



O Impacto da Filosofia Lean na Sustentabilidade: Caso de Estudo

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**The Impact of Lean Philosophy on Sustainability:
Case Study**

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Mechanical Engineering, with a specialization in
Industrial Management**

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ABSTRACT

Currently, we face significant global challenges such as climate change, resource scarcity, and the growing awareness of organizations' social and environmental responsibility. In this context, the pursuit of sustainability has become an undeniable priority. This is where lean philosophy comes in, a fundamental approach to addressing these challenges by promoting not only operational efficiency but also the adoption of more sustainable practices.

The goal of lean philosophy is to improve production processes, reduce waste, and increase value delivered to the customer. However, as environmental, and social concerns gain prominence, this philosophy has been adapted to incorporate sustainability principles, aiming to minimize the negative impact of companies' operations on the environment and society.

How can the application of lean philosophy contribute to process improvement and promote sustainability? This study focused on investigating the above question using the action research methodology.

Throughout the research, it became evident that lean philosophy strategies not only improved J. Baptista's production processes but also had a significant impact on its operational sustainability. The implementation of lean tools, such as the Ishikawa diagram, VSM (Value Stream Mapping), A3 report, Standard Work, Visual Management, among others, not only allowed for waste reduction and efficiency improvement but also enabled the minimization of the environmental and social impact of the company's operations.

The integrated approach resulted in a 66.4% reduction in CO2 emissions and a 46.7% reduction in Non-Value-Added Activities time. This integrated approach demonstrated that lean philosophy can be a powerful ally in the pursuit of more sustainable business practices. By aligning operational efficiency objectives with sustainability goals, companies can not only improve their competitiveness in the market but also play an active role in building a more sustainable future for future generations.

KEYWORDS: Sustainability; Lean Philosophy; Improvement; Waste Reduction; DMAIC

RESUMO

Atualmente, enfrentamos desafios globais significativos, como as alterações climáticas, a escassez de recursos e a crescente consciência da responsabilidade social e ambiental das organizações. Neste contexto, a procura pela sustentabilidade tornou-se uma prioridade incontestável. É aqui que entra a filosofia lean, uma abordagem fundamental para enfrentar esses desafios, promovendo não só a eficiência operacional, mas também a adoção de práticas mais sustentáveis.

O objetivo da filosofia lean é melhorar os processos de produção, reduzir desperdícios e aumentar o valor entregue ao cliente. No entanto, à medida que as preocupações ambientais e sociais ganham destaque, esta filosofia tem sido adaptada para incorporar princípios de sustentabilidade, visando minimizar o impacto negativo das operações das empresas no ambiente e na sociedade.

Como pode a aplicação da filosofia lean contribuir para a melhoria dos processos e promover a sustentabilidade? Este estudo centrou-se na investigação desta questão utilizando a metodologia “action-research”.

Ao longo da pesquisa, tornou-se evidente que as estratégias da filosofia lean não só melhoraram os processos de produção da empresa J. Baptista, como também tiveram um impacto significativo na sua sustentabilidade operacional. A implementação de ferramentas lean, tais como o diagrama de Ishikawa, Value Stream Mapping (VSM), A3 Report, Standard Work, Gestão Visual, entre outros, permitiu não só a redução de desperdícios e a melhoria da eficiência, mas também a minimização do impacto ambiental e social das operações da empresa.

A abordagem integrada resultou numa redução de 66,4% nas emissões de CO₂ e numa redução de 46,7% no tempo de atividades que não agregam valor. Esta abordagem integrada demonstrou que a filosofia lean pode ser um poderoso aliado na busca de práticas empresariais mais sustentáveis. Ao alinhar os objetivos de eficiência operacional com as metas de sustentabilidade, as empresas podem não só melhorar a sua competitividade no mercado, mas também desempenhar um papel ativo na construção de um futuro mais sustentável para as próximas gerações

KEYWORDS: Sustentabilidade; Filosofia Lean; Melhoria de Processos; Redução de Desperdícios; DMAIC

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ACRONYMS AND SYMBOLS

CSR	Corporate social responsibility
DIN	Deutsches Institut für Normung
DMAIC	Define Measure Analyse Improve Control
I4.0	Industry 4.0
ISEP	Instituto Superior de Engenharia do Porto
JIT	Just In Time
KPI	Key Performance Indicator
LSS	Lean Six Sigma
NVAA	Non-Value-Added Activities
OEE	Overall Equipment Effectiveness
OPL	One Point Lesson
P.Porto	Instituto Politécnico do Porto
SIPOC	Suppliers Inputs Process Outputs Customers
SME	Small and Medium Enterprises
SMED	Single Minute Exchange of Die
TBL	Tripple Bottom Line
TPM	Total Productive Maintenance
TPS	Toyota Product System
VAA	Value-Added Activities
VSM	Value Stream Mapping

1. Introduction

1.1. Contextualization

Considering the growing awareness of the importance of corporate sustainability, the Lean philosophy emerges as a potential catalyst to drive more balanced and responsible business practices. Originating from the Toyota Production System, the Lean approach has been globally recognized for its impact on operational efficiency and waste reduction within organizations. However, as environmental concerns escalate, there is an urgent need to explore how the implementation of Lean principles can directly influence corporate sustainability.

In this scenario, the present case study focuses on the company J. Baptista, operating in the conveyor belt production sector. Facing typical operational challenges of the industrial sector, J. Baptista acknowledges the importance of adopting more sustainable business practices.

The aim of this study is to investigate how the implementation of Lean principles, using the DMAIC methodology (Define, Measure, Analyze, Improve, and Control), can impact corporate sustainability at J. Baptista. By examining the interactions between the Lean approach and sustainable practices, considering the three fundamental pillars of sustainability - economic, social, and environmental - the study seeks to identify opportunities for improvement and strategic alignment.

Through a detailed analysis of J. Baptista's operations and the application of Lean principles, the objective is not only to enhance operational efficiency but also to promote social responsibility, sustainable resource management, and environmental impact reduction. Thus, this study aims to contribute to the advancement of sustainable business practices by integrating Lean principles and fostering a more balanced and responsible approach to contemporary challenges.

1.2. Purpose

The Lean philosophy has been recognized as an effective approach for process improvement and sustainability promotion within organizations. This study aims to investigate how the implementation of Lean principles influences operational efficiency and sustainability, based on a case study conducted at J. Baptista Company, which faces certain challenges in these domains. A key question of this investigation is: How can the application of Lean philosophy contribute to process improvement and promote sustainability? By exploring this question, the study seeks to uncover the mechanisms through which Lean tools and methodologies drive enhancements

in process efficiency while simultaneously fostering environmental, economic, and social sustainability.

The first objective is to analyse cases of Lean philosophy application, aiming to understand the strategies and tools used. This involves conducting a literature review to identify Lean tools that have a greater impact on process improvement and sustainability. Additionally, it seeks to understand how the application of DMAIC can contribute to this purpose, as well as identify other tools that can be aligned with this methodology in its various phases.

Subsequently, the goal is to adapt the tools and strategies identified in the literature review to the case study at J. Baptista Company, which faces challenges in the domains of sustainability and efficiency of its processes.

Finally, it is crucial to evaluate the results of implementing the Lean philosophy at J. Baptista Company, analyzing gains in operational efficiency and impacts on sustainability. This involves investigating the effects of Lean implementation on social, environmental, and economic levels, considering both benefits and challenges.

This study aims to contribute to a deeper understanding of the role of the Lean philosophy in process improvement and promotion of organizational sustainability, through a practical approach at J. Baptista Company. It is expected that the results will provide valuable insights not only for the company under study, but also for other organizations interested in adopting the Lean philosophy to achieve efficiency and sustainability goals.

1.3. Structure of the Dissertation

The present dissertation is divided into five chapters, each addressing different essential aspects of the study conducted. In the first chapter, a comprehensive introduction to the topics that will be explored throughout the dissertation is provided. This chapter includes the contextualization of the problem, the objectives of the study, and the methodology used to conduct the research. The introduction aims to provide a clear understanding of the theoretical and practical framework of the dissertation, establishing the foundation for the subsequent chapters.

The second chapter is dedicated to the review of relevant literature on the topics addressed in the case study. In this chapter, the fundamental concepts, theories, and previous research that inform the context of the study are explored. The literature review not only clarifies the current state of knowledge in the field but also identifies gaps and opportunities for the practical application of lean philosophy and the DMAIC methodology in the business context.

In the third chapter, the specific case study and the company where the research was conducted are presented. This chapter offers an analysis of the organizational structure of the company, the products it produces, and the processes involved in its production. Through a critical analysis, the main strengths and weaknesses of the company are identified, as well as opportunities for improvement and challenges faced. This analysis serves as the basis for the practical application of the studied methodologies.

The fourth chapter focuses on the five stages of the DMAIC methodology implementation. Each stage is explained in detail, including the objectives, methods, and tools used.

The fifth chapter is dedicated to discussing the results obtained from the implementation of the DMAIC methodology. In this section, the impacts of the changes made to the company's processes are analysed, both from an operational and sustainability perspective. The discussion addresses the successes achieved, the difficulties encountered, and the lessons learned during the implementation process. The results are compared with the initial objectives of the study, evaluating the effectiveness of the interventions.

Finally, the last chapter presents the final conclusions of the dissertation. In this chapter, the limitations of the study are also identified, recognizing aspects that could be improved or that require further investigation. Lastly, directions for future work are suggested.

This organized and detailed structure allows for a clear and comprehensive understanding of the study, from the theoretical introduction to the practical application and critical analysis of the results, providing a complete view of the impact of lean philosophy on promoting business sustainability.

1.4. Methodology

The methodology used in this dissertation was carefully structured to address the impact of lean philosophy on process improvement and organizational sustainability. This chapter details the steps followed, from the literature review to the adaptation and application of the DMAIC methodology to the specific case study.

First, a comprehensive literature review was conducted to understand how lean philosophy can positively influence process improvement and organizational sustainability. This review included the analysis of scientific articles, books, and case studies that highlight the application of lean principles in different business contexts. The aim of this step was to identify best practices and key challenges associated with lean implementation, as well as its implications for sustainability. During the literature review, the VOSviewer software was used to map and analyze networks of co-occurrence of terms. VOSviewer allowed for a clear visualization of research trends and emerging themes related to lean philosophy. This tool was essential for identifying the most relevant areas and guiding the collection of pertinent information for the study.

The methodology chosen for this dissertation was action research. Action research is a participatory and collaborative approach that aims to solve real problems through an iterative cycle of planning, action, and reflection. This methodology is particularly suitable for studies that seek not only to understand a phenomenon but also to implement practical changes and improvements in the context being studied. In the context of this dissertation, action research involved direct collaboration with the company under study, allowing for an in-depth understanding of the organization's specific processes and challenges.

Within the structure of action research, the DMAIC cycle, a structured continuous improvement method from Six Sigma, was applied and adapted to the specific context of the case study. The implementation of each phase is described below:

- **Define:** In this phase, the aspects requiring intervention were identified, and the metrics to be considered were established. This stage involved clearly defining the problems to be solved, the project's objectives, and the success criteria.

- **Measure:** In the Measure phase, data on the metrics defined in the previous phase were collected to establish a baseline of the initial situation. These measurements allowed for quantifying the current performance of the processes and identifying areas with the greatest potential for improvement.
- **Analyse:** During the Analyze phase, the causes of the identified problems were thoroughly examined. Analytical tools were used to identify the root causes of the problems. Based on this analysis, viable solutions to the problems were determined.
- **Improve:** In the Improve phase, the improvement proposals identified in the previous phase were implemented. This stage involved applying various lean tools to optimize processes and reduce waste.
- **Control:** Finally, in the Control phase, control mechanisms were established to ensure the sustainability of the implemented improvements.

By following this methodology, it was possible to systematically and effectively address the challenges faced by the company, promoting significant improvements in its processes and contributing to its sustainability.

2. State of the Art

To provide a theoretical foundation for the case study in question and to understand prior research on the impact of lean philosophy on process improvement and sustainability, a review of the existing literature was conducted.

Firstly, a search on Web of Science was conducted using the keywords "Lean," "Sustainability," and "Lean Tools." The results were filtered for articles. A total of 394 articles were obtained from the platform, of which 273 were selected based on the title and abstract. Out of these 273, only 191 were available and were read in their entirety, with 119 being utilized in this literature review. The flowchart of the PRISMA methodology is shown in Figure 1 - Prisma methodology.

