, organizations can effectively implement the Kaizen methodology and drive continuous improvement at all levels of the organization (Imai, 2004).

## 2.4 Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is an all-encompassing performance metric with considerable significance in manufacturing processes. With its ability to evaluate and enhance process efficiency, OEE has become an indispensable tool for organizations pursuing continuous improvement and diagnostic insights. OEE is computed by multiplying three variables: availability, productivity, and quality (Ondokuz et al., 2010; Pedro & Rodrigues Da Silva, 2013). The calculation formula for OEE is as follows:

$$OEE = Availability \times Productivity \times Quality \quad (1)$$

This formula yields a single value between 0 and 1 that represents the overall efficacy of the equipment or process. A higher OEE indicates a higher level of efficacy, whereas a lower OEE indicates that one or more of the factors could be improved.

When it comes to controlling this KPI, organizations gain a variety of advantages. First, it enables the identification of areas of the production process that are underperforming. By meticulously analysing OEE data, businesses gain valuable insight into specific bottlenecks, inefficiencies, and constraints that inhibit productivity. This knowledge enables them to prioritize development efforts and allocate resources effectively, assuring a targeted strategy for enhancing the overall efficacy of the equipment.

In addition, a KPI functions as a benchmark for establishing attainable goals. By establishing baseline values, organizations can establish achievable availability, performance, and quality objectives. These objectives provide organizations with a road map for development initiatives, enabling them to measure their progress over time. With defined objectives in place, efforts to improve OEE become more focused and purpose-driven, resulting in measurable and enduring process efficiency improvements.

OEE is essential for fostering a culture of continuous improvement within organizations. OEE functions as a catalyst for continuous optimization by providing quantifiable data on the efficacy of development efforts. It serves as the basis for implementing Lean manufacturing principles, Six Sigma methodologies, and other improvement strategies. By continuously monitoring and analysing these metrics, organizations can identify emergent trends, implement targeted corrective actions, and cultivate a culture in which process optimization is ingrained in the culture of the organization.

In addition to its function in process enhancement, OEE is a valuable diagnostic tool for identifying operational problems. By examining the various components of OEE, organizations can obtain a deeper understanding of inefficiencies and abnormalities in their processes. As part of the availability component, for instance, the analysis of interruption events and their causes enables organizations to identify equipment failures, changeovers, and maintenance activities that contribute to production disruptions. With this information, organizations can take immediate corrective measures to minimize equipment downtime and maximize equipment availability.

Furthermore, the OEE performance analysis reveals areas where the output of the equipment falls short of its utmost potential. This in-depth analysis assists organizations in identifying factors that contribute to low performance, such as equipment inefficiency, suboptimal production processes, and operator skill disparities. Armed with this knowledge, organizations can implement targeted enhancements to increase production rates, optimize equipment performance, and ultimately increase overall equipment effectiveness (Kasim et al., 2015).

Lastly, OEE incorporates the quality factor, which helps organizations assess defect rates and identify opportunities for improvement. By comparing the number of defect-free products or units produced to the total number of units produced, organizations can determine where quality control is lacking.

# 3 Initial State

## 3.1 Value Stream Analysis

This chapter includes an overview of the current situation as well as a detailed description of operational methods. As previously stated, the evaluation of the initial state is performed through the Value Stream Analysis. The goal of this diagnostic phase is to identify the major challenges, develop a future vision, plan alternative solutions, and quantify the projected benefits.

An extensive value stream mapping effort was conducted collaboratively with a multidisciplinary team, encompassing all operational activities, intermediate inventory levels, as well as inspection and quality control stages. The resulting Figure 5 combines the data from this extensive investigation. This value stream mapping project introduces the operational method of the company, offering useful insights into the flow of material and promoting an in-depth understanding of the present circumstances.

Figure 5 - Value Stream Mapping

Following the study of the preceding process, it is clear that a substantial number of inefficiencies exist. These inefficiencies take the shape of intermediary stocks that inhibit the uninterrupted progression of operations.

The present phase included an effort to systematically identify the main concerns and organize them into different areas to focus solutions on the critical aspects. These areas will now be explored in the following sections.

## 3.2 Planning

The organization currently employs a mostly manual method for its strategic planning, with no assistance from specialist tools or technologies. This approach, although traditional, raises considerable concerns, chiefly owing to its implications for the efficiency and accuracy of the planning process.

The absence of digital tools limits visibility into the manufacturing process and cycle times, a key disadvantage of this method. Without the capability of an automated system to regularly monitor, collect, and analyse vital data, it is more difficult to identify production constraints, inefficiencies, and improvement opportunities. This lack of transparency not only hinders informed decision-making but also complicates the deployment of effective process improvement initiatives.

Achieving optimal planning necessitates a clear understanding of both the process and product maturity to ensure effective adjustment for production. However, the business has encountered several difficulties in this area, particularly in engineering solutions and departmental communication.

A pressing issue has been the lack of standardization across the manufactured generators. This dearth of regularity in completed items causes discrepancies, making quality control difficult to meet consumer expectations. Production disparities are made worse by inconsistencies, which are linked to mechanical, electrical, and technical failures.

Changes in production references often trigger issues during the initial assembly process due to the absence of an updated bill of materials for each generator and their respective assembly instructions. The subsequent need for extensive rework introduces inefficiencies, impeding the smooth conduct of production processes.

Additionally, the practice of adjusting orders to align with the current manufacturing batch, even at the cost of overproduction, leads to significant resource wastage. This includes not only raw materials but also valuable labour hours and operational costs. The gap between orders and actual production capacity widens due to the absence of a systematic, data-driven approach to planning.

Another challenge lies in the disorganization and absence of structure in the current planning process. Without a defined approach and set planning principles, it becomes arduous to identify priorities, manage resources efficiently, and prevent schedule conflicts. This structural weakness can potentially result in delivery delays, customer dissatisfaction, and missed business opportunities.

The manual approach also increases the susceptibility to errors and inefficiencies since managing large datasets and tracking dependencies becomes cumbersome without a system to enforce planning rules and constraints. As a result, the company has struggled to streamline manufacturing operations and optimize resource allocation effectively.

It is clear that for the company to elevate its production capability and address the existing challenges, a strategic shift towards adopting modern, digital tools for planning and operation is needed. The implementation of such tools, accompanied by the necessary training and change management, could significantly enhance visibility into the production process, improve decision-making, and ultimately increase overall efficiency.

## 3.3 Metal Mechanics Section

The manipulation of sheet metal, particularly through cutting and bending techniques, falls under the domain of metal mechanics' section. These operations necessitate the use of one cutting machine and two bending devices. For diverse operational requirements, bending equipment is available in both manual and automatic varieties.

The centrepiece of this section is a high-precision machine manufactured by Salvagnini. Salvagnini is a globally renowned brand in sheet metal fabrication and refining equipment. The automotive, aerospace, and electronics industries make extensive use of their cutting-edge devices.

The products of Salvagnini are renowned for their innovative design and cutting-edge technology. These sophisticated machines, which are enhanced by automation and adaptability, expedite the process of fabricating sheet metal, and maximize output. In this industry, Salvagnini's extensive selection of panel benders, perforation machines, fibre laser cutting machines, and shearing machines makes them a veritable force.

Due to the existing method of bulk production, the metal mechanics section of the company faces limitations in fully maximizing the utilization of metal sheets. The manufacturing process of generators necessitates the incorporation of numerous components, which are available in various sizes and configurations.

Currently, the cutting of metal sheets occurs in batches, and the company lacks functional software capable of optimizing the allocation of parts, leading to suboptimal nesting arrangements. The opportunity to nest smaller parts more effectively is constrained by the optimization of metal sheet consumption, which only considers cutting the same area of the generator.

Consequently, the company has incurred significant financial losses amounting to €1.8 million due to the inefficient utilization of metal sheets, resulting in wastage of raw materials.

The manual readjustment process in sheet metal cutting is characterized by time-consuming procedures, susceptibility to human errors, and inefficiencies. To achieve optimal fit and minimize gaps, it is necessary to visually inspect, measure, and physically manipulate metal components. However, this manual method proves to be inefficient due to several factors.

First, manual readjustment is time-consuming, especially when dealing with items with intricate shapes or designs. Often, multiple trial-and-error iterations are required to achieve the intended layout, resulting in increased production time.

In addition, manual processes produce inconsistent results. Inaccurate alterations can result in suboptimal layouts, increased material waste, and a reduction in overall yield. The lack of precision and standardization inherent in manual adjustments contributes to inefficiency.

Moreover, manual readjustment increases labour expenses. The readjustment duties necessitate the use of skilled labour, which increases the total cost. If the procedure were automated, the time spent on manual readjustment could be allocated to activities with greater value.

Furthermore, manual readjustment is not scalable. As production volumes increase or more intricate cutting patterns are introduced, manual operators face increasing obstacles to effectively managing their workload. Manual process limitations hinder the scalability of sheet metal cutting operations.