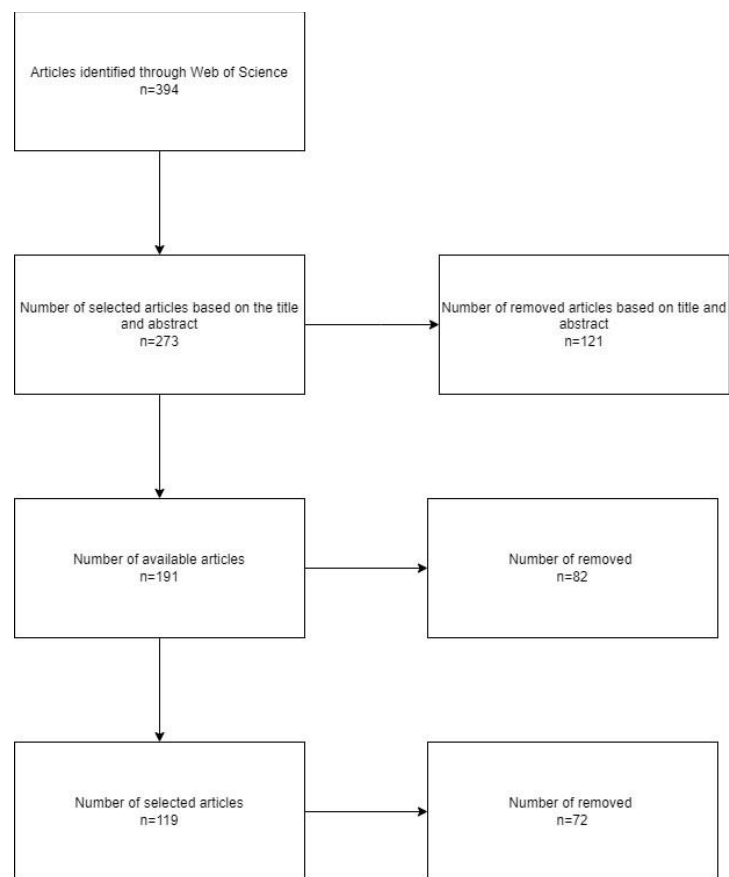


Figure 1 - Prisma methodology

organizational sustainability. By visually mapping and analyzing key terms and their relationships, VOSviewer enhanced the understanding of prevailing research trends and contributed to the comprehensive analysis conducted in this dissertation. This approach not only supported the literature review process but also informed subsequent stages of the research, including the adaptation and application of the DMAIC methodology in the specific case study.

Table 1 - Keywords with the highest occurrence

Keyword	Occurrences	Total Link Strenght
Lean	80	270
Sustainability	37	123
VSM	22	74
Green Manufacturing	14	62
Lean Six Sigma	13	42
5S	10	33
Lean Management	10	27
TPM	10	37
Simulation	9	24
DMAIC	8	31
Industry 4.0	8	26
Lean Tools	8	30
Sustainable Manufacturing	8	21
Six Sigma	7	22
SME's	7	31
Green Lean	6	24
SMED	6	23
Environmental Sustainability	5	17
Green Waste	5	19
Manufacturing	5	10
Supply chain	5	18
Sustainability Performance	5	22
Triple Bottom Line	5	19

The articles were also analysed by year of publications. According to the Figure 3 - Article per year it was concluded that until 2013 there was not a significant amount of research on the effects of lean on sustainability. However, from this year onwards, there was a sharp increase in the number of articles published on this topic, reaching the top in 2020.

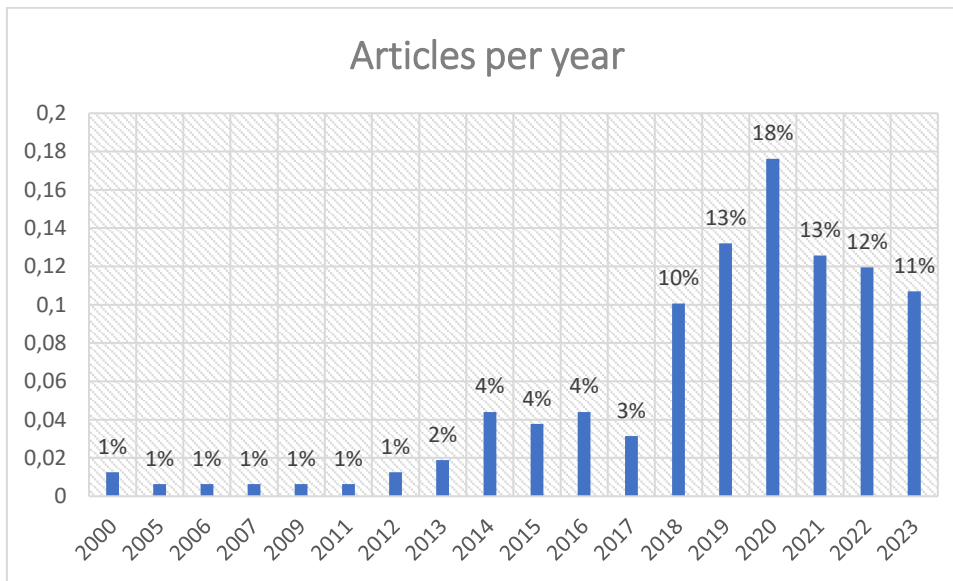


Figure 3 - Article per year

2.1. Sustainability

At the present time, the global landscape is marked by a series of unprecedented challenges that demand a collective and urgent response. Climate change, natural resource scarcity, and a growing awareness among various stakeholders of their social and environmental responsibilities are pressuring companies to rethink their business models and adopt more sustainable practices (Zhang et al., 2020). Corporate sustainability has emerged as a holistic approach to address these challenges, recognizing the interconnectedness of economic, social, and environmental aspects of development. At the core of this approach lies the concept of the Triple Bottom Line (Figure 4 - Triple Bottom Line) or "three pillars of sustainability" - people, profits, and planet - which advocates that companies should seek not only financial profit but also the well-being of people and the preservation of the environment (Gimpel et al., 2020).

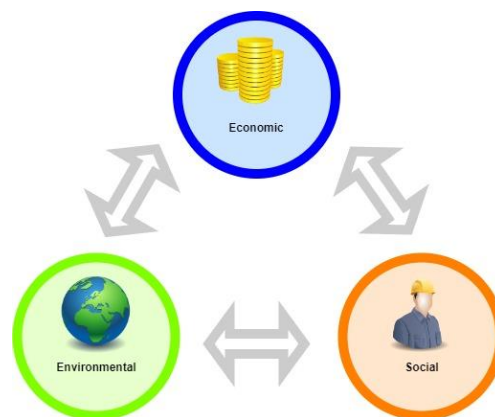


Figure 4 - Triple Bottom Line

The economic aspect of corporate sustainability goes beyond mere short-term profit maximization. It involves creating shared value, where companies aim to meet customer needs

in an ethical and responsible manner while generating sustainable financial returns for investors (Kovilage, 2021). This includes practices such as investing in innovation, developing sustainable products, and adopting ethical supply chains (Vinodh et al., 2016).

However, true corporate sustainability extends beyond the economic aspect and encompasses social and environmental dimensions. Sustainability tries to ensure that organizations can deliver the desired products and services with effective and efficient resource consumption, while avoiding potential harm to people and the environment, as well as other living things (Tasdemir et al., 2018).

In the social aspect, companies are called upon to promote fair and inclusive work practices, respect human rights throughout their value chain, and positively contribute to the communities in which they operate. This may include promoting diversity and inclusion in the workplace, employee education and training programs, corporate social responsibility initiatives, as well as prioritizing the well-being and mental health of their employees (Mubin et al., 2023).

On the other hand, the environmental aspect of corporate sustainability requires companies to minimize their negative impact on the environment and contribute to the conservation of natural resources. This may involve reducing greenhouse gas emissions, conserving water, and protecting biodiversity (Naeemah et al., 2022). Companies are increasingly adopting cleaner production practices, investing in renewable energy, and adopting resource-efficient technologies.

In addition to economic, social, and environmental aspects, corporate sustainability also involves cultural and organizational change. This requires committed leadership, employee engagement, and a long-term approach to sustainable development. Companies that succeed in this journey are those that integrate sustainability into their business strategy, establish measurable and transparent goals, and be accountable for their performance to all stakeholders.

However, despite significant advances in recent decades, the path to full corporate sustainability is far from complete. Persistent challenges, such as inadequate regulation, pressure for immediate profits, and lack of awareness of the benefits of sustainability, continue to hinder progress in this area.

Nevertheless, there are reasons for optimism. As more companies recognize the risks associated with inaction and the benefits of a sustainable approach to business, new opportunities for innovation and sustainable growth are emerging. As we advance into the 21st century, it is imperative that companies fully embrace the challenge of corporate sustainability and work together to build a fairer, more prosperous, and sustainable future for all.

2.2. Lean Philosophy

Lean is a system which utilize less inputs to create the same outputs as traditional mass production system while reducing non-value-added activities and increasing value to the costumer. Nowadays, Lean practices are not applied only for elimination of wastes, but also to create and improve customer value in the process of eliminating waste (Vinodh et al., 2011).

The Lean philosophy originated in Japan after World War II, with the creation of the Toyota Production System by Toyota. Initially focused on the automotive industry, TPS quickly expanded to other sectors and was adapted for various applications, including manufacturing, services, healthcare, and technology (Womack & Jones, 1996). This concept has established itself as a fundamental approach to enhancing operational efficiency and promoting sustainability in various organizations. The Lean philosophy is based on a series of fundamental ideas, including waste elimination, respect for people, creating value for the customer, and continuous improvement (Liker, 2004). Its main goal was to run its production with less money and time, leading to lower losses and defects (Zhang et al., 2020).

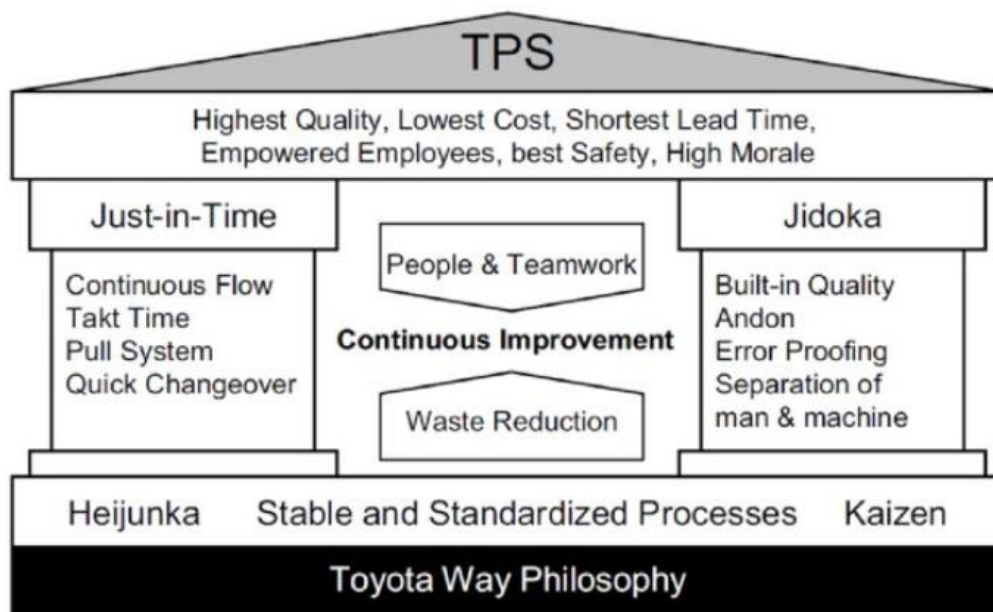


Figure 5 - House of TPS (Liker, 2004)

In this philosophy, waste, called "Muda" in Japanese, refers to any activity or element that does not add value to the product from the customer's perspective. Therefore, it should be eliminated or reduced to the minimum possible. According to Taiichi Ohno (1988), there are seven types of waste: overproduction, transport, waiting, excessive processing, inventory, unnecessary motion, defects (Figure 6 - Seven types of waste).