Finally, human operators may lack the analytical skills required to determine the layout that minimizes material waste while maximizing efficiency. Depending solely on intuition and experience may not always result in the best outcome. In the absence of sophisticated analysis tools and optimization algorithms, it is more difficult to maximize yield and minimize waste.

## 3.4 Painting Section

The painting section plays a crucial role in the protective treatment of all metal components used in the assembly of a generator, including those that are not visible from the exterior. This exhaustive and detailed approach to painting is essential, as any unprotected component may oxidize over time, compromising the material's durability and functionality.

The painting process consists of three distinct phases: cleansing, painting, and curing.

During the initial phase, every component is subjected to a thorough cleansing procedure in which an acidic solution is used to remove any surface impurities. Compressed air is used to rinse the components in this system, ensuring that they are not only clean but also completely dry and ready for the subsequent painting phase.

Components are presented to the painting process in the second stage, the painting zone. This phase relies significantly on automation, with three automatic paint weapons at the helm. In addition, the presence of two painters ensures that each component receives a comprehensive and uniform application of paint, thereby guaranteeing an excellent finish.

The painted components are then transferred to a specialized furnace for the curing process. These components remain in the furnace for a predetermined amount of time, enabling a full combustion cycle. This step reinforces the paint's adhesion and durability, forming a robust layer of protection against environmental factors and potential oxidation.

The painting section of the company has encountered several challenges in the process of painting the generator components. The manufacturing process involved batch-cutting the generator parts, which were then hung on a line for painting at a pace of 0.8 meters per minute.

Due to the previous batch-oriented strategy, the painting area was underutilized, resulting in time and resource waste. The inefficient use of the available painting line resulted from the inefficient sequencing and allocation of the parts. As the subsequent analysis (Figure 6) demonstrates, the effective area utilization was extremely low.

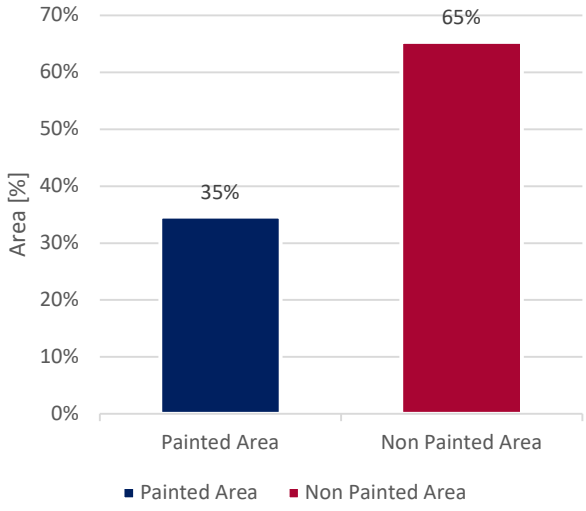



Figure 6 - Added Value vs Non-Added Value Analysis of the Painted Area

A dearth of optimization in sequencing and allocation has manifested in several negative outcomes. Initially, insufficient utilization of the painting line has resulted in unwarranted delays in the painting process. Consequently, the overall production cycle for the painted components has been extended, negatively affecting the lead time.

Secondly, the inefficient allocation of parts on the painting line has led to an inconsistent flow of work, causing disruptions and bottlenecks within the painting section. This inconsistency further hampers productivity and increases the likelihood of errors or oversights during the painting process.

In addition, the suboptimal current method has resulted in poor utilization of available resources, such as paint, equipment, and labour. This has resulted in increased costs and a decline in the painting section's overall efficiency.

Apart from the absence of efficiency in the allocation of parts, two other concerns have been observed: a significant frequency of line stoppages and underutilization of the line's maximum speed.

Firstly, the operators in the painting section frequently encounter difficulties with the tool and piece retrieval. Without a well-organized system for storing and locating tools and components, operators waste valuable time seeking the required items. This additional time spent seeking contributes further to the delays and interruptions in the painting process as demonstrated in Figure 7.

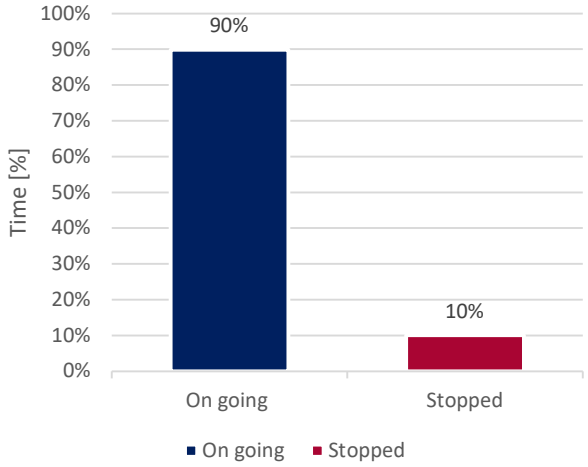



Figure 7 - Added Value vs Non-Added Value Analysis of the Interruptions of the Painting Line

Secondly, it has been determined that the painting line is not operating at its optimum capacity. In this case, the time it takes to bake the components in the oven is the limiting element that determines the pace of the line. Nonetheless, it is important to note that the specified pace is significantly slower than the estimated maximal value of approximately 1.2 meters per minute.

Despite being recognized as one of the most critical sections, process indicator control has not been executed in the company. At the beginning of the Kaizen project, an Overall Equipment Effectiveness (OEE) analysis was conducted to monitor the performance of the painting line.

Neglecting to control OEE and process indicators has repercussions. Essentially it hinders the capacity to identify and address inefficiencies or constraints, thereby impeding process optimization opportunities.

Additionally, the absence of control restricts the accurate measurement and comparison of performance over time, thereby hindering the ability to implement targeted enhancements. Without effective monitoring of OEE and process indicators, the company may not be able to maximize productivity, quality, and operational performance on the painting line.

## 3.5 Pre-assembly Section

The Pre-assemblage Section of the manufacturing process plays an important role in the preliminary assemblage of individual components that will ultimately be incorporated into the generator on the primary assembly line. This section is mainly responsible for the pre-assembly of a few minor assemblies with accessories such as door hinges and locks, as well as the final assembly of the chassis. This stage initiates once the individual parts have been duly painted.

It is essential to observe, however, that the pre-assembly process cannot begin immediately because the painting and cutting operations of the generator components are not implemented in an one-piece flow system. Before beginning pre-assembly, it is necessary to allow sufficient time for all the components to complete the baking process.

Not only is the pre-assembly section responsible for the initial assembly of generator components but also for the incorporation of insulation materials within these components. Specifically, the insulation materials include foam and wool, which are custom-tailored in this section to suit the exact dimensions of the generator that is being manufactured.

During the final phases of pre-assembly, these custom-sized insulating materials are adhered to the roof, entrances, and sides of the generator, among other components. The placement of these materials is intended to ensure that the final product has superior noise insulation.

The current methodology frequently generates a significant amount of intermediate stock. Additionally, this procedure facilitates the emergence of deviations. As parts undergo multiple transport stages and manual handling, they are susceptible to potential damage, such as scratches, which degrades the quality of the result. This is primarily due to the fact that each additional transport or handling phase introduces an additional opportunity for defects to occur.

A careful evaluation of the operational dynamics inside the pre-assembly section reveals numerous frequent issues that are negatively affecting the overall efficiency and productivity of this phase. The primary concerns are the excessive accumulation of intermediate stock, the substantial amount of time spent locating materials, and the absence of a systematic and organized working method. The VA/Muda analysis is summarised in Figure 8.

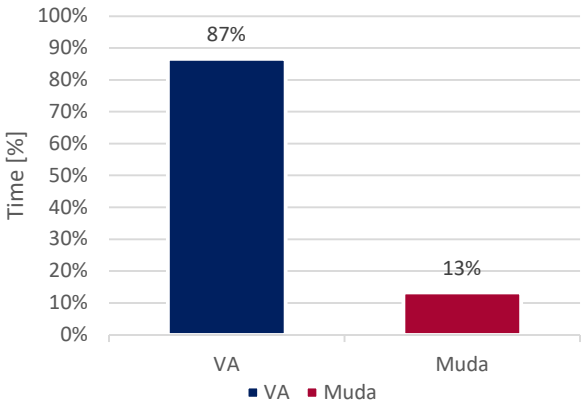



Figure 8 - Added Value vs Non-Added Value Analysis of the Pre-Assembly Section

These issues stem primarily from the suboptimal sequencing of parts on the painting line, which is a result of bulk metal cutting, in addition to an inadequately structured work environment and a lack of workspace organization. Essentially, the absence of one-piece flow process in this section results in inefficiencies and non-conformities. These procedural inefficiencies force the organization to undertake significant rework in addition to increasing expenses.

## 3.6 Assembly Line

Prior to the beginning of the Kaizen project, the assembly line was characterized by several operational inefficiencies and systemic obstacles that had the potential to inhibit productivity, quality control, and overall satisfaction among workers. The organization used a compartmentalized approach to task execution, with operators trained and assigned to specific duties.