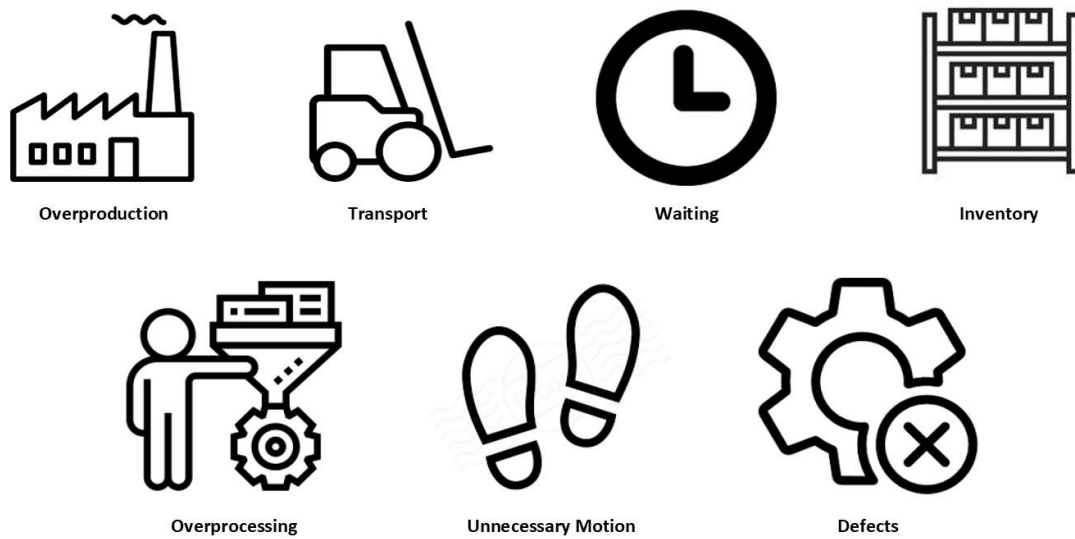


Figure 6 - Seven types of waste

According to Womack and Jones (1996), the Lean philosophy is grounded in five principles. The first principle is Identify Value. This involves deeply understanding what is valued by the customer and directing all efforts to provide that value efficiently and effectively. The second principle is Map the Value Stream. This entails analysing and optimizing all processes involved in delivering value to the customer, identifying, and eliminating waste along the way. The third principle is Create Flow. Here, the aim is to design production systems that allow work to flow smoothly and without interruptions, ensuring efficient and consistent delivery of value. The fourth principle is Implement Pull Production. This means establishing systems where work is done only when needed, based on the actual demand from the customer, thus avoiding overproduction and unnecessary inventory buildup. Lastly, the fifth principle is Strive for Perfection. This principle reflects the ongoing commitment to improvement and excellence in all areas of the organization, never settling for the status quo and always seeking ways to do things better and more efficiently. These five principles form the core of Lean thinking and provide a powerful framework to guide organizations towards operational excellence and customer satisfaction.

2.3. Lean Tools

The Lean philosophy can be considered a set of tools that aim to reduce costs and increase the quality of products and services provided to the customer (Ioppolo et al., 2014). These tools can also be used for the identification, diagnosis, and implementation of initiatives to improve the production process (Tanasic et al., 2022b). Furthermore, these tools are easily adapted and extended for sustainability principles (Pattanaik et al., 2019). In the table 2 some lean tools are presented.

Table 2 - Lean Tools

Poka - Yoke	Error and defect prevention tool aimed at eliminating or minimizing process failures, ensuring the quality of the final product or service (García Alcaraz et al., 2022).
Kanban	Visual management system which is a control tool designed to optimize workforce capacity utilization to achieve Just-In-Time (JIT) goals (Mojarro-Magaña et al., 2018).
5S	It is a simple yet productive tool for reducing non-value adding activities of operators, delay in searching for tools and other process related items. It improves the traceability, quality of operator job and prevents scraps and reworks (Pattanaik et al., 2019).
Daily Kaizen	Events to keep those involved motivated to participate in continuous improvement activities and develop their problem-solving skills. They can have an impact on increasing productivity, quality, reducing time and costs (Štefanić et al., 2012).
Heijunka	Evenly distributing the volume and mix of products across time (production levelling). (Mohapatra et al., 2021)
Jidoka	Machines detecting errors and promptly implementing corrective measures (Mohapatra et al., 2021)
Visual Management	Technique that allows information to be transmitted in a perceptible way so that throughout the processes, everyone involved can manage, control, improve and correct it. This tool consists of the development of visual devices that influence, direct, delimit and/or control behavior through information disseminated visually (Bevilacqua et al., 2013).
TPM	Maximize overall equipment efficiency and establish a preventive maintenance system for the entire life of the equipment (Chan et al., 2005). Prevent production flow disruptions that may arise from a lack of calibration and product defects, thus reducing downtimes and minimizing occupational accidents (García Alcaraz et al., 2022b)
Value Stream Mapping	VSM is a graphic model utilized to showcase material flows within the company's processes, providing a visual representation of all productive activities. This model aids in identifying the value chain and pinpointing specific areas within the process where the highest amount of waste is generated (Dominguez-Alfaro et al., 2021)
SMED	Single Minute Exchange of Die (SMED) supports small-scale production in batch sizes, reducing inventory and enhancing productivity (Thekkootte, 2022).
Kamishibai	Visual management tool, as that allows for a quick understanding of the state of operations and tasks to be performed. It consists of a series of cards, each corresponding to a specific sector or area of the organization. Each card contains a list of tasks or standards to be fulfilled by the employees (José et al., n.d.).
Yokoten	The horizontal sharing of knowledge, techniques, processes, and solutions among different areas or departments within the same organization (Rodrigues et al., 2019).

Out of the selected articles, 62 describe the impact of Lean tools on the sustainability of companies. Some focus on a single tool, while others study multiple tools simultaneously. An analysis was conducted to understand which Lean tools stand out in this context, and the results are presented in the Table 3. The graph (Figure 7 - Lean tools) shows that, among the analysed case studies, VSM is the most applied tool when it comes to sustainability. In contrast, Heijunka and the Spaghetti Diagram are the least utilized in this regard.

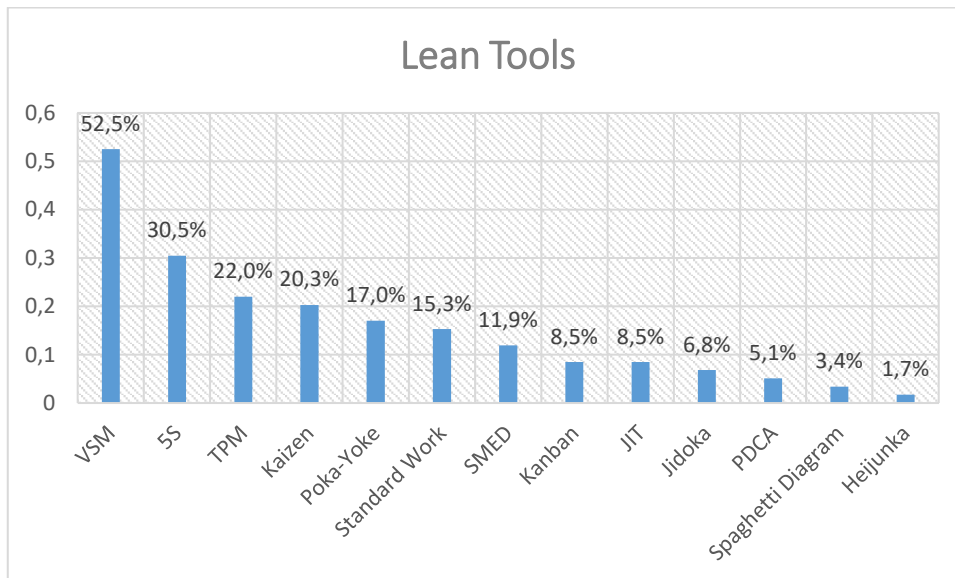


Figure 7 - Lean tools

Table 3 - Lean tool referred to in each article

	Heijunka	TPM	PDCA	Kanban	Spaghetti Diagram	JIT	SMED	Standard Work	Poka-Yoke	Kaizen	VSM	5S	Jidoka
(Gholami et al., 2021)											x		
(Díaz-Reza et al., 2022)		x											
(Vinodh et al., 2011)												x	
(Vinodh et al., 2016)								x		x	x	x	
(Ahmad et al., 2022)		x		x			x				x	x	
(Verma et al., 2021)											x		
(Mubin et al., 2023)											x		
(Papetti et al., 2019)											x		
(Wang et al., 2015)		x											
(Das, 2018)		x						x	x		x		
(Garza-Reyes, Kumar, et al., 2018)		x				x				x			

	Heijunka	TPM	PDCA	Kanban	Spaghetti Diagram	JIT	SMED	Standard Work	Poka-Yoke	Kaizen	VSM	5S	Jidoka
(Aguado et al., 2013)		x				x				x			
(Brown et al., 2014)											x		
(Kurdve et al., 2015)											x		
(Helleno et al., 2017)											x		
(Souza et al., 2018)										x	x	x	
(Garza-Reyes, Torres Romero, et al., 2018)			x								x		
(Leme et al., 2018)							x						
(Erdil et al., 2018)										x	x		
(Baysan et al., 2019)											x		
(Baumer-Cardoso et al., 2020)				x							x		
(Tiwari et al., 2020)							x	x	x	x	x	x	
(Sadiq et al., 2021)											x		

	Heijunka	TPM	PDCA	Kanban	Spaghetti Diagram	JIT	SMED	Standard Work	Poka-Yoke	Kaizen	VSM	5S	Jidoka
(Rathi et al., 2022)				x								x	
(Farias et al., 2019)		x					x			x	x	x	
(Amjad et al., 2023)			x										
(Garza-Reyes et al., 2016)									x				
(Cherrafi et al., 2019)								x					
(Choudhary et al., 2019)									x				
(Jamil et al., 2020)									x				
(Sony et al., 2020)									x				
(Thekkoote, 2022b)		x								x		x	
(Utama et al., 2022)									x				
(Gholami et al., 2019)											x		
(Kumar et al., 2018)											x		

	Heijunka	TPM	PDCA	Kanban	Spaghetti Diagram	JIT	SMED	Standard Work	Poka-Yoke	Kaizen	VSM	5S	Jidoka
(Chen et al., 2019)		x											
(Silva et al., 2022)		x										x	
(Tanasic et al., 2022b)								x	x	x	x	x	x
(Acero et al., 2020)											x		
(Florescu et al., 2022)											x	x	
(Medyński et al., 2023)		x						x					
(García Alcaraz et al., 2022b)		x											x
(Mendes et al., 2023)		x		x		x		x	x	x	x	x	x
(Gavriliuță et al., 2021)								x				x	
(Shahbazi et al., 2019)											x		
(Cantini et al., 2020)					x								
(Schoeman et al., 2020)											x		

	Heijunka	TPM	PDCA	Kanban	Spaghetti Diagram	JIT	SMED	Standard Work	Poka-Yoke	Kaizen	VSM	5S	Jidoka
(Gargalo et al., 2021)											x		
(García-Alcaraz et al., 2021)							x					x	
(Carrera et al., 2021)												x	
(Marques et al., 2022)										x			
(Fonda et al., 2022)							x						
(Dinis-Carvalho et al., 2023)								x			x		
(Niekurzak et al., 2023)					x		x						
(Dominguez-Alfaro et al., 2021)											x		
(Jain et al., 2023)												x	
(Kääriä et al., 2023)											x		
(Herron et al., 2006)			x			x				x		x	
(Mohapatra et al., 2021)	x			x		x			x		x	x	x

2.3.1. VSM

Value Stream Mapping (VSM) is a powerful tool utilized within the Lean methodology to visualize and assess the flow of materials and information throughout a process. Derived from the principles outlined in the seminal book "Learning to See" by Mike Rother and John Shook, VSM enables organizations to identify opportunities for improvement and streamline their operations.

Central to the analysis conducted through VSM are several key metrics that provide insights into different aspects of process performance. Lead Time, for instance, denotes the total duration from the initiation to the completion of a process, encompassing all steps and activities involved. Cycle Time, on the other hand, represents the average duration required to complete one unit of work within the process, excluding any waiting time or delays between tasks.

Additionally, Value-Added Time highlights the duration spent on activities directly contributing to creating value for the customer, while Non-Value-Added Time encompasses activities that do not contribute to value creation, such as waiting or unnecessary processing. Monitoring Work in Progress levels is crucial for identifying bottlenecks and optimizing flow within the process, while First-Time Yield measures the percentage of defect-free products or services produced on the first attempt.

By analysing these metrics in conjunction with a Value Stream Map, organizations can gain valuable insights into process efficiency, identify areas of waste or inefficiency, and implement targeted improvements to enhance operational effectiveness and customer satisfaction.

Value Stream Mapping (VSM) stands out as one of the most prominent Lean tools utilized by organizations in conjunction with sustainability initiatives. This is attributed to its ability to provide a comprehensive analysis of processes through a visual approach (Ahmad et al., 2022). Traditionally, Value Stream Mapping was devised to assess both value-added and non-value-added activities within industries (Vinodh et al., 2016). However, innovative adaptations of this tool have emerged to address specific areas of concern.

For instance, Choudhary et al. (2019) introduced the Green Integrated VSM, which has demonstrated effectiveness in eliminating Lean's seven wastes while concurrently reducing emissions, carbon footprint, and energy consumption. Furthermore, Gargalo et al. (2021) developed the SustainSC-VSM to evaluate the performance and sustainability of supply chains. Ergonomic considerations were addressed with the adaptation of VSM into ErgoVSM by Dominguez-Alfaro et al. (2021), focusing on mitigating associated risks.

In addition, Faulkner et al. (2014) proposed Sus-VSM, a strand of VSM specifically tailored to address sustainability concerns. These adaptations highlight the versatility and applicability of VSM in addressing various dimensions of sustainability within organizational processes. The Table 4 - Case Studies: VSM refers to the application of VSM in case studies.

Table 4 - Case Studies: VSM

Author	Analysis
(Faulkner et al., 2014)	This paper is based on three case studies to analyse the application of Sus-VSM. This tool allowed companies across cases to identify improvement opportunities. Besides that, it

Author	Analysis
	was evident that sustainability metrics are not widely available at the manufactures.
(Garza-Reyes et al., 2018)	This paper investigates an approach grounded in the PDCA cycle for implementing Environmental Value Stream Mapping. The study applied this approach to the helical rolling process within a mining consumables business unit. The results demonstrated the efficacy of this approach as a viable solution to address critical sustainability issues. Upon implementation, the approach proved effective in eliminating green waste and reducing energy consumption in the helical rolling process. This underscores the potential of the PDCA-based Environmental-VSM approach for enhancing sustainability practices within industrial processes.
(Gholami et al., 2019)	Development of a Social Value Streaming Mapping. This tool was tested on a hard disc drive substrate manufacturing. This new version of VSM allows organisations to identify societal issues due to manufacturing operations.
(Dominguez-Alfaro et al., 2021)	This research aims to identify potential ergonomic risks arising from the adoption of Lean Manufacturing practices within organizations. It underscores the necessity of incorporating ergonomics alongside productivity indicators in process analysis, leading to the development of the ErgoVSM methodology. The findings indicate that the application of ErgoVSM allows for process enhancements from an ergonomic standpoint without compromising productivity.

2.3.2. 5 S

The 5S methodology is a Japanese approach to workplace organization and management that is widely adopted globally. Each "S" represents a fundamental stage of the process:

1. **Seiri - Sort:** In this phase, unnecessary items are identified and eliminated, prioritizing what is essential. This frees up space and optimizes efficiency.
2. **Seiton - Set in Order:** This involves efficiently organizing the workspace. Essential items are arranged logically and accessibly, facilitating quick retrieval when needed.
3. **Seiso - Shine:** Focuses on maintaining cleanliness and order in the workplace. Regular cleaning routines are implemented to ensure a safe and pleasant environment.
4. **Seiketsu - Standardize:** Establishes consistent standards and procedures to maintain the first three "S" over time. This includes clear guidelines, training, and monitoring systems.
5. **Shitsuke - Sustain:** Aims to maintain discipline and promote positive work habits. All team members must commit to following established standards and maintaining an organized and efficient environment.

The importance of 5S is that it effectively helps to reduce cost, by increasing process efficiency, through the formation and maintenance of a clean and high-quality work environment.



Figure 8 - 5S

After VSM, the 5S stands out as the most employed tool for promoting sustainability. This is attributed to the fact that the 5S method facilitates the organization of workspace, creating a clean, stable, and efficient work environment that contributes to improved performance. Additionally, the 5S is an easily applicable tool (Gavriluță et al., 2021). Also, this tool has been evolving over time. Jiménez et al., (2019) added a sixth 'S' to represent issues related to safety and to respond to the occupational safety and health needs. According to Sá et al., (2021) the organization and cleanliness promoted by the 5S not only improve operational efficiency but also significantly contribute to accident prevention. Additionally, Visual Management has been identified as an effective tool for communicating safety information clearly and accessibly, increasing awareness and compliance with safety standards. These findings underscore the crucial role of lean practices not only in process improvement but also in promoting a safer and more productive work environment. More recently, Carrera et al., (2021) added the seventh 'S,' focusing on Corporate Social Responsibility.

Table 5 - Case Studies: 5S

Author	Analysis
(Carrera et al., 2021)	The objective of this article is to assess the correlation between Corporate Social Responsibility and the 5S tool. To acquire insights on this matter, a survey was conducted in Spanish multinational organizations. The findings demonstrated a current trend among corporations to improve their sustainability performance. Additionally, a proposed extension

Author	Analysis
	of the 5S tool incorporating a sixth "S" focusing on safety was introduced. This suggests a potential avenue for future research, exploring the implementation of a seventh "S" specifically tied to sustainability.
(Vinodh et al., 2011)	This article centres on the examination of sustainability issues through the lens of lean initiatives. It also presents strategies and techniques that facilitate the attainment of sustainability objectives via lean practices. Key issues addressed include a commitment to eliminating environmental waste through lean implementation, identification of environmental improvement opportunities, active engagement of Environmental, Health, and Safety staff in planning and executing lean events with environmental opportunities, elimination of environmental waste using process improvement tools, and the facilitation of waste reduction through the application of the 7S workplace evaluation checklist. This underscores the integration of lean principles with sustainability considerations to address contemporary environmental challenges.

2.4. Lean Six Sigma

Six Sigma constitutes a structured and methodical approach to enhance strategic processes, as well as to foster innovation in new products and services. It leverages statistical and scientific methodologies to achieve significant reductions in defect rates defined by customers. Contemporary manufacturing establishments embrace a dual strategy, integrating both lean and six sigma methodologies, to streamline operations by eliminating waste and reducing defects. The synthesis of these approaches is embodied in Lean Six Sigma a potent manufacturing strategy that harmoniously blends the principles of both lean and six sigma (Ruben et al., 2018). The systematic application of the phase improvement cycle, known as DMAIC (Define, Measure, Analyze, Improve, and Control), is a crucial advantage of the Six Sigma approach. DMAIC serves the purpose of enhancing, optimizing, or stabilizing current processes through an objective and problem-solving-oriented framework. In the context of Lean Six Sigma (LSS), the DMAIC cycle is strategically directed towards minimizing process variability through the implementation of standardized practices, waste reduction, and the reduction of lead time (Noskievičová et al., 2022). The Lean Six Sigma tool, as well as the DMAIC, are often applied to promote the sustainability of companies.

Following that, the impact of Lean Six Sigma on sustainability was examined. The application of Lean Six Sigma principles has proven to be efficient in this context, especially the application of the DMAIC cycle (Noskievičová et al., 2022). The Lean Six Sigma improvement process distinctly focuses on integrating both human and process elements to achieve clear and tangible bottom-line results (Ruben et al., 2018).

The iLeanDMAIC methodology presented by Ferreira, C et al., (2020) innovatively integrates Lean tools with the DMAIC cycle to streamline processes and boost efficiency in manufacturing.

By aligning Lean principles with DMAIC phases, the approach aims to systematically identify and eliminate waste while enhancing overall operational performance, demonstrating the methodology's effectiveness in fostering continuous improvement and competitiveness within organizations.

Most companies implement various Lean Six Sigma tools with positive outcomes such as improved problem-solving, waste reduction, and enhanced internal communication. Implementing a Quality Management System (QMS) based on ISO 9001, combined with Lean tools, engages organizations in a continuous cycle of improvement. Companies that adopt a greater number of LSS tools tend to achieve larger waste reductions, indicating that more mature and intensive approaches yield more significant results (José Carlos Sá et al., 2022).

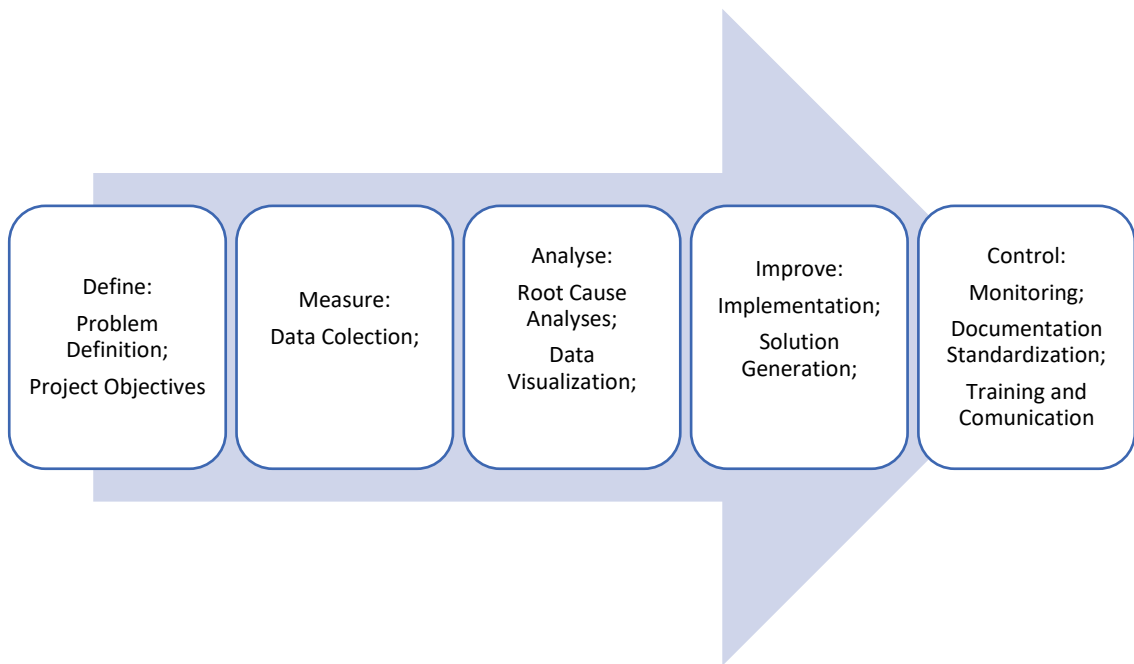


Figure 9 - The five phases of DMAIC

In the application of DMAIC, techniques and methodologies designed to assist in specific phases of the DMAIC process can be encompassed. These tools serve as valuable aids for data collection, analysis, and decision-making, ultimately contributing to the successful execution of Lean Six Sigma projects. Here are the tools and descriptions of each step according to Kosieradzka et al. (2018) and Tang et al. (2007):

Table 6 - DMAIC Tools and Techniques (Kosieradzka et al. (2018) and Tang et al. (2007)):

Phase	Description	Tools
Define	<ul style="list-style-type: none"> Clearly identify the problem or improvement opportunity to be addressed. Establish quantifiable goals the project should achieve. 	<ul style="list-style-type: none"> Process mapping Project management tools

Phase	Description	Tools
	<ul style="list-style-type: none"> • Determine who will be affected by the project and engage relevant stakeholders. • Outline the steps to be followed to achieve project objectives 	
Measure	<ul style="list-style-type: none"> • Determine which metrics will be used to assess the current process performance. • Gather relevant data about the current process using appropriate methods. • Assess whether the process is in control and capable of meeting specifications. • Identify improvement opportunities: analyse data to identify problem areas or improvement opportunities 	<ul style="list-style-type: none"> • QFD • Kano analysis • Sampling • Measurement system analysis • Run charts • Capability analysis
Analyse	<ul style="list-style-type: none"> • Use statistical and analytical tools to identify root causes of identified problems. • Determine which root causes have the greatest impact on the problem or improvement opportunity. • Generate and evaluate different solutions to address identified root causes. 	<ul style="list-style-type: none"> • Basic graphical improvement tools • FMEA • Statistics analysis • Cost analysis • Forecasting • Basic queueing systems • Simulation and modelling
Improve	<ul style="list-style-type: none"> • Put selected solutions from the analysis phase into practice. • Test solutions on a small scale to verify their effectiveness before full-scale implementation. • Track the results of implemented changes and adjust as necessary. 	<ul style="list-style-type: none"> • Optimization and control of queues • Mathematical programming techniques • Heuristics • Sensitivity analysis

Phase	Description	Tools
Control	<ul style="list-style-type: none"> • Develop systems and processes to ensure that improvements are sustained over time. • Create documentation and standard operating procedures to ensure consistency and compliance. • Continue monitoring key performance indicators to ensure the process remains under control and meets established goals. 	<ul style="list-style-type: none"> • Mistake proofing • Validation testing • Control plans • Basic control charts

The Table 7 - Case Studies: Lean Six Sigma presents some studies related to Lean Six Sigma and DMAIC.

Table 7 - Case Studies: Lean Six Sigma

Author	Analysis
(Pereira et al., 2019)	This article investigates how the application of Lean Six Sigma principles can optimize processes in the moulds industry. Employing a methodological approach based on the PDCA/DMAIC cycle, the study utilizes techniques such as value stream mapping, Pareto analysis, and overall equipment effectiveness assessment. Findings indicate significant improvements, including a notable 20% increase in overall equipment effectiveness for specific CNC machines. Despite the unique challenges associated with mould projects, the research underscores the effectiveness of Lean Six Sigma in enhancing operational efficiency and competitiveness within the industry.
(Noskievičová et al., 2022)	This research involved the application of Lean Six Sigma principles to enhance efficiency in the beer bottling line. Ultimately, all machines successfully decreased stoppage frequency by 20%. Moreover, there was a notable improvement in the Sigma level for almost every machine. The achieved reduction in brief stoppages and other forms of waste, coupled with cost savings resulting from the extensive collection and analysis of diverse data, contributed significantly to sustainability. From an economic perspective, this initiative led to annual cost savings of 8,000 euros.
(Craveiro et al., 2023)	This study explored Lean and Six Sigma implementation in Portuguese laboratories and their impact on performance. Despite limited adoption, mostly in larger labs, those employing these methodologies showed enhanced organizational performance compared to non-adopters. The study's small sample size (15% of the population) limits broad conclusions but provides crucial insights for strategic decisions in this sector.