This method resulted in a lack of knowledge sharing and collaborative problem-solving among the operators, which could lead to substantial delay and productivity loss. If an operator was absent or unable to perform their assigned task for any reason, there were no readily available replacements, leading to the possibility of costly bottlenecks.

One issue that stood out was the absence of designated workstations for particular tasks. This absence of delineation not only resulted in a chaotic and unpredictable workflow but also reduced the physical space. Because all the border of line materials were allocated at the end of the assembly line. This compression meant that operators frequently had to move more than necessary, which increased the risk of fatigue, decreased productivity, and created a less ergonomic workplace.

The absence of visibility and transparency regarding assembly line progress exacerbated these problems further. Without a clear comprehension of completed tasks, there was a substantial danger of duplication of effort, missing steps, and unsolved errors. This intransigence could result in frustration and confusion among operators, thereby diminishing their overall job satisfaction. Without accurate visibility, it was difficult to identify constraints, quality issues, and improvement opportunities. This compartmentalized, unstructured, and opaque operational approach was likely to undermine the performance of the assembly line, compromise product quality, and hinder progression opportunities.

Another significant obstacle on the assembly line was the immaturity of the mechanical design of the assembled products. Inadequacies and errors in the engineering design were prevalent, resulting in significant assembly process disruptions. As a result of these design defects, an already challenging assembly line process became even more complicated. The operators, who were predominantly proficient in specific duties, frequently encountered unanticipated problems resulting from these design defects.

Additionally, the assembly line was complicated by the variety of product models. Significant differences between each model necessitated a thorough and adaptable understanding of each product, which was difficult to acquire due to the absence of knowledge sharing and standardization of assembly procedures.

This situation was exacerbated by the lack of formal assembly standards, which made it more challenging to ensure consistent, high-quality assembly across all product models. Without these standards, each operator may approach the assembly of a particular model differently, resulting in differences in the quality of the final product, inefficiencies, and even potential safety risks.

In essence, the underdeveloped mechanical design of the products, combined with the wide variety of models and the absence of assembly standards, created a challenging and unpredictable assembly line environment. This complexity contributed to a variety of operational issues, including an increase in error rates and a decline in product quality, inefficiencies in workflow, and an insufficient number of standardized procedures. It also emphasizes the need for interventions aimed at enhancing product design, standardizing assembly procedures, and enhancing operator knowledge sharing.

An intervention was required to rectify these problems, expedite assembly line operations, and cultivate a more collaborative, structured, and transparent workplace.

## 3.7 Electrical Section

An important section of the company under consideration is responsible for manufacturing switchboards, engine and alternator wiring, relays, and QTCs.

The essential challenges linked with this sector are mostly based on a lack of structure and space, which is heavily driven by overproduction. The department operates on an ad-hoc basis and produces the necessary components for weekly duties. However, in the absence of a balanced activity plan, the team manufactures excess components for supply during the remaining time. This excess production for inventory not only dissipates resources but also causes congestion in the workplace, thereby limiting productivity and operational efficiency.

Another source of inefficiencies is a lack of information on extra parts that may be included in purchase orders. This information disparity results in superfluous revisions prolongs the delivery of products to the assembly line, and ultimately delays the generator's production and shipment. Therefore, this circumstance is likely to have a negative impact on customer satisfaction and may result in lost business opportunities due to prolonged delivery times.

In terms of both physical infrastructure and personnel hierarchy, the department's organizational structure exhibits clear deficiencies. The division lacks an authoritative leader who can effectively communicate supply chain-related information. In the absence of such leadership and explicit communication channels, erroneous information, unaccounted-for issues, and operational inefficiencies may result.

This disorderly and unorganized environment in a crucial production division may have a negative impact on the overall productivity and efficiency of the entire organization.

## 3.8 Quality Section

This section consists primarily of thorough inspections of all component connections and the identification and correction of remaining defects. Particular attention is paid to details such as the paint job and the omission of unnecessary components from the assemblies.

This quality control department encounters one of its greatest obstacles in the inconsistency of the verification methods employed. Due to the noticeable absence of standardized work procedures, there is no assurance that all relevant aspects will be inspected at this stage. This deficiency of standardization not only results in divergent operator interpretations of nonconformities but also inconsistencies in control measures and total task duration. These discrepancies can result in decreased operational efficiency and an increase in error rates.

Moreover, due to the absence of a systematic method for inspecting an assembly group and the prevalent lack of line efficiency, a significant accumulation of units with a large number of defects has been observed. These items must be revisited, resulting in an unnecessary cycle of review and transformation. In addition to the inefficient use of resources and increased production time, this issue also necessitates additional logistical effort to shift these groups back for revisions.

These problems within the quality section can significantly hinder the company's overall efficiency and diminish the quality of the final products.

## 3.9 Logistics Section

An integral team is assigned to internal and external logistics in the examined organizational structure. This team is responsible for provisioning and inspecting materials, as well as managing the receipt and shipment of both raw materials and finished goods. This department is substantially impacted by the inefficiencies identified previously, ranging from inadequate spatial organization, and impeding material movement, to a lack of transparency that hampers the correct distribution of materials.

These logistical challenges are not limited to issues resulting from inefficient processes. In addition, the department struggles with the absence of a well-defined work plan. Despite the inherent variability of logistics, it is essential to achieve optimum burden balance and define the scope of team members' mutual assistance. Prior to the implementation of the kaizen project, responsibilities were largely compartmentalized, with individuals devoting themselves to specific duties, and mutual assistance was defined only during critical moments. This role definition may restrict flexibility and adaptability, especially during periods of high demand or unanticipated disruptions.

This dearth of well-coordinated collaboration and predefined operational workflow in the logistics department can result in bottlenecks and delays, negatively impacting the organization's operational efficiency and effectiveness.

## 3.10 Overview of the Main Problems

The following Table 1 is intended to provide a synopsis of all the problems discovered, broken down by section so that after the presentation of solutions, the methodologies used to solve the problems can be summarised.

Table 1 - Overview of the main problems per section

| Section | Problem |
|---|---|
| **Planning** | Mostly manual methods |
| | Lack of transparency of production quantities |
| | Variability of the productive mix |
| | Lack of planning principles |
| **Metal Mechanics** | Batch production |
| | Precarious nesting |
| | Dysfunctional layout |
| | Absence of standard work |
| **Painting** | The velocity was below the maximum value |
| | Loss of use of the painting area |
| | Raw material waste |
| | Frequent interruptions |
| | Neglected KPI's control |
| **Pre-Assembly** | Batch production |
| | High quantities of intermediate stock |
| | Multiple non-conformities |
| **Assembly line** | Knowledge was not uniform |
| | Lack of visibility of completed tasks |
| | Unadjusted board of line |
| | Engineering problems |
| **Electrical** | Overproduction |
| | Lack of organization |
| | Communication issues |
| | Insufficient hierarchical structure |
| **Quality** | Discrepancies in the inspection method |
| | Accumulation of pendants |
| **Logistics** | Disorganization of space |
| | Insufficient coordination in logistics activities |

# 4 Design of Solutions

Transitioning into this crucial section of the thesis, the emphasis shifts to an in-depth examination of the different approaches and strategies employed to address the wide range of challenges enumerated in the problem description. Each problem, with its unique complexities and nuances, requires a distinct approach and resolution strategy.

The purpose of this chapter is to describe these mitigation measures in detail, considering their theoretical foundations, practical implementation, and consequential effects on the enhancement of the overall process. This chapter also provides an opportunity for in-depth consideration of these measures' outcomes.

## 4.1 Cutting Improvement

Regarding the improvement of the cutting procedure, several Kaizen events have been implemented. These were created primarily to implement a continuous improvement strategy that aims to address fundamental operational aspects, foster process excellence, optimize resource management and promote cost-effectiveness.

A refined nesting analysis has been implemented in the context of metalworking operations, considering a variety of cutting scenarios. This has led to a strategic reduction in the starting batch size from 20 to smaller, more manageable quantities. The decision regarding the appropriate quantity size for use was dictated by the nesting of the metal sheet.

Therefore, for two of the references, a batch size of two was used, while the remaining references were cut in batches of one.

When planning the weekly production, a concerted effort is made to consolidate groups that are cut in pairs, thereby maximizing the utility of the cut material. This methodical approach not only improves our production efficiency but also corresponds with our commitment to sustainable practices by maximizing resource utilization.

In addition to this nesting analysis, all parts were automatically cut, and the manual bending machine plan was revised to reduce manual bending and increase automatic bending.

Table 2 outlines the percentage and monetary benefits accrued from the improvement in the cutting process made possible by the adoption of the unitary cut method. It is imperative to note that the monetary benefit was calculated using the current cost of the metal, which is approximately €1.39 per kilogram.