Author	Analysis
(Srinivasan, Muthu, Prasad, et al., 2014)	The study aims to improve the quality of the painting process by identifying key issues, collecting relevant data, conducting detailed analysis to pinpoint root causes of defects, proposing and implementing solutions, and establishing control methods to ensure sustainable improvements. The article highlights the effectiveness of the Six Sigma DMAIC approach in continuous process improvement, contributing to enhancing the quality and efficiency of shock absorber production.
(Srinivasan, Muthu, Devadasan, et al., 2014)	Through this approach, the researchers aim to identify and address inefficiencies in the heat exchange process. They begin by defining the problem, measuring key performance metrics, analyzing data to identify root causes of inefficiency, implementing improvements, and establishing controls to sustain the enhancements. By applying Six Sigma DMAIC phases, the study seeks to optimize the performance of shell and tube heat exchangers, ultimately leading to enhanced effectiveness in heat transfer processes.
(Curbano et al., 2020)	The study yielded significant improvements in reducing Defect X occurrences. By applying Lean Six Sigma methodologies, root causes were identified and addressed, leading to a noticeable decrease in defects. Results were sustained through effective monitoring and control measures. Overall, the study demonstrated the efficacy of Lean Six Sigma in enhancing product quality and process efficiency for Company Y.
(Rathi et al., 2022)	This study aims to analyse the implementation of a GLSS program which facilitated enhancements in operational performance and environmental sustainability. The introduction of Kanban, 7S, and an optimized plant layout contributed to a reduction in cycle time and an improvement in lead time. The implemented improvement measures yielded significant advancements in environmental metrics, notably in terms of raw material consumption, coolant usage, energy utilization, and overall environmental impact. Specifically, there was a reduction of 17.81% in raw material consumption, 17.31% in energy utilization, and 25.81% in coolant consumption.
(Nedeliakova et al., 2020)	This study aims to reduce delays in a railway transport company through the application of lean tools and lean six sigma. Slovak Republic's main line delays were monitored between 2015 and 2018. From this data, software was created with the aim of managing the risk of delays.
(Skalli et al., 2023)	Development of Circular Lean Six Sigma 4.0 and exploratory study of 12 Moroccan manufacturing firms conducted through interviews with top executive managers.
(Ruben et al., 2018)	This article aims to conduct a comprehensive literature review on Lean Six Sigma within the context of manufacturing firms. Employing a qualitative review methodology, the analysis yields insights that contribute to the development of a generic framework for implementing Lean Six Sigma, integrating

Author	Analysis
(Kääriä et al., 2023)	<p>environmentally friendly tools. The objective is to reduce costs, minimize waste, mitigate environmental impacts, and address inefficiencies associated with manufacturing processes.</p> <p>The aim of this article is to scrutinize the existing state of the Order-to-Cash (O2C) process within the case company and pinpoint areas for improvement. This analysis is conducted through the utilization of Lean Six Sigma tools, particularly employing methodologies such as value stream mapping (VSM). The study discovered that enhancing the performance of activities within the Order-to-Cash (O2C) process and fostering improved communication among internal and external stakeholders can lead to a more effective O2C process overall. This, in turn, results in the delivery of enhanced customer value.</p>
(Marrucci et al., 2020)	<p>This study seeks to examine supermarket waste management systems with the goal of identifying more sustainable and circular processes. A particular case study was scrutinized to evaluate and enhance the waste management system within a supermarket setting. The data collection process employed the Lean Six Sigma model DMAIC. The environmental impact of the waste management system was assessed through the analysis of the carbon footprint. The study successfully demonstrated the efficacy of Lean Six Sigma and DMAIC in improving sustainability outcomes.</p>
(Ishak et al., 2019)	<p>The study explores the integration of Six Sigma DMAIC methodology and Grey Failure Mode Effect Analysis (FMEA) in quality control processes. It assesses the effectiveness of this combined approach in improving product quality and reliability. The review examines how Six Sigma DMAIC provides a structured framework for process improvement, while Grey FMEA offers a method for analyzing potential failure modes and their effects. By combining these methodologies, the review aims to provide insights into optimizing quality control practices for enhanced efficiency and effectiveness.</p>
(Maulida Hakim et al., 2018)	<p>The project aims to identify key factors contributing to production flexibility, measure the current state of operations, analyze root causes of inefficiencies, implement improvements, and establish controls to sustain the enhancements. Through this approach, the project seeks to optimize production processes, reduce lead times, and enhance the company's ability to respond quickly to changing market demands in the automotive industry.</p>
(Carlos de Queiroz Santos et al., n.d.)	<p>The project aims to evaluate the current sigma level of the industry's processes, identify areas for improvement, and implement targeted measures to enhance process efficiency and quality. By utilizing DMAIC, the project seeks to systematically analyze data, identify root causes of inefficiencies, implement improvements, and establish controls to sustain the enhancements, ultimately aiming to increase the sigma level and improve overall performance in the thermoplastic industry.</p>
(Jevgeni et al., 2015)	<p>This article is a structured approach aimed at enhancing efficiency and productivity in manufacturing operations. It</p>

Author	Analysis
	involves implementing methodologies such as Lean Six Sigma and Total Quality Management to systematically identify, analyze, and optimize production processes. Key components include process analysis, data collection and analysis, problem-solving methodologies, cross-functional collaboration, continuous monitoring, standardization, training, and performance metrics. This framework fosters a culture of continuous improvement, driving operational excellence and sustained enhancements in production processes and product throughput.
(Barbosa et al., 2017)	The article offers a hands-on strategy to tackle quality issues encountered during the tire production preparation phase. It likely provides real-world solutions and insights into overcoming challenges in this specific stage of tire manufacturing. The authors may discuss practical methodologies and techniques utilized to diagnose and address root causes of quality concerns, aiming to improve overall product quality and streamline production processes within the tire industry.
(Alsaffar et al., 2018)	The review titled "Reviewing the Effects of Integrated Lean Six Sigma Methodologies with Ergonomics Principles in an Industrial Workstation" likely assesses the impact of combining Lean Six Sigma methods with ergonomics principles within industrial work environments. It probably investigates how this integration influences various aspects such as productivity, quality, and worker health and safety. By examining practical examples and research findings, the review aims to highlight the benefits of leveraging both Lean Six Sigma and ergonomics to optimize workstations, enhance operational efficiency, and promote employee well-being in industrial settings.
(Rizky Alfiansyah et al., 2020)	The article likely emphasizes enhancing operational efficiency in airline catering services by identifying and removing wasteful processes. It probably discusses implementing Systematic Layout Planning (SLP) to optimize facility layout and resource utilization, aiming to boost productivity. The overarching objective is to cut inefficiencies, reduce waste, and elevate productivity levels, leading to improved service quality and customer satisfaction in airline catering.
(Ishak, Siregar, et al., 2020)	The project focused on using Lean Six Sigma methodologies to enhance the wooden pallet production process by reducing waste and improving product quality. This involved identifying and eliminating inefficiencies and defects, resulting in streamlined operations and minimized variations. The project likely led to a reduction in defects, increased process efficiency, and cost savings through waste reduction. Overall, it demonstrated the effectiveness of Lean Six Sigma in optimizing the wooden pallet production process at PT. XYZ.
(Ishak & Elizabeth Zalukhu, 2020)	A case study was conducted to enhance the quality control of bolt products using the Six Sigma DMAIC method. This involved a systematic approach to define, measure, analyse, improve, and control quality aspects. By applying Six Sigma principles, the study aimed to identify, analyse, and address defects in bolt production processes, ultimately leading to improved product quality and customer satisfaction.
(Henny et al., 2019)	This approach integrates Lean principles, focusing on reducing waste and improving flow, with Six Sigma tools, which target variation reduction and process improvement. By implementing Lean Six Sigma,

Author	Analysis
	organizations can streamline operations, optimize resource utilization, and enhance overall efficiency, resulting in reduced waste and improved productivity.
(Fajrianto et al., 2020)	In this case study, Six Sigma methodology is applied to minimize scrap material from Castor 5 Inch products in the EOP Warehouse. The approach likely involves utilizing the DMAIC (Define, Measure, Analyze, Improve, Control) process to systematically identify, analyze, and address the root causes of scrap material generation. By defining key metrics, measuring scrap material levels, analyzing data to identify patterns and causes, implementing targeted improvements, and establishing controls, the study aims to reduce scrap material and optimize operations in the EOP Warehouse. Ultimately, the case study demonstrates the effectiveness of Six Sigma in minimizing waste and improving efficiency in the handling of Castor 5 Inch products
(Mahajan et al., 2019)	Application of Lean principles to enhance workflow efficiency and promote sustainability. This involves identifying and eliminating waste, refining process flow, and boosting overall productivity while reducing environmental footprint. Through the implementation of Lean techniques like value stream mapping, 5S methodology, and Just-in-Time production, the manufacturing unit seeks to streamline operations, minimize resource usage, and foster greater sustainability.
(Wirawan et al., 2016)	At PT 'X', a plastic molding manufacturing company, a case study delves into quality enhancement through the integration of quality tools and TRIZ methodology. This involves employing various quality tools and TRIZ principles to innovate and resolve quality-related challenges. The study illustrates how this integration fosters continuous improvement and optimizes manufacturing processes within PT 'X'.
(Azizi, 2015)	The evaluation focuses on enhancing production productivity performance by leveraging Statistical Process Control (SPC), Overall Equipment Efficiency (OEE), and Autonomous Maintenance (AM). This likely involves analysing production data using SPC methods to monitor and control processes, optimizing equipment efficiency through OEE measurement and improvement initiatives, and empowering operators with AM to perform routine maintenance tasks. By integrating these approaches, the evaluation aims to identify areas for improvement, streamline production processes, and enhance overall productivity performance.
(Pathan et al., 2020)	The article describes how a steering manufacturing and assembly plant resolves the issue of improper mating between the rack and valve assembly using Six Sigma methodology. It details the steps taken to identify the root causes of the problem, measure defects, analyse data, implement improvements, and establish controls. Through this systematic approach, the plant aims to improve assembly processes, ensuring proper mating and enhancing overall product quality and efficiency.
(Hong, 2017)	This approach likely includes identifying and eliminating waste, reducing variability, and improving overall efficiency in inventory control within the supply chain. By integrating Lean Six Sigma, organizations aim to streamline inventory management,

Author	Analysis
	minimize excess stock, enhance order fulfilment, and ultimately improve the overall performance of the supply chain.
(Razali et al., 2018)	The case study examines how the Six Sigma approach is used to enhance the quality of stripping in automotive electronics components. By employing Six Sigma's methodology, the focus is on identifying, analysing, and rectifying issues related to the stripping process. Ultimately, the aim is to improve the quality of the stripped components, thereby enhancing overall performance and customer satisfaction within the automotive electronics sector
(Setiyaningrum et al., 2019)	The case study focuses on applying Lean Six Sigma methods to prevent crank defects in a hospital equipment company. This involves utilizing Lean principles and Six Sigma methodologies to identify, analyse, and prevent crank defects in the manufacturing process. By implementing a structured approach, the company aims to streamline operations, reduce variability, and improve overall quality to ensure the production of defect-free hospital equipment.
(Ismail et al., 2017)	The project centres on developing a Six Sigma methodology to enhance the CNC milling process. This likely involves applying Six Sigma principles to identify and address inefficiencies, reduce defects, and optimize the milling process. By utilizing a structured approach, the aim is to systematically analyse data, identify root causes of variations, implement targeted improvements, and establish controls to ensure sustained process enhancements. Ultimately, the goal is to increase efficiency, precision, and quality in CNC milling operations.
(Nunes, 2015)	The proposal suggests combining ergonomics principles with Lean Six Sigma methods to improve both process efficiency and worker comfort. This involves creating a model that integrates ergonomic considerations into the DMAIC process of Lean Six Sigma. By doing so, the aim is to streamline workflows, reduce physical strain on employees, minimize errors, and boost productivity.
(Elattar et al., 2020)	This study highlights the crucial role of safety maintenance in upholding Lean practices and improving overall performance by managing faults effectively. This entails incorporating safety protocols into Lean methodologies to reduce risks and errors. By giving priority to safety alongside Lean principles, the objective is to cultivate a culture that not only streamlines processes but also safeguards employee well-being. This combined approach aims to facilitate ongoing enhancement while mitigating interruptions caused by faults or accidents

2.5. Lean Green

The term "Lean and Green" combines the principles of Lean Manufacturing with environmentally sustainable practices. Lean Manufacturing is a management approach focused on maximizing value for the customer while minimizing waste of resources, time, and effort. On the other hand, the "green" aspect refers to practices aimed at reducing the environmental impact of industrial operations. As Lean practices are not only effective in reducing waste and increasing operational efficiency, but also in decreasing resource consumption and environmental emissions. This is crucial in a context where companies are increasingly pressured to adopt sustainable practices to mitigate their impact on the environment (Silva et

al., 2020). When applied together, Lean and Green seek to integrate operational efficiency with environmental responsibility. This can include reducing the use of natural resources, minimizing waste and emissions, optimizing the use of energy and water, among other sustainable measures.

In the analysed articles, the benefits of Green Manufacturing and Lean for the sustainability of companies are evident (Table 8 - Case Studies: Lean and Green). Green manufacturing safeguards the environment by minimizing or eliminating toxic materials, employing environmentally friendly raw materials and manufacturing processes, and creating eco-friendly products with designs geared towards environmental considerations, reusability, remanufacturing, and recyclability (Leme et al., 2018). The integration of lean production and environmentally sustainable (green) practices can yield various advantages, including cost reduction, shortened delivery times, enhanced process and environmental quality, as well as improved employee commitment (Thekkootte, 2022b). In addition to environmental gains, the article demonstrates that implementing Lean tools results in significant cost savings. Reducing cycle times, energy consumption, and waste not only enhances companies' profitability but also makes them more competitive in the market (Silva et al., 2020).

Table 8 - Case Studies: Lean and Green

Author	Analysis
(Dhingra et al., 2014)	The main question of this paper is whether lean and green initiatives lead to improve sustainability. It was concluded that there is a synergy between both topics.
(Leme et al., 2018)	This paper delves into the implementation of a Lean-Green model, combining Single-Minute Exchange of Die (SMED) principles with Carbon Footprint analysis, within a Brazilian machining centre. The application of SMED led to a notable reduction in setup time, accompanied by an impressive 81% decrease in carbon footprint. The eco-efficiency indicators provided valuable insights, enabling companies to enhance energy consumption practices. This integrated approach showcases the potential for synergies between Lean and Green methodologies in fostering sustainability within manufacturing processes.
(Tayyab et al., 2018)	The study focuses on developing a model for minimizing costs and carbon emissions in a multistage manufacturing process characterized by uncertain demand and process information. The results indicated an impressive 84.07% satisfaction level in terms of cost minimization and a substantial 64.74% satisfaction level regarding the reduction of CO2 emissions. This model showcases its effectiveness in simultaneously addressing economic and environmental considerations, even in the face of uncertain demand and process information.
(Garza-Reyes et al., 2016)	This study reports the development of a new tool called Sustainable Transportation Value Stream Map and its implementation in a logistics organization. It was proved that this methodology is an effective approach to improve environmental and operational efficiency.

Author	Analysis
(Verrier et al., 2016)	This paper seeks to build upon prior research efforts by offering a structured implementation framework for a Lean and Green methodology. The focus of this approach lies in the identification and elimination of wastes within production processes.
(Baumer-Cardoso et al., 2020)	This study endeavours to evaluate the practicality of Lean Manufacturing tools and examine the influence of Lean practices on green performance within a real-world company case. The research focuses on the integration of Lean and Green principles in the job shop of a Brazilian company, supported by a discrete-event simulation model. The findings reveal a reduction in material consumption and energy usage with the adoption of Lean practices. However, it's noteworthy that the application of certain Lean tools leads to an increase in water consumption.
(Sony et al., 2020)	The objective of this study is to introduce a sustainable Green Lean Six Sigma (LSS) initiative within the organization. By conducting a thorough analysis of existing literature, the study aims to develop an implementation framework. This framework is subsequently applied in a practical context through a case study, focusing on mitigating graphite and dust pollution in a mine located in India.
(Kovilage, 2021)	This study explores the synergy between lean and green management practices and their combined impact on organizational sustainable performance in Sri Lanka. Dominant green practices involve reducing water and material consumption, improving energy efficiency, and addressing water pollution and greenhouse gas emissions. Key lean practices include pull production, lot size reduction, continuous improvement, preventive maintenance, employee involvement, and cycle time reduction. The study identifies prominent sustainable performance measures such as inventory levels, profitability, quality, cost, employee and customer satisfaction, lead time, and resource consumption (material, water, energy), along with waste generation.
(Thanki et al., 2016)	This paper introduces a novel tool called the Value-Value Load Diagram (VVLD) designed for modeling and assessing the operational (lean) and environmental (green) performance of production systems. The VVLD enables the identification of processes with lower efficiency, highlighting areas that demand immediate attention to enhance resource utilization efficiency. This tool proves valuable in evaluating and optimizing the performance of production systems, particularly in terms of both operational and environmental considerations.

2.6. Industry 4.0

Industry 4.0 represents a transformative process that integrates and disseminates new technologies and innovations at a faster and more widespread pace than previous industrial revolutions. This facilitates the creation of innovative virtual and physical manufacturing systems, ultimately fostering the development of smart factories. (Mendes et al., 2023). This

concept offers numerous advantages, such as financial savings derived from improved planning, reduced implementation times, and increased efficiency in production processes. Additionally, Industry 4.0 places emphasis on minimizing production waste and enhancing working conditions, including aspects like the heightened safety of machines (Dahmani et al., 2021). From the bibliographic analysis of the articles presented in the table, it is concluded that, in combination with the lean philosophy, Industry 4.0 can be utilized to achieve the sustainable objectives of companies.

Furthermore, recent research on Portuguese organizations underscores how Industry 4.0 practices and digital transformation strategies significantly impact competitiveness and productivity. The study highlighted in this context revealed that organizations can achieve improved productivity, operational efficiency, and enhanced competitive positioning through the adoption of digital technologies and a strong commitment to digital transformation. This empirical evidence not only supports the benefits of Industry 4.0 but also emphasizes the critical role of human resources and knowledge management in navigating the complexities of digitalization and maximizing its potential benefits (Cardoso et al., 2024).

Table 9 - Case Studies: Industry 4.0

Author	Analysis
(Dahmani et al., 2021)	This paper investigates the interconnection between lean eco-design and Industry 4.0 (I4.0) strategies in the context of developing eco-efficient products, drawing insights from a comprehensive literature review. The study focuses on the alignment of Lean design, Ecodesign, and I4.0 strategies, each uniquely purposed to enhance product design, reduce costs, minimize environmental impacts, and improve overall business efficiency. The overarching goal is to create intelligent products that offer increased value while generating less waste. This is achieved through the incorporation of Circular Economy principles, utilizing diverse strategies to optimize the product design process.
(Mendes et al., 2023)	This study attempts to identify models that integrate Lean Philosophy, Industry 4.0, and maintenance management activities. A novel model, termed Maintenance Management in Sustainable Operations, has been developed and tested on a conveyor belt system. The application of this new model yielded a notable increase in operational time, rising from 82.3% to 87.7%. Additionally, improvements in flexibility, efficiency, and effectiveness were observed, showcasing the potential of the MMSO model in optimizing sustainable operations.
(Florescu et al., 2022)	This study analyses a possible combination of Lean tools and Industry 4.0 Technologies. A case study of a flexible manufacturing was analysed through simulation. It was found that this combination results on increasing productivity and processes' flexibility.
(Skalli et al., 2023)	Development of Circular Lean Six Sigma 4.0 and exploratory study of 12 Moroccan manufacturing firms conducted through interviews with top executive managers.
(Fiorello et al., 2023)	This paper seeks to present a framework for examining the ways in which a smart environment, utilizing Industry 4.0 tools and

Author	Analysis
	technologies, can facilitate the advancement of a lean-green company towards enhanced operational performance. The objective is to assist practitioners in strategically selecting smart technologies in conjunction with specific lean and green practices. To gain insights into the potential benefits of the framework, a semi-structured interview was conducted with four small and medium-sized manufacturing enterprises.
(Tripathi et al., 2022)	The objective of this research is to create a smart production management system and propose an effective process optimization approach to improve industrial sustainability. The focus is on addressing challenges in complex shop-floor conditions within the context of I4.0. The developed management system was validated through a case study involving an earthmoving machinery manufacturing unit. The analysis demonstrated that the system could boost operational excellence and industrial sustainability in the Industry 4.0 landscape by optimizing resource utilization on the shop floor, even within constraints.

2.7. Bibliographic review analysis

This literature review provides a comprehensive overview of the current landscape of corporate sustainability, particularly focusing on the Triple Bottom Line approach, Lean philosophy, Lean tools, Lean Six Sigma, Lean and Green practices, and the integration of Industry 4.0 with Lean principles.

The review thoroughly examines various facets of corporate sustainability, encompassing economic, social, and environmental dimensions, along with pertinent methodologies like Lean, Lean Six Sigma, and Industry 4.0. It offers a complete understanding of the topic.

Furthermore, it delves into the economic, social, and environmental aspects of corporate sustainability in depth, exploring avenues for companies to generate shared value through innovation, sustainable product development, and ethical supply chain practices. It underscores the significance of promoting equitable and inclusive work environments, respecting human rights, and mitigating adverse environmental impacts, such as greenhouse gas emissions reduction and water conservation.

A significant portion of the review is dedicated to elaborating on the Lean philosophy and its associated tools, aiming to enhance operational efficiency and sustainability. It elucidates Lean's origins in the Toyota Production System, elucidating core principles such as waste reduction, empowerment of personnel, customer value creation, and continual improvement. Various Lean tools, such as Value Stream Mapping (VSM) and the 5S methodology, are explored for their applicability in fostering sustainability within organizations.

Moreover, the review discusses the integration of Lean principles with Six Sigma methodologies, known as Lean Six Sigma, as a means of further improving operational efficiency and minimizing defects. It examines the DMAIC cycle as a structured approach to process enhancement, highlighting its relevance in advancing sustainability objectives.

Another focal point of the review is the amalgamation of Lean Manufacturing principles with environmentally sustainable practices, termed "Lean and Green." It examines how Lean methodologies can be tailored to reduce waste and environmental impact, leading to cost savings, reduced delivery times, and enhanced environmental standards.

Lastly, the review addresses the integration of Industry 4.0 technologies with Lean principles to achieve sustainable goals. It explores how Industry 4.0 enables the establishment of smart factories and drives innovation in manufacturing processes while minimizing waste and improving working conditions.

An identified gap was the limited number of studies exploring the application of Lean in specific sectors beyond traditional manufacturing. Sectors such as services, healthcare, and education lack detailed analyses on how Lean principles can be adapted to achieve significant improvements in these particular contexts. Additionally, there were difficulties in finding studies presenting precise and robust metrics to assess the sustainable impacts of Lean practices. The lack of clear metrics may hinder organizations' ability to adequately quantify the environmental benefits of Lean initiatives. There is also a significant lack of information on the application and impact of less studied Lean tools, such as Heijunka, Spaghetti Diagram, Kamishibai, and Yokoten. These tools have the potential to enhance operational efficiency and promote sustainable practices, but further research is needed to understand how they can be effectively implemented and their specific impacts on corporate sustainability.

This critical analysis of the literature review highlights the potential benefits of the Lean philosophy for sustainability, while identifying specific areas that require further research, such as integrating Lean into the three aspects of the triple bottom line, assessing social impact, and exploring less studied Lean tools in detail. The proposed master's thesis will contribute to filling these gaps by investigating how Lean practices, including less explored tools, can be effectively adapted and applied to promote more sustainable and responsible business practices. This will strengthen the understanding and application of Lean as an integral tool for corporate sustainability

3. Company Presentation

Since its foundation in 1944, the company J. Baptista has played a significant role in the industrial landscape. Initially focused on trading equipment for the textile industry, the company gradually expanded its activities to cover a wide range of products, ranging from transmission, conveyor, and process belts to modular belts, printing screens, coatings, and special lubricants, among others. This diversification strategy has allowed the company to meet the growing demands of the market, consolidating its position in the sector.

Guided by fundamental values of Quality, Rigor, Commitment, and Trust, J. Baptista maintains a constant commitment to excellence in all its operations. Within its facilities, conveyor, process, and transmission belts are manufactured, all tailored to the specific needs of each customer. In addition to production, the company offers a wide range of customer support services, including specialized technical assistance, on-site repairs, and bonding services. Over the years, J. Baptista has earned a solid reputation and recognition in the industrial market due to its dedication to quality, commitment to customers, and relentless pursuit of operational excellence.



Figure 10 - J. Baptista Logo

3.1. Organizational Structure

The organizational structure of J. Baptista company consists of several departments that perform specific functions to ensure the effective operation of the company. These departments include Sales, Finance, Purchasing, Logistics, and Production. The company's organizational chart is represented in the Figure 11 - Organogram.