Table 2 - Nesting Analysis

| Model | Sheet Weight [kg] | Initial Nesting [%] | Unitary Nesting [%] | Gain [%] | Gain [€] | Weekly Demand [units] | Annual Gain [€] |
|---|---|---|---|---|---|---|---|
| **1600** | 319,95 | 82,10 | 85,84 | 3,74 | 16,51 | 19 | 16 315,10 |
| **1950** | 391,05 | 83,00 | 85,04 | 2,04 | 11,00 | 38 | 21 753,47 |
| **2300** | 1087,44 | 81,070 | 83,72 | 2,65 | 39,77 | 23 | 47 561,93 |
| **3100** | 1456,29 | 81,88 | 83,42 | 1,54 | 30,95 | 9 | 14 484,13 |
| **4000** | 1831,32 | 79,92 | 83,85 | 4,93 | 124,59 | 2 | 12 957,56 |
| | | | | | **Total** | 91 | 113 072,18 |

An evaluation of the nesting procedure revealed numerous opportunities for improvement. Specifically, the strategy of not clustering identical parts for cutting allowed smaller components to be accommodated on the same sheet, maximising its utilisation. Once the one-piece flow is implemented, these incremental modifications will substantially streamline the factory flow, resulting in a reduction in associated costs. This analysis has significant financial ramifications, resulting in a cost savings of approximately 113 thousand euros per year.

Figures 9 a) and b) illustrate an example of the organisation made in this zone, in which the provisioning of some nesting parts was driven by consumption (kanban).

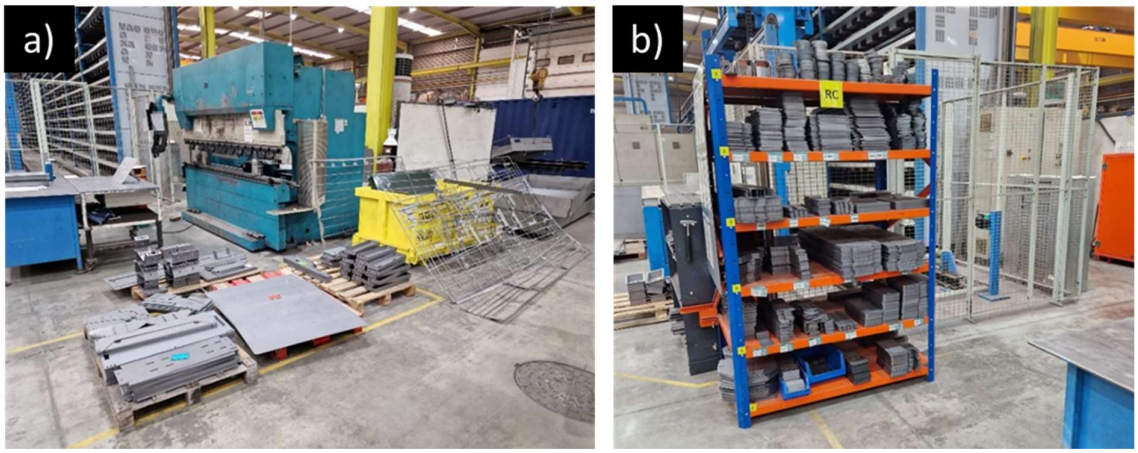



Figure 9 - Manual Bending Machine Layout: a) before and b) after 5S's methodology implementation

## 4.2 Painting & Pre-Assembly Improvements

The painting and pre-assembly sections will be discussed conjointly, as the final solution closely links these two departments together. A portion of the proposed solutions requires the revaluation and reorganization of tasks and mutual assistance between these two operational domains.

This phase of the procedure focuses primarily on analysing and improving the Overall Equipment Efficiency (OEE) of the painting line. The improvement in line utilization is attributed to the effects of numerous initiatives, which will be elaborated on in greater detail.

The initial step involved the installation of a refrigeration device adjacent to the exit of the oven, which facilitated a more rapid cooling of the parts. This adjustment allows for a decreased handling wait time, thus optimizing the overall process.

As described in the preceding section, the components are now being cut in a one-piece flow system. This change enabled the development of a standardized sequence for the positioning of parts on pallets. This sequencing is crucial because it ensures optimal utilization of the painting area when loading parts onto the painting line while adhering to the mechanical constraints, notably the height restrictions associated with piece loading and the distance between pieces, which varies based on the thickness of the sides.

The submission order has been meticulously examined to ensure the most effective use of the painting area. Appendix A shows the standard work for loading the parts.

Despite the significant improvement in the utilization of the painting area, the values for OEE continue to fall short of the factory's requirements, especially in light of the initial goal of doubling production output. In response to this difficulty, a series of workshops were held to address several issues anticipated to produce immediate efficiency gains for this section. These include an increase in line speed, a decrease in unscheduled stoppages, and an equitable distribution of set-ups.

The Kobetsu Kaizen methodology was utilized to facilitate a structured resolution to the presented challenge, as in previous workshops. Data pertaining to downtime was gathered and an investigation was initiated to identify the root causes of the interruptions.

A Pareto chart was created so that the most significant issues could be identified. Figure 10 illustrates how this visual representation facilitates resource allocation by highlighting the problems that require urgent attention and action.

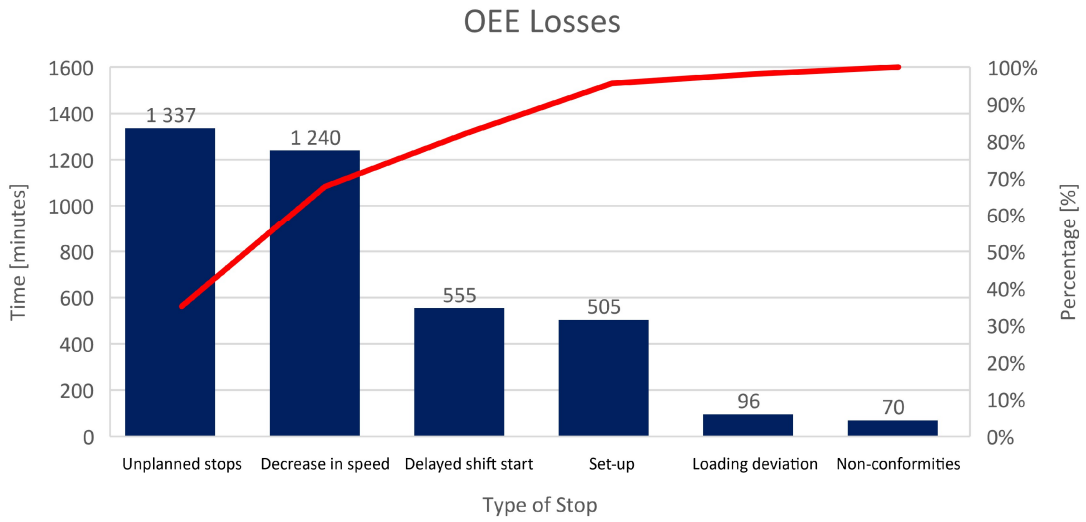



Figure 10 - Pareto Chart: OEE Losses

Following the data collection, team members, including the production manager, line coordinator, and operators, engaged in a discussion. The principal causes of each category of OEE loss were investigated, and solutions were proposed for each identified problem.

Concerning the issue of unscheduled stoppages, it was observed that the loading standard was not consistently adhered to, which resulted in certain parts not meeting the minimum requirements for painting. The proposed corrective strategy involved enhancing operator training regarding the activity's standard.

The majority of the speed decrease occurred during lunch hours when schedules were asynchronous and there was only one painter in the paint booth. Shift organisation was restructured to prevent this negative impact on OEE.

The delayed start of shifts was the third most significant factor in OEE decline. To eliminate this inefficiency, coworkers were instructed to be entirely prepared and outfitted at the exact start of their duties.

This issue regarding the distribution of setups was brought up during a planning meeting, resulting in a reduction of the daily setup limit to one.

Using an impact and effort matrix, the main solutions were subsequently grouped to facilitate the prioritization of particular actions. The solutions that promised the greatest impact with the least amount of effort were then implemented according to a plan of action.

Immediate improvements or "quick wins" were identified, and the effects of these solution implementations are depicted in Figure 11 by the evolution of the OEE.

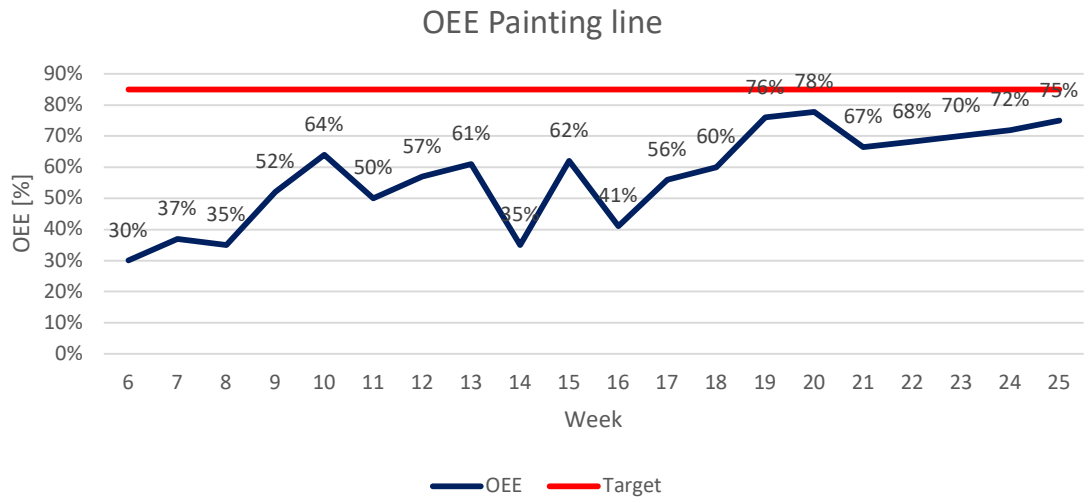



Figure 11 - Evolution of the OEE of the Painting Line

In addition to the efforts made to overcome the inefficiencies of the painting line, the pre-assembly activities were also studied. A significant advance in the flow generator parts has been observed allowing for a reorganization of pre-assembly tasks. This restructuring enabled the production of chassis and canopies in accordance with the unit flow model.