The Management is responsible for establishing the company's strategic vision, defining goals, and general guidelines. They make high-level decisions and guide the overall operations of the organization. The sales department focuses on developing sales strategies, managing customer relationships, and identifying new business opportunities. They negotiate contracts, seek partnerships, and ensure customer satisfaction. The finance department is responsible for managing the company's finances, controlling budgets, preparing financial reports, tax planning, and maintaining adequate cash flow for operations. The purchasing department handles the acquisition of materials and resources necessary for production. They negotiate with suppliers, place purchase orders, and ensure that the inventory is always stocked. The logistics department coordinates the efficient transportation, storage, and distribution of products. They manage the supply chain, optimize delivery routes, and monitor inventory to ensure effective logistics. Finally, the production department is responsible for manufacturing the company's products. They supervise manufacturing operations, ensuring product quality and efficient use of available resources.

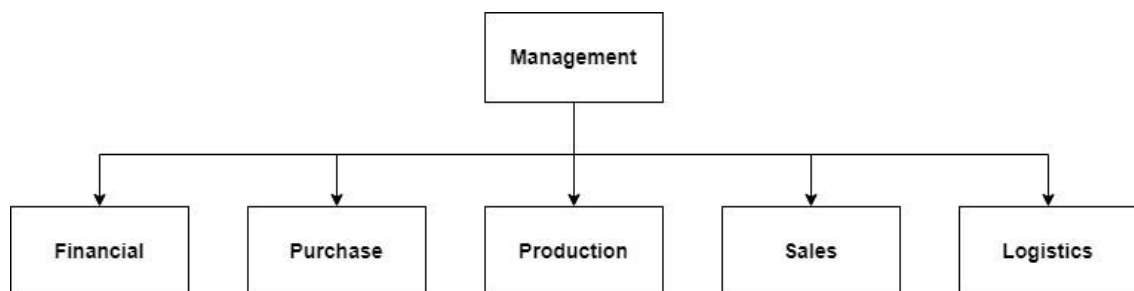


Figure 11 - Organogram

3.2. Conveyor belts

Conveyor belts play a crucial role in the efficient movement of materials in various industries. They are extensively used in sectors such as manufacturing, distribution, packaging, and logistics to transport a wide range of products, including raw materials, finished goods, packages, and bulk materials. These belts are typically constructed with layers of rubber or synthetic materials reinforced with fabric or steel cords to provide strength and durability. The choice of belt material and construction depends on factors such as the type of material being transported, environmental conditions, and operational requirements. Conveyor belts can be customized in terms of length, width, and thickness to accommodate specific application needs. They are available in various configurations, including flat belts, troughed belts, cleated belts, and sidewall belts, each designed to handle different types of materials and loading conditions. In addition to transporting materials horizontally, conveyor belts can also be configured to incline or decline to overcome obstacles or transport materials to different elevations within a facility. This versatility makes them indispensable in facilities with varying layouts and production processes. To ensure safe and efficient operation, conveyor belts are equipped with various accessories and safety features. These include side guards, emergency stop switches, belt cleaners, and monitoring systems to detect belt misalignment, slippage, or excessive

tension. Overall, conveyor belts are integral components of modern industrial processes, enabling seamless material handling and contributing to increased productivity, efficiency, and safety in manufacturing and distribution operations.



Figure 12 - a) Rubber conveyor belt; b) Synthetic conveyor belt

Belts are typically composed of textile fibres coated with an upper and lower layer of rubber. These fibres play a crucial role in the structure and performance of the product. The most common textile materials used in these belts are nylon, polyester, and aramids, each contributing specific characteristics to the final product. Nylon is known for its high tensile strength, allowing the belt to withstand significant stretching forces without breaking, which is essential as belts are subjected to heavy loads. Additionally, it offers good resistance to abrasion, ensuring that the belt can withstand wear caused by repeated contact with transported materials. Polyester also significantly contributes to the belt's tensile strength, making it capable of bearing heavy loads and tensions without deforming. Moreover, polyester offers excellent resistance to abrasion and impact, prolonging the belt's lifespan. Its temperature resistance is also an advantage, allowing the belt to effectively function in a wide range of environmental conditions. Aramids, such as Kevlar, are known for their high tensile strength and durability, making conveyor belts extremely robust and capable of handling heavy loads and adverse conditions. Additionally, aramids provide excellent impact resistance, making the belt less susceptible to damage from sudden shocks.

The upper and lower layers of rubber play a fundamental role in protecting the conveyor belt's screens and preserving their mechanical properties. The rubber layers act as a protective barrier between the belt screens and the transported materials. They absorb impact and reduce wear caused by direct contact with materials, thereby extending the belt screens' lifespan. Rubber is known for its ability to stretch and return to its original shape, providing elasticity to the belt screens. This is important during material transport, where the belt needs to adapt to different load and tension conditions. Rubber elasticity helps reduce the probability of belt screen rupture or deformation. The rubber layers provide a gripping surface that helps keep transported materials in place during the transportation process. This is crucial to prevent spills or cargo slips, ensuring the safety and efficiency of the transportation system. In addition to protecting the belt screens and improving grip between the belt and transported products, the rubber layers also facilitate belt handling and installation. They can be easily cut and moulded to fit the specifications and requirements of each application.

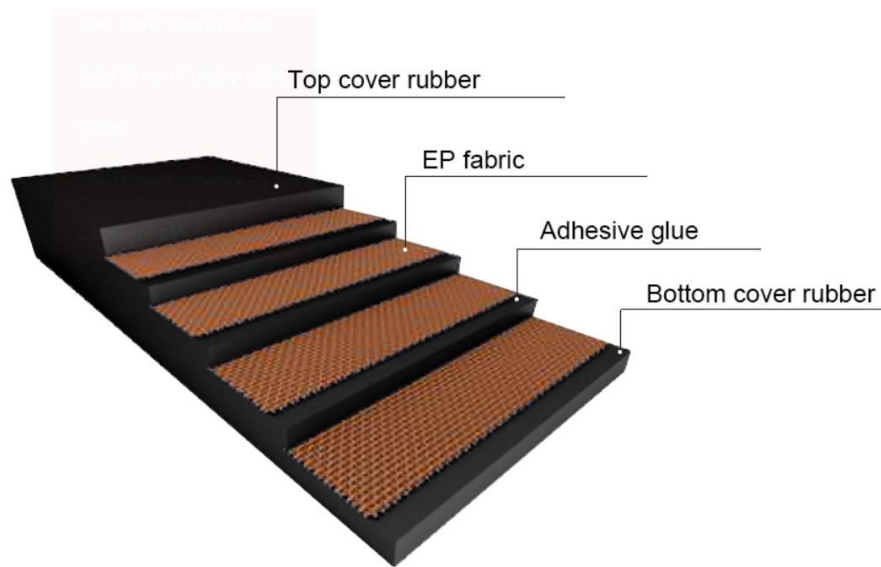


Figure 13 - Rubber conveyor belt layers

In some cases, conveyors use a configuration that includes a table to support the belt. In this specific situation, the conveyor belt does not have the lower rubber layer, as is common in other types of belts. The absence of this rubber layer is intended to reduce friction between the two surfaces, facilitating the movement of the belt over the table, minimizing energy consumption, and extending the equipment's lifespan. In this context, the rubber used to coat the upper part of the belt, which encounters the transported materials, is called "slide." This slide rubber is specially formulated to offer low-friction properties, reducing the sliding resistance between the belt and the contact surface, contributing to a more efficient operation of the conveyor, saving energy, and minimizing belt wear. The slide rubber can be formulated with special additives to ensure its durability and resistance to wear, even under the most demanding operational conditions. It plays a crucial role in the smooth and efficient operation of the conveyor, helping to ensure a continuous and reliable flow of materials throughout the industrial process.

In addition to rubber belts, there are also belts made of synthetic polymers that are used in the food, chemical, and agricultural industries. These offer a series of benefits compared to traditional belts made of materials such as rubber or nylon fabric. Polymers used in the manufacture of conveyor belts, such as polyurethane and PVC, are known for their excellent resistance to abrasion. This means that these belts can withstand the wear caused by continuous friction with transported materials and contact surfaces, resulting in a longer lifespan and less maintenance required. Many polymers, such as PVC, are highly resistant to a wide variety of corrosive chemicals. This makes polymer conveyor belts ideal for applications in industrial environments where there is exposure to aggressive chemical substances, such as acids, solvents, and cleaning chemicals. Polymer conveyor belts, especially those made of PVC, are easy to clean due to their smooth and non-porous surface. This is especially important in industries such as food, pharmaceuticals, and packaging, where hygiene is crucial, and belts need to be regularly cleaned to prevent contamination of transported products. Many polymers have high dimensional stability, meaning they maintain their dimensions and shape even when

subjected to variations in temperature and humidity. This results in more precise and consistent operation of conveyor belts, minimizing problems such as misalignment and irregular wear. Compared to traditional materials such as rubber, many polymers are lighter in weight. This can result in additional benefits, such as lower energy consumption and less load on conveyor systems, especially in long-distance or elevated applications. Polymers can be formulated to offer a wide variety of specific properties, such as fire resistance, static resistance, electrical conductivity, among others. This allows polymer conveyor belts to be tailored to meet the specific needs of different applications and work environments. Although polymer conveyor belts may have a slightly higher initial cost than traditional belts, such as rubber ones, they often offer a lower total cost of ownership over their lifespan. This is due to their greater durability, lower maintenance requirements, and lower operating costs, resulting in long-term savings for companies.



Figure 14 - Synthetic materials for conveyor belts

3.3. DIN 22102

The DIN standard from the German Institute for Standardization (Deutsches Institut für Normung - DIN) is widely used in the industry to ensure the quality and performance of rubber suppliers. This standard specifies the standard dimensions of conveyor belts in terms of width, length, and thickness, ensuring uniformity and compatibility with industrial equipment. It defines minimum requirements for tensile strength, elongation, abrasion, tearing, adhesion between belt layers, among other mechanical properties important for conveyor belt performance. It establishes guidelines to ensure operator safety and prevent accidents related to the use and maintenance of conveyor belts. It defines testing procedures and test methods to be used to evaluate the performance of conveyor belts according to the requirements set out in the standard. The standard classifies conveyor belts according to various criteria, such as type of cover, tensile strength, belt thickness, among others. Each type of belt receives a specific designation according to these characteristics, following the following pattern:

1000 m DIN 22102 AB 1000 EP 630/4 6+2 Y

Where:

1000 m – Length

DIN 22102 – Applicable standard/norm

AB – Manufacturer’s acronym

1000 - Belt Width in mm

EP – Carcass material

630 – Belt min. breaking strength in kN/m

4 – Number of plies

6 – Top cover thickness in mm

2 – Bottom cover thickness in mm

Y – Cover grade

3.4. Production Process

The manufacturing process of a conveyor belt involves several stages, from material selection to the final assembly of the product. Initially, appropriate materials are chosen for constructing the belt, considering factors such as strength, durability, and flexibility.

3.4.1. Material Selection and Preparation

The production of rubber conveyor belts begins with the critical task of selecting the right rubber material. This entails a thorough evaluation to ensure that the chosen material meets the exacting requirements for durability, flexibility, and other essential properties.

Once the ideal rubber material is identified, it is transported to the production area. Given the bulky nature of raw material rolls, specialized machinery such as forklifts or overhead cranes is deployed to handle and transport them with efficiency and precision.

Within the confines of the production area, the rubber material is meticulously laid out, stretched to the desired length, and measured. The piece is marked, indicating where it needs to be cut to achieve the required dimensions for the conveyor belt. Then operators shape and slice the rubber material to exacting specifications. The cutting can be done using manual tools such as knives and utility knives, or with electric machines, depending on the characteristics of the rubber.