The substantial increase in process visibility greatly facilitated the relocation of several assembly-line tasks to this section. That strategic relocation reduced the amount of time required for each generator's throughput. In addition, the layout was reorganized to improve ergonomics, cleanliness, and organization. For each operator, specific work regulations were implemented to further buttress these efficiency improvements. In addition to streamlining the training process for new employees by establishing a clear framework for task execution, these guidelines also establish an optimal method for performing each task.

## 4.3 Assembly Line Improvements

Within the context of the assembly line, the initial strategy entailed an exhaustive analysis of all activities, the process mapping of each activity, and the corresponding timeframes. This analysis served as the foundation for dividing tasks across stations and determining the order of operations. The integral principle of takt time was accounted for in the assignment of tasks to distinct stations.

A demand for 100 generators per week would require a generator to be completed and ready at the final station every 40 minutes in accordance with the takt time principle.

The alignment of production with this takt time provides numerous benefits. First, it ensures that the production rate is proportional to consumer demand, thereby preventing waste and overproduction. Second, it facilitates the creation of a streamlined workflow by eliminating obstructions and inefficiencies. Lastly, it provides a distinct benchmark for production goals, nurturing accountability, and productivity among the workforces. The takt time is essential for maximizing productivity and effectiveness in the production process.

In addition, the detailed description of each activity provided crucial details regarding the tools and bolts required for each task. This knowledge ultimately enabled the creation of a customized border of line for each stage. Figure 12 a) depicts the border of line concentration after the assembly line. Figure 12 b) depicts the distribution of all necessary materials on the border of line throughout the production stages

Figure 12 - Boarder of line: a) before and b) after station division

These efforts significantly increased the visibility of completed tasks for each generator, resulting in a substantial decrease in rework and a reduction in errors caused by incomplete tasks. Simultaneously, the implementation of a customized line board for each station has substantially reduced superfluous operator movements, material shortages and supply issues.

The team underwent a strategic reorganisation subsequent to the initial approach. The purpose of this reorganisation was to ensure the incorporation of an individual with substantial expertise and proficiency, who could effectively train and reassign colleagues based on any potential delays that may occur.

It is essential to emphasise that all members of the team received full instruction in a variety of activities. The objective was to standardise and disseminate knowledge among the operators, thereby nurturing a cohesive team with a unified understanding and set of abilities.

Despite the significant improvements that have been implemented, the company continues to face numerous mechanical and electrical construction-related issues that require ongoing resolution.

The variety of models is a substantial barrier to properly sharing engineering achievements. To mitigate these issues, a rigorous practice of documenting and transmitting any information regarding assembly line anomalies has been implemented. This methodical approach not only ensures expeditious resolution but also prevents the propagation of these errors.

Figure 13 illustrates the progression of average equivalent generator daily output throughout the weeks. It is essential to note that this indicator pertains to equivalent generators due to significant fluctuations in workload and execution times across various models.

Upon careful evaluation, it is evident that our organisation has achieved a substantial increase in weekly production volumes relative to our baseline. Nonetheless, it is equally important to recognise the production fluctuations.

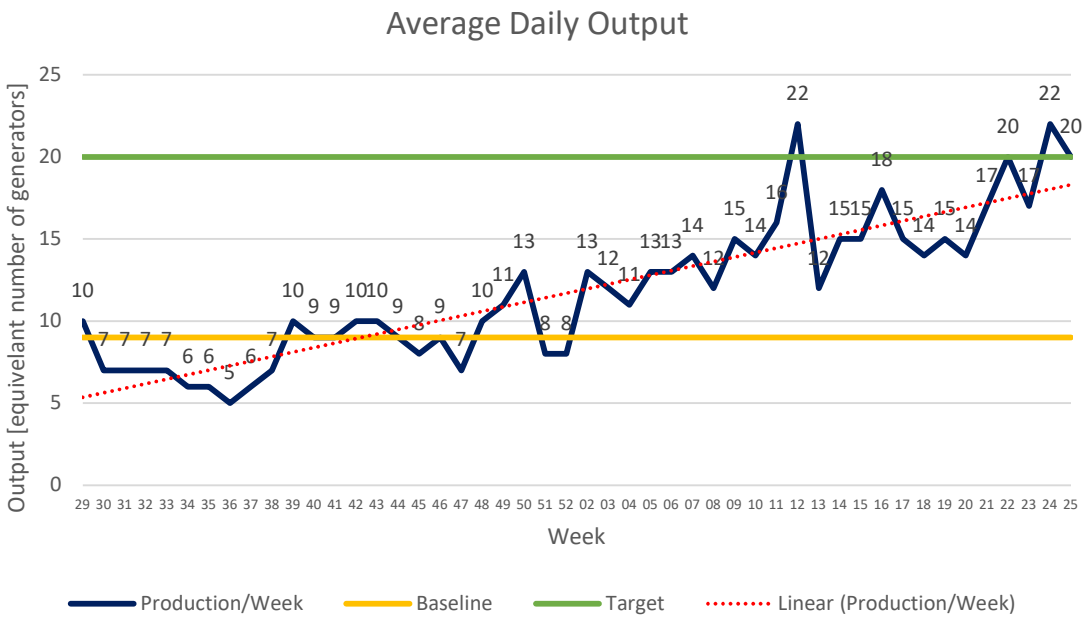



Figure 13 - Key Performance Indicator: Weekly Output

During the preliminary phases of planning and value stream analysis, it was anticipated that variation in model types and execution durations would be unavoidable. In order to solve this predictability, we established the Mura Station, a solution designed to combat the inherent process variations.

Mura Station plays a crucial role, as its primary purpose is to optimise and incorporate inconsistencies in the production process. At this station, it was implemented a strict quality control procedure in order to promptly address any issues that may arise. This strategy for immediate problem resolution eliminates the need for time-consuming problem-solving after the generator has left the assembly line. In doing so, we assure a more effective and consistent production cycle, thereby increasing our overall operational effectiveness.

## 4.4 Electrical Section Improvements

In an effort to reduce the elevated levels of copper waste in this section, a specialised production strategy was implemented tailored to the layout and each generator model. Due to the increased clarity and transparency within the Gemba, it became possible to communicate the assembly line requirements directly to the electrical cells one day in advance.

Subsequently, components were manufactured in precise quantities and dimensions, in accordance with the requirements of their respective generators. In addition to the adoption of the 5S methodology, the implementation of this streamlined flow not only reduced waste but also increased cell productivity.

This strategy produced observable outcomes. Rework and nonconformities decreased substantially as a result of the team's dissemination of detailed specification requirements. Consequently, it is feasible to assert that the efforts have resulted in improved production efficiency and waste management in general.

## 4.5 Quality Section Improvements

In the pursuance of quality assurance, it was implemented improvements in three distinct areas: the incorporation of self-inspection within assembly-line activities, the establishment of the Mura Station, and the redesign of our workflow.

A self-quality policy has been implemented to eliminate outstanding items after inspection. Under this initiative, assembly line operators conduct a prompt and visual evaluation of quality upon completion of a specific task. This not only fosters a sense of responsibility but also ensures that potential issues are immediately identified and addressed, thereby maximising productivity and minimising rework.

As previously mentioned, the final stage of the assembly line is now devoted to a full quality evaluation and overall generator control. This station is intended to facilitate the detection and correction of mechanical and electrical nonconformities. This strategy improves the quality of the final product and optimises the allocation of resources for defect correction.

The operational methodology was restructured to ensure seamless coordination with the logistics group. Under this revised strategy, a generator is initiated, completed, packaged, and prepared for dispatch to the client in a single, continuous process. Harmonising these processes required a comprehensive analysis of all concluding activities and their ensuing coordination with logistics tasks. By standardising these procedures, there was an increase in efficiency and decreased congestion, as fewer generators require corrective actions as can be seen in the before and after situations represented in Figures 14 a) and b) respectively.

Figure 14 - Quality Section: a) before and b) after one-piece flow implementation

## 4.6 Internal Logistics Improvements

Internal logistics has encountered significant changes, especially in terms of the operational methods of the workforce and the hierarchy of responsibilities. These changes are the consequence of a transition from batch production to one-piece flow and the incorporation of the takt time concept in the manufacturing process. Both factors have a substantial impact on logistics operations.

The description of the solution will be addressed in two key areas: supplying the border of line and internal logistics duties associated with finished products and raw materials.

Establishing the line board of the assembly line required the allocation of materials strategically at each station. Nevertheless, the method of provisioning, whether kanban or junjo, influences the mode of transport and the line-edge obstruction. For high-volume materials, junjo provisioning is favoured, whereas kanban provisioning is considered suitable for low-volume materials.

Increasing production levels inevitably increase the demand for basic materials. The implementation of a Mizusumashi, a specialised logistics train, was considered essential to prevent potential material shortages on the assembly line. This system, whose route is synchronised with takt time, is intended to ensure the regular and timely delivery of all assembly-required materials.

The adoption of the Mizusumashi system has numerous advantages. Not only does it facilitate a constant flow of materials, mitigating possible delays and production line interruptions, but it also increases operational efficiency by minimising interruptions. This system enables a more accurate prediction and control of inventory levels, thereby reducing the danger of overstocking or understocking and contributing to cost efficiency. In addition, the Mizusumashi system enables rapid response to fluctuate demand, making it an integral part of an efficient and flexible production environment.

As a result, the logistics train was implemented with complete supply routes encompassing the painting and pre-assembly section, the assembly line, and the electrical section.

Following the implementation of this strategy, instances of raw material shortages were eradicated, effectively removing one of the assembly line's primary impediments to efficiency. This action resulted in a significant improvement in production outcomes, reinforcing our dedication to operational excellence. Appendix B displays the standard work of the Mizusumashi operator.

Subsequent to the delineation of the revised logistics responsibilities, an in-depth analysis of workforce engagement was undertaken, and individual tasks were meticulously mapped.

To improve the efficacy of all logistics operations, distinct zones for material reception, cargo preparation, and supply were established. As in any other industry, logistics operations are susceptible to substantial variation, necessitating a high degree of transparency and effective team communication.

The delineation of these specialised zones facilitates all team members’ and supervisors' visual comprehension of any extant gaps. This visualisation enables the leadership to designate personnel strategically based on the specific requirements at any particular moment, thereby optimising resource utilisation and enhancing operational efficiency.

In addition to improving the visibility of logistics operations as a whole, it was essential to establish a standardised work procedure and a distinct mode of operation. The objective of this measure was to cultivate cooperation between quality and logistics operators, whose responsibilities overlapped following generator testing. As a result, a thorough examination of

the activities led to the formulation of a standard for the application and packaging of vinyl on the units.

The time required for the printing of the vinyl when it was to be applied was identified as a significant obstacle during this procedure. In response, it was proposed to establish a vinyl supermarket. This vinyl supermarket is supplied by one of the logistics operators, who prints a predetermined amount of vinyl to restock the supermarket, thereby instituting a consumption-based replacement system. This approach improves the overall efficacy of the process by minimising time loss and maintaining a constant supply of vinyl that is available for use.

Finally, the essential collaboration among logistics operators has been carefully specified, given that some activities involve cooperation between two individuals. Consequently, these team members' workflow consists of a continuous component, a variable component that is primarily dependent on external orders, and an intermediate component. The last part is intended to ensure the efficient execution of critical duties, such as service order segregation, shipment management, material verification, and material supply. This exhaustive definition of roles and responsibilities facilitates efficient coordination, boosts productivity, and ensures that all essential tasks are properly completed.

## 4.7 Layout Reorganization

It is worth noting that one of the most common improvements was the systematic reconfiguration of section layouts across all sections. The initial analysis revealed that the disorganised layout of the factory floor led to an excessive and unnecessary amount of employee movement.

An analysis of the operators' movements within each section was performed using a spaghetti diagram to solve the situation. In collaboration with the team, strategic modifications to reduce superfluous movements were identified.

Upon determining the optimal layout design, the team started the creation of conditions necessary for its implementation, integrating the 5S methodology's principles in all areas. It is essential to note that the transition to unit flow production facilitated the implementation of these layout enhancements. This was primarily due to a reduction in intermediate stock, which in turn liberated crucial space for movement and transportation.

At the engine coupling station, one of the most notable examples of disorganisation was observed. The absence of organisation was palpable, and engine provisioning was conducted without a structured methodology or procedure.

Originally located at the very end of the factory, the coupling station transported engines continuously to the beginning of the line. This station was relocated to a location closer to the assembly line as the primary course of action. Figures 15 a) and b), and 16 a) and b) depict the concluding results of implementing the various phases of the 5S methodology.

Figure 15 - Coupling Station before 5S's methodology implementation

These modifications to the process decreased the duration of material transport and the waiting time for the engine to be installed on the chassis. This increased the line's efficacy and the operators' comfort while performing their duties.

Figure 16 - Coupling Station after 5S's methodology implementation

## 4.8 Daily Kaizen

The implementation of these enhancements necessitates an additional effort to instil a culture of continuous improvement and to sustain all actions taken. To facilitate a transformational transition and revitalise the organisational culture, Daily Kaizen was implemented across all departments. The primary objective of these meetings is to provide a daily forum for addressing issues, analysing outcomes, and facilitating effective communication.

Prior to the introduction of the Kaizen initiative, the lack of effective communication and cooperation between departments was identified as a significant issue. In an organisation where both product and process maturity are not optimal, it is essential for team leaders to coordinate closely in order to expedite problem resolution. This imperative need to improve communication and actively engage all employees in the introduced changes was the primary impetus behind the implementation of Daily Kaizen.

Each day, team leaders account for employee attendance, disseminate the work plan, reallocate personnel as needed, and discuss the previous day's performance indicators. This final aspect of the meeting had a significant impact on the company's culture, particularly considering that in the past, the analysis of indicators was neglected, making the detection of process failures more difficult.

The incorporation of Kaizen methodologies into team dynamics offers a variety of substantial benefits. Initially, the methodology promotes an increase in overall productivity by emphasising the elimination of inefficient practices and encouraging the development of streamlined operations. The gradual, incremental changes brought can result in substantial gains in productivity and efficiency over time.

Second, the Kaizen emphasis on a meticulous, improvement-driven culture can lead to a significant reduction in errors, thereby enhancing the quality of the final product or service. This strategy also improves cooperation by encouraging frank communication and collaboration. It allows every member of the organisation to contribute ideas for development, fostering a sense of unity and shared goals.

In addition, Kaizen's inclusive nature improves team morale. The participation of all employees in refining processes enhances job satisfaction and motivation. Implementing employee-suggested improvements can foster a sense of pride and ownership, resulting in a more committed and productive workforce.

In addition to promoting a proactive approach to problem-solving, Daily Kaizen fosters a mindset of unceasing identification and resolution of issues before they become significant obstacles. This proactive strategy facilitates the formation of teams that are adaptable and adept at overcoming obstacles.

The Daily Kaizen continuous process efficiency and productivity improvements can result in significant cost savings. These resources may be re-invested back into the organisation for its continued growth and development.

The emphasis on continuous, measured improvement ensures long-term success. In contrast to certain strategies that emphasise drastic, frequently unsustainable changes, Kaizen enables teams to continuously refine and improve their practices, adapting to ever-changing conditions and obstacles. This strategy also increases customer satisfaction, as the enhancements in efficiency, quality, and responsiveness result in the timely delivery of consistently high-quality products or services.

Lastly, Kaizen fosters an environment conducive to learning and growth. It promotes personal and professional development among team members by cultivating an environment that values learning and experimentation, thereby facilitating the acquisition of new skills and competencies that can aid in their career advancement.

## 4.9 Planning Meetings

As stated previously, the issue of communication within the organisation posed significant obstacles to production. To solve this and expedite the resolution of daily issues, a daily meeting with all section leaders was instituted. These gatherings focus primarily on the state of production as a whole, emphasising particulars within each section. This meeting follows the structure of a Daily Kaizen meeting and concludes with an analysis of the production indicator, namely the number of generators produced the day before.

This type of meeting has invaluable benefits because it ensures that all team leaders have the same understanding of the production's status and objectives. They contribute to the development of a sense of shared responsibility and enable leaders to exchange ideas and solutions. This results in a more cohesive and effective team, capable of proactively and efficiently addressing challenges.

These meetings should be as concise and concrete as possible to enhance communication efficiency and boost productivity. To achieve this, a planning board (Figure 17) has been implemented. Furthermore, it's important to underscore the role of visual management in communication. Visual management tools, like the planning board, offer a simple and clear view of tasks, goals, and progress, thus facilitating more effective and productive discussions. This aids in fostering an environment of transparency and teamwork, ultimately bolstering the overall performance and efficiency of the team.

Figure 17 - Planning Board

Given the importance of the number of pending groups to the organization's effective functioning, an indicator of the number of pending groups is also examined. This highlights the significance of effective communication in identifying and resolving potential production obstacles. This type of consistent and targeted communication substantially improves the ability of line leaders to deal with daily obstacles.

After these daily meetings, a weekly iteration that is more in-depth is held. This meeting is intended to establish the weekly production schedule and anticipate any engineering-related issues. This forward-looking approach enables the identification and mitigation of prospective problems prior to their impact on production.

During the course of these meetings, it was determined that several internal products required extensive preparation time, including the exhaust crossbars and exhaust pipe welding. Consequently, by monitoring assembly line delays, it was possible to identify and address this issue by conceptualising and creating an intermediate product supermarket. This designated area contains all types of exhaust connections, thereby preventing any potential delays caused by a lack of this essential internal product.

During this weekly meeting, additional generator products are analysed in order to facilitate preliminary planning.

It is impossible to exaggerate the value of such organised meetings. They increase transparency, boost productivity, encourage effective problem-solving, and nurture a collaborative environment. Ultimately, these frequent interactions facilitate effective communication, resulting in an organisation that is more agile and responsive.

## 4.10 Gemba Walk

Indeed, process validation remains an essential phase for sustaining the implemented changes. While Daily Kaizen fosters a culture of continuous development, a stricter control mechanism is necessary to ensure adherence to predetermined standards. In this context, and in order to prevent any unwarranted misuse of the implemented enhancements, Gemba Walk is frequently used as an effective auditing mechanism.

The Gemba Walk entails on-site engagement with the work environment and employees. This technique enables leadership to acquire an in-depth understanding of the work process, identify potential areas for development, and encourage employees to propose creative solutions.

The Gemba Walk, which is implemented as a section-by-section audit, verifies compliance with work standards and evaluates the organisation of workspaces. All section leaders, as well as the production and operations directors, should conduct this exercise to ensure a comprehensive understanding of the process. The active participation of leadership in these audits ensures that the normalisation of activities and spaces is maintained. The sections should be audited by individuals who are not directly associated with the section in question.

Such audits have substantial benefits from the perspective of continuous improvement. First, they cultivate a culture of employee accountability and ownership. By emphasising the significance of following established procedures, employees are more likely to uphold the established standards.

Secondly, these audits offer opportunities for continuous advancement and learning. Potential enhancement areas can be identified and addressed promptly through the consistent and complete examination of processes and workspaces.

Lastly, this hands-on strategy improves leadership and employee communication. By interacting directly with those on the work floor, executives can gain a deeper understanding of their challenges and perspectives, resulting in enhanced decision-making and morale.

These audits are facilitated using a Kamishibai system. The Japanese term "Kamishibai" refers to a form of narrative; in business, it is a visual management instrument used for performance monitoring and development. Appendix C shows an example of this audit mechanism.

## 4.11 Overview of the Main Solutions

In order to correlate each identified issue with the corresponding solution implemented, Table 3, which was partially introduced in the overview of the current situation, is elucidated in greater detail below. This includes the descriptions of the solutions implemented for each section.

Table 3 - Overview of the main solutions per section (1)

| Section | Problem | Solution |
|---|---|---|
| **Planning** | Mostly manual methods | N.A. |
| | Lack of transparency of production quantities | Daily and weekly planning meeting with KPI's analysis |
| | Variability of the productive mix | N.A. |
| | Lack of planning principles | Planning according to the customer's orders and nesting specifications |
| **Metal Mechanics** | Batch production | One-piece Flow |
| | Precarious nesting | Redefinition of all nesting models |
| | Dysfunctional layout | Layout redefinition<br>5S's |
| | Absence of standard work | Standard Work |
| **Painting** | The velocity was below the maximum value | Maximum velocity implemented |
| | Loss of use of the painting area | Standard Work |
| | Raw material waste | Standard Work |
| | Frequent interruptions | Kobetsu Kaizen |
| | Neglected KPI's control | Daily Kaizen |
| **Pre-Assembly** | Batch production | One-piece Flow |
| | High quantities of intermediate stock | One-piece Flow |
| | Multiple non-conformities | Layout redefinition<br>One-piece Flow |

Table 4 - Overview of the main solutions per section (2)

| Section | Problem | Solution |
|---|---|---|
| **Assembly line** | Knowledge was not uniform | Standard Work |
| | Lack of visibility of completed tasks | One-piece Flow<br>Stations implementation |
| | Unadjusted board of line | Redefinition of Boarder of Line<br>Mizusumashi |
| | Engineering problems | Kobetsu Kaizen |
| **Electrical** | Overproduction | One-piece Flow |
| | Lack of organization | Layout redefinition<br>5S's |
| | Communication issues | Daily Kaizen |
| | Insufficient hierarchical structure | Team Management Model |
| **Quality** | Discrepancies in the inspection method | Standard Work |
| | Accumulation of pendants | One-piece Flow |
| **Logistics** | Disorganization of space | Layout redefinition<br>5S's |
| | Insufficient coordination in logistics activities | Levelling and balancing activities<br>Definition of mutual assistance |

# 5 Conclusions

The primary objective of this study was to examine the incorporation of Kaizen methodologies within the Power Generator Industry. The Kaizen's dedication to continuous improvement and operational excellence provided the potential impetus for productivity enhancement. To address the difficulties faced by the industry in matching escalating demand, this study centred on the potential to double output using these methodologies.

Noteworthy results have been uncovered through the meticulous examination and pragmatic application of Kaizen principles within the targeted organisation. In the twelfth week of the current year, with average daily production of twenty-two generators, the company reached its maximum production capacity. As previously stated, the organisation confronts a significant backlog in product engineering and insufficient operator familiarity with less frequent models. The efficacy of the organisation is negatively impacted by the convergence of these factors. However, it has been demonstrated that the envisioned project path is feasible if all specificities of the product are met.

These results demonstrate not only the viability of Kaizen but also the potential to have a significant effect on the operational effectiveness of power generator production. This transformation enables the organisation to simultaneously meet production goals and prepare for a resilient and adaptable future.

The painting line achieved its highest OEE value of 78% during the twentieth week. Although the predetermined objective has not yet been attained in its entirety, it is commendable that the section's efficacy has improved significantly. Given the presence of mechanical and physical constraints in this area, maintaining a consistent performance record is of the utmost importance to ensure that the factory receives a continuous supply of vital components. In this sense, the changes made as part of the Kaizen initiative had a considerable positive impact on the performance of the section.

In this study, the deployment of the Kaizen Business System resulted in significant enhancements throughout the organization's operations. Kaizen has an undeniably transformative impact on process optimisation, waste reduction, output quality enhancement, and fostering a culture of continuous improvement among employees.

Kaizen's holistic approach, which combines pragmatic, ground-level tactics and philosophical commitment to excellence, demonstrates its potential as an effective instrument for confronting the challenges of the industry.

# 6 Future Work

Despite the concerted efforts made to improve the performance of the company, there are still significant opportunities for further development, particularly in three key areas: production, maintenance, and commercial strategy.

Significant opportunities for improvement exist in the efficient resolution of engineering and product design problems at the manufacturing level.

Regarding equipment maintenance, the company places little emphasis on preventive measures and relies significantly on a corrective approach. Conducting an exhaustive study and subsequently implementing an action plan centred on preventive maintenance, tailored to the specific requirements of the company, would be advantageous to the potential growth of this industry.

In addition, the commercial strategy should align its resources with production efforts, with the goal of increasing sales of products that have a minimal impact on the assembly line, while transitioning out products that significantly hinder productivity without yielding significant economic benefits.

By using the synergy of these factors, the company is able to capitalise on a variety of business expansion opportunities, resulting in increased production levels and profits.

## References


A. Munro, R. (2015). *The Certified Six Sigma Green Belt Handbook* (2nd edition).

Bastos, A. (2008). *Strat to Action*.

Coimbra, E. (2013). *Kaizen in Logistics & Supply Chains*.

Imai, M. (1986). *KAIZEN*.

Imai, M. (2004). *Gemba Kaizen*.

Imai, M. (2021). *Strategic Kaizen: Using Flow, Synchronization, And Leveling Assessment To Measure And Strengthen Operational Performance*.

K. Institute. (2018a). *Breakthrough Kaizen*.

K. Institute. (2018b). *Daily Kaizen*.

K. Institute. (2018c). *Kaizen Lean Manufacturing*.

K. Institute. (2018d). *Total Flow Management (TFM)*.

K. Institute. (2019). *Kaizen Business System (KBS)*.

Kasim, N. I., Musa, M. A., Razali, A. R., Mohamad Noor, N., & Wan Saidin, W. A. N. (2015). Improvement of Overall Equipment Effectiveness (OEE) through Implementation of Total Productive Maintenance (TPM) in Manufacturing Industries. *Applied Mechanics and Materials*, *761*, 180–185. https://doi.org/10.4028/www.scientific.net/AMM.761.180

Mendez, J., & Vila-Alonso, M. (2018). "Three-dimensional sustainability of Kaizen". *The TQM Journal*, *30*, 391–408.

Nawras, S. (2017). *The 8 Wastes of Lean*.

Ohno, T. (1988). *Toyota Production System-Beyound LArge-Scale Production* (1 edition).

Ondokuz, B. E., Üniversitesi, M., Elevli, S., & Elevli, B. (2010). Performance Measurement of Mining Equipment by Utilizing OEE. In *Acta Montanistica Slovaca Ročník* (Vol. 15, Issue 2). https://www.researchgate.net/publication/47517712

Pedro, J., & Rodrigues Da Silva, A. (2013). *OEE-A FORMA DE MEDIR A EFICÁCIA DOS EQUIPAMENTOS OEE-THE WAY TO MEASURE EQUIPMENT EFFECTIVENESS*. www.wikipedia.org.

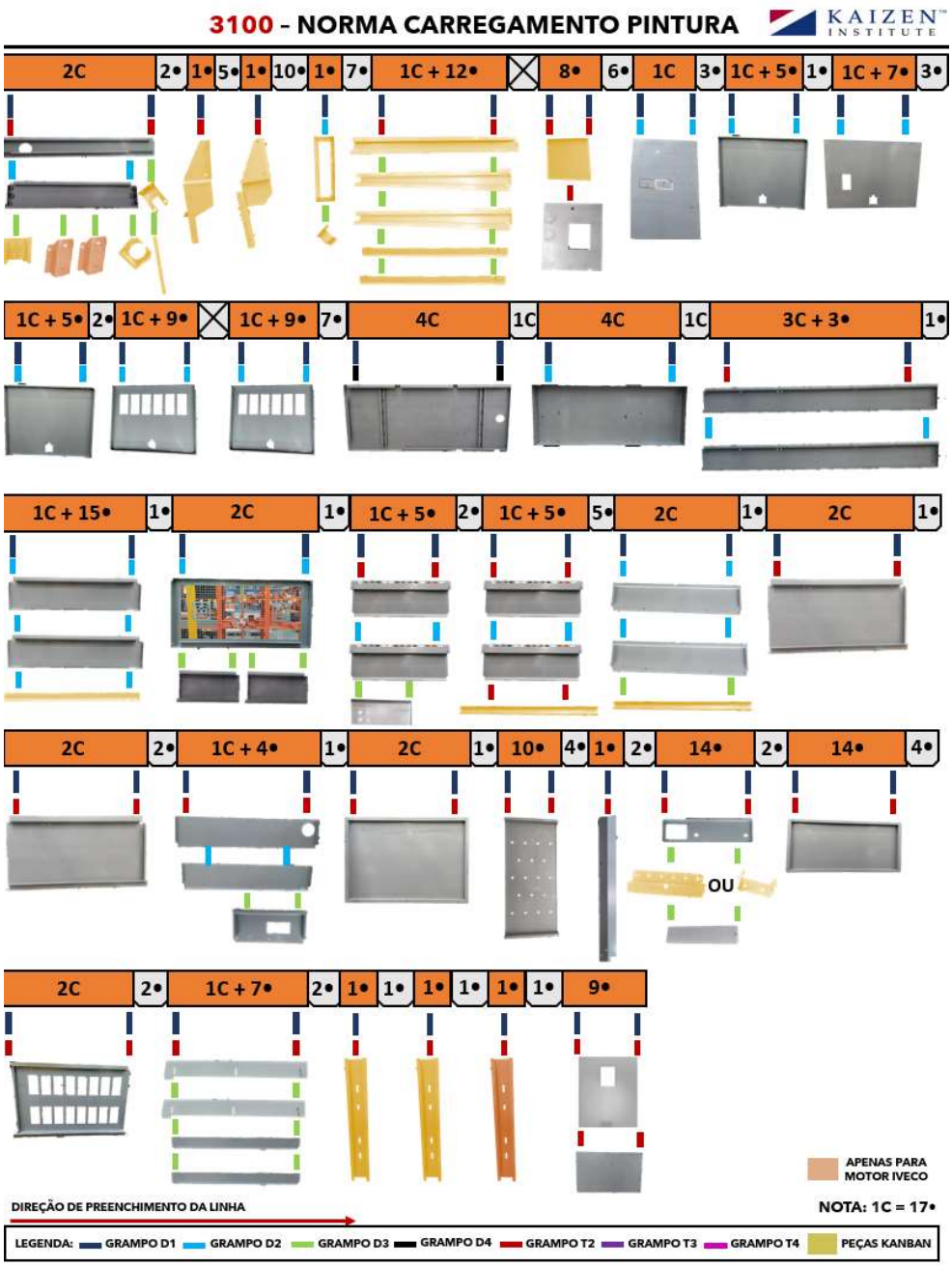
Rother, M., & Harris, R. (2001). *Creating Continuous Flow An Action Guide for Managers, Engineers & Production Associates*.

Schipper, T., & Swets, M. (2010). *Innovative Lean Development*.

Shingo, S. (1983). *A Revolution in Manufacturing: The SMED System*.

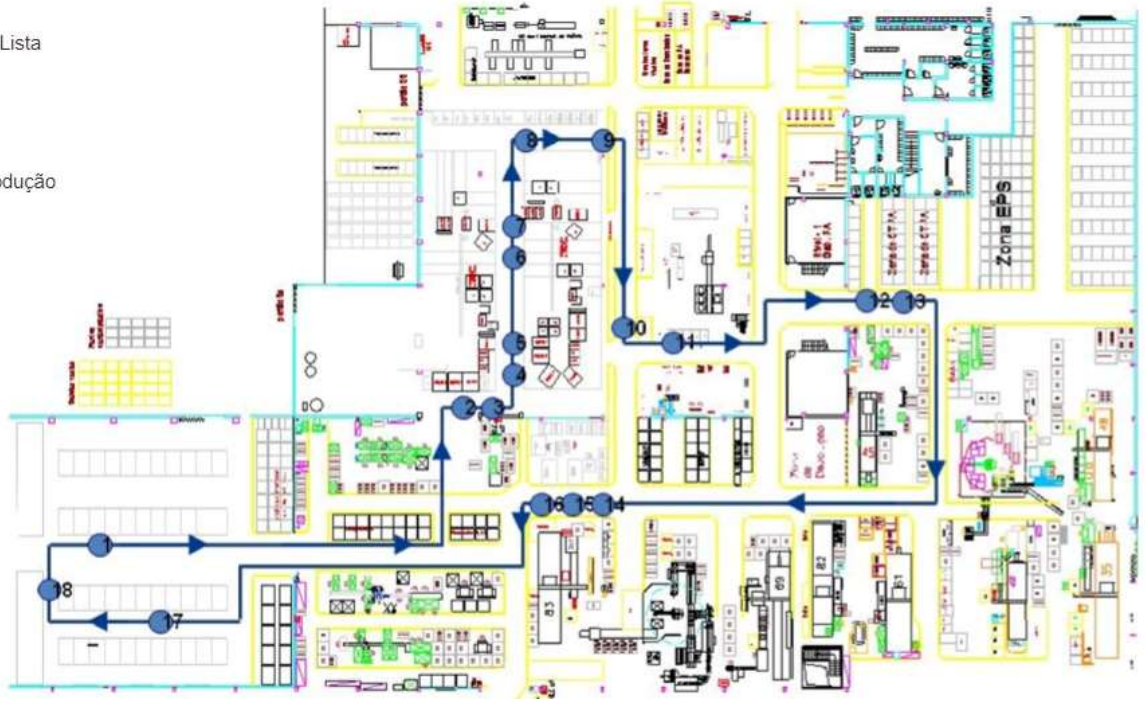
Tapping, Don., & Shuker, Tom. (2003). *Value stream management for the lean office : eight steps to planning, mapping, and sustaining lean improvements in administrative areas*. Productivity Press.

## APPENDIX A: Standard Work - Loading parts in the painting line



## APPENDIX B: Standard Work - Mizusumashi

1. Início do Ciclo
2. Retirar Kanban's de Produção da Caixa de Nivelamento e Lista de Junjo
3. Abastecer Caixas (I1 - parte Sup.) + Colocar Kanban de Produção no sequenciador
4. Abastecer caixas (I1 - Lado Esq.)
5. Abastecer Caixas (I2 - Lado Dir.) + Colocar Kanban de Produção no sequenciador
6. Trocar KIT Jungo de Estrutura/ Embalagem (I1 e I2)
7. Abastecer Caixas (Estrutura I1 e Estrutura I2)
8. Atrelar Carros EPS e Tampas + Retirar Fitas e Proteções
9. Picking para KITS Junjo (I1 e I2) Parte 1
10. Abastecer Caixas (I2 - Lado Esq.)
11. Picking de Placas
12. Picking Junjo Válvulas (I1 e I2)
13. Picking para Kits Junjo (I1 e I2) Parte 2
14. Picking Reservatórios (I2)
15. Picking Rede e Tubo Branco (I1 e I2)
16. Picking Junjo Torneiras (I1 e I2)
17. Trocar Caixas no Supermercado - Média 10 Caixas
18. Deixar Carro de Caixas vazias



## APPENDIX C: Gemba Walk - Kamishibai