Table 10 - Material selection and preparation

Material Selection and Preparation

Transport the roll to the work area and unroll it



Measure and mark the rubber according to the conveyor requirements

Cut the material according to the desired width and length



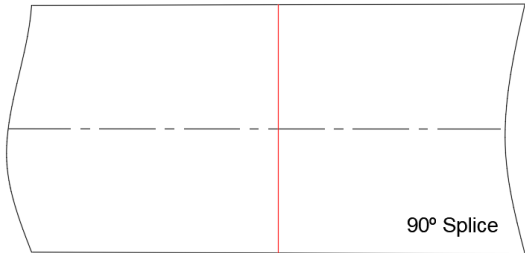
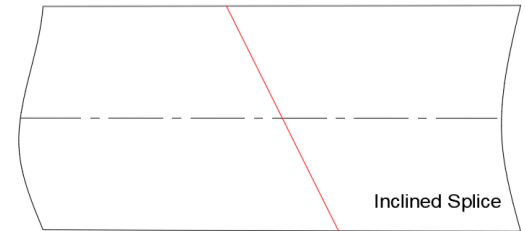
3.4.2. Splice Preparation

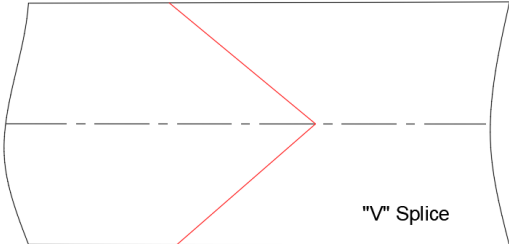
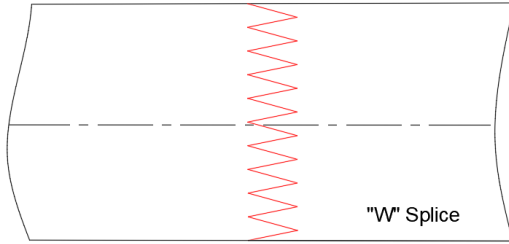
After the material selection, the materials are cut and prepared according to the project specifications. This may include cutting rubber sheets, preparing special coatings, and assembling components. The actual assembly of the belt is performed using specific techniques such as vulcanization or mechanical splicing, ensuring a secure and durable connection between the different elements of the belt. Throughout the manufacturing process, it is essential to maintain strict quality control, as deviations in this process can compromise the product's performance.

After the material is cut, it is crucial to join the two ends of the belt to ensure the integrity and efficiency of the conveyor. This process is known as "splicing" and plays a fundamental role in the operation of the transportation system. The quality and method of splicing can directly influence the durability, strength, and performance of the belt. The choice between performing the splicing on-site or beforehand depends on various factors, including the availability of suitable equipment and materials, access to the installation site, environmental conditions, and the specifics of the transportation to be carried out. In some situations, it may be more practical and efficient to perform the splicing beforehand, while in others, it is preferable to do it on-site to ensure a precise and proper fit to the specific conditions of the conveyor. There are different

methods for performing the splicing, each with its own advantages and considerations. The most common methods include hot vulcanization, cold vulcanization, and the use of mechanical fasteners. Hot vulcanization involves the use of heat and pressure to fuse the ends of the belt, creating a strong and durable bond. Cold vulcanization uses special adhesives or solvents to join the ends of the belt without the need for excessive heat. Mechanical fasteners consist of metallic or plastic devices that are attached to the ends of the belt, providing a secure and adjustable connection. In addition to the splicing method, the shape of the splice is also an important aspect to consider. Splices can be performed in various ways, including straight splices, angled splices, V-shaped splices, among others. The choice of splice shape may be influenced by the specific application, belt characteristics, and tensile strength requirements. For example, diagonal splicing, mentioned in the context of J. Baptista, is a common technique for rubber belts designed to provide sufficient tensile strength and prevent opening when in contact with conveyor rollers. The choice of splicing method and shape should be carefully considered based on the specific needs of the system and operating conditions. A well-executed splice can prolong the life of the belt, minimize downtime, and optimize the performance of the conveyor. The Table 11 - Types of splices enumerates some of the most common types of joint execution.

Table 11 - Types of splices

Splice Type	Properties
 <p data-bbox="691 1402 783 1429">90° Splice</p>	<ul style="list-style-type: none"> <li data-bbox="916 1218 1286 1290">• Ease of manufacturing and installation <li data-bbox="916 1317 1211 1344">• Stress concentration <li data-bbox="916 1370 1115 1397">• Deformation
 <p data-bbox="659 1778 783 1805">Inclined Splice</p>	<ul style="list-style-type: none"> <li data-bbox="916 1588 1339 1659">• More uniform distribution of force along the joint <li data-bbox="916 1686 1307 1758">• Lower probability of stress concentration point <li data-bbox="916 1785 1246 1812">• Good tensile strength

Splice Type	Properties
 <p data-bbox="660 568 751 598">"V" Splice</p>	<ul style="list-style-type: none"> <li data-bbox="916 421 1134 450">• Uneven wear <li data-bbox="916 479 1227 508">• Low tensile strength <li data-bbox="916 537 1177 566">• Material buildup
 <p data-bbox="660 943 751 972">"W" Splice</p>	<ul style="list-style-type: none"> <li data-bbox="916 745 1235 775">• High tensile strength <li data-bbox="916 804 1310 833">• Uniform stress distribution <li data-bbox="916 862 1257 891">• Installation complexity

To perform the splice, the operator must ensure that the end of the rubber forms an angle relative to its base. Then, a line with the desired inclination for the splice is drawn, usually ranging between 17° and 30°. Subsequently, the line defining the length of the splice is drawn, which depends on the type of belt, its dimensions, and applications. It is also necessary to define the extent of each step of the belt, which is related to the number of layers. This marking will be made on the upper face of one end and on the lower face of the other end.

After this stage, the removal of the rubber coating begins. This task requires skill from the operator to avoid damaging the underlying plies. Tools such as pliers and cutting instruments like knives are used carefully and precisely. The objective is to remove the rubber coating without compromising the integrity of the inner layers of the belt.

Once the rubber coating has been removed, the surface is refined using a rotary sander. This process aims to ensure a smooth and uniform surface, facilitating the adhesion and quality of the splice to be performed. The operator must carry out this step attentively to avoid irregularities that could compromise the effectiveness of the splice and the subsequent operation of the conveyor.

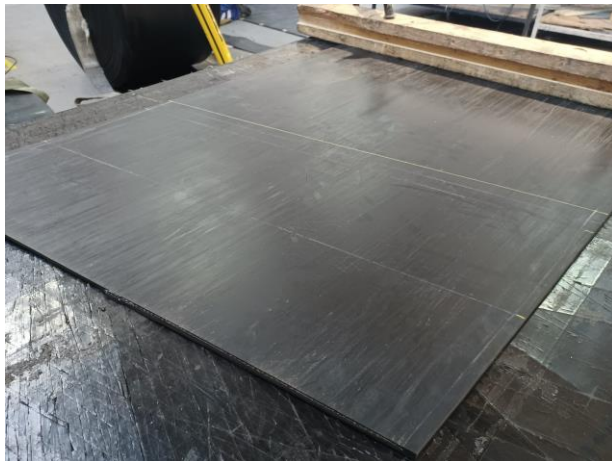
Table 12 - Execution of splice

Execution of splices

Securing the end of the rubber to the table, using clamps



Marking the splices using a ruler and pencil.



Removing the rubber in the splice area so that only the screens remain on the surface, using a utility knife and gripper.



Remove the remaining rubber residue in the splice area using a sander.



3.4.3. Joining the Splices

After the two splices are completed, they must be rectified to fit together without deviating from the client's specifications. Once this is done, the bonding materials are applied.

In the case of hot vulcanization splices, it is necessary to first apply glue to the splice area and the bonding rubber, allowing it to dry. Once the glue is completely dry, the bonding film is placed over the splice area. The placement should be done in a way that expels any trapped air. After the bonding rubber film is applied, the entire covered area is pressed with rollers to ensure proper adhesion.

The splice zone prepared with the bonding materials is ready for the vulcanization process, a fundamental step to ensure the integrity and durability of the splice. Vulcanization is carried out in a specialized press, where temperature and pressure are precisely controlled to achieve a solid and long-lasting bond. The time required for vulcanization varies depending on various factors, including the types of bonding materials used, the specified vulcanization temperature, and the thickness of the conveyor belt. These parameters are carefully adjusted to ensure that the vulcanization process is effective and produces a high-quality splice. After the vulcanization time is completed, the heating of the press is turned off, but pressure is maintained on the splice zone until the temperature drops to approximately 40°C. This cooling period under pressure is essential to ensure that the splice is properly consolidated and maintains its structural integrity.

Finally, after adequate cooling, the conveyor belt is carefully removed from the vulcanization press. It is important to perform this step with care to avoid damaging the newly vulcanized splice. Once removed from the press, the belt is ready to be installed on the conveyor, where it will provide a reliable and durable connection between belt sections.

Table 13 - Joining the splices

Joining the Splices

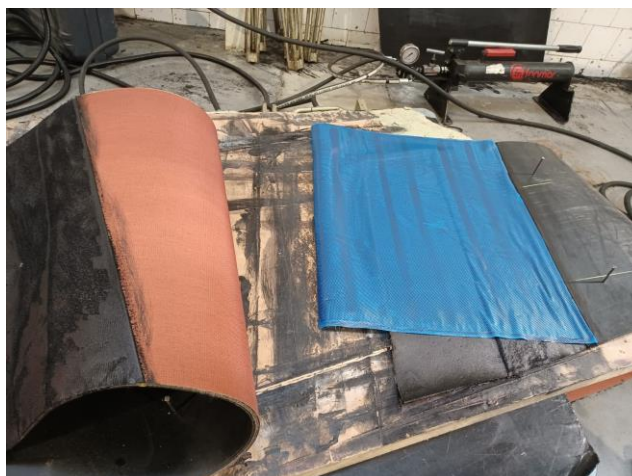
Place the conveyor on the press and align the splices



Apply glue using a brush and let it dry



Apply the bonding rubber



Overlap splices



Close press



Program the press to the desired temperature



3.4.4. Conveyor belts with profiles

As previously mentioned, there are some cases where it's necessary to apply profiles on the conveyor belt to assist in the movement of the materials being transported, preventing their regression. The application of these profiles involves the elaboration of the mold, which is used to trace the drilling locations on the conveyor belt and on the profiles. Additionally, it's necessary to drill the profiles and the screen and screw them together.



Figure 15 - Conveyor belt with profiles

Table 14 - Conveyor belt with profiles

Conveyor belt with profiles

Cut the profiles according to the desired dimensions



Make the mold

Mark profiles

Drill profiles



Mark conveyor



Drill conveyor



Screw profiles



The full process flowchart is represented on Appendix A.

3.5. Critical Analysis

As previously mentioned, J. Baptista is a growing family-owned company specializing in the production, assembly, maintenance, and design of conveyor belts. Its production process adopts a Just in Time approach, where the specifications of each belt depend on the specific conditions in which they will be used, such as the type of industry and the dimensions of the conveyor. This means that the company does not maintain a stock of finished products, producing only when it receives a specific order from the customer. This strategy allows J. Baptista to respond quickly to customer needs, ensuring that each belt is precisely tailored to their requirements and the environment in which it will be installed. However, this flexible approach can be challenging when customers present urgent orders, which may interfere with the planned production flow. Managing these urgencies becomes even more complex when multiple urgent orders arise simultaneously, temporarily impacting the company's ability to fulfil all orders within the stipulated deadlines. This scenario underscores the importance of agile and flexible production management, capable of quickly adapting to the unforeseen needs of customers without compromising quality or the fulfilment of other ongoing orders.

Additionally, J. Baptista faces several obstacles that affect its operations and future growth potential. The nature of the raw material, characterized by its large dimensions, makes both its transportation and storage challenging, resulting in safety and productivity related issues. The excess of small scraps from larger rolls poses another challenge, as there is no demand for products with these specific dimensions, leading to wastage of space and resources. The lack of modernization in processes and the outdated layout of facilities also negatively affect the company's production capacity and operational efficiency. The limited space in the production area, due to the large dimensions of the manufactured belts, restricts the number of conveyor belts that can be produced simultaneously, exacerbating operational challenges. Internally, inefficiency in the flow of information between departments compromises production management and the proper allocation of labour. This is exacerbated by the difficulty in

scheduling technicians to perform services and meet production demands, reflecting a possible shortage of qualified labour and adequate training.

The company J. Baptista faces several challenges in its operational sustainability, covering the three pillars of the triple bottom line: economic, environmental, and social. In economic terms, significant waste of raw materials due to the accumulation of scraps in stock stands out. These unused materials represent a direct loss of financial resources, negatively impacting the company's profitability. Additionally, operational inefficiency resulting from a lack of modernization in processes and an outdated layout translates into higher operational costs, such as overtime and increased energy consumption. In the environmental realm, the waste of natural resources is a pressing concern. The accumulation of unused raw materials contributes to the depletion of natural resources, such as raw materials and energy, essential for production. Moreover, the transportation and storage of large-sized materials have a negative environmental impact, resulting in additional emissions of greenhouse gases and an increase in energy consumption, especially when heavy equipment such as forklifts and overhead cranes are used. Regarding social aspects, working conditions in the company can be challenging due to operational inefficiency and layout problems. This can result in inadequate space, safety risks, and increased stress for employees. Additionally, the shortage of qualified labour and the difficulty in scheduling technicians to meet production demand can create instability in the work environment and affect the satisfaction and well-being of employees.

In summary, the company J. Baptista faces a series of challenges regarding sustainability in its operations. It is essential for the company to adopt measures to reduce waste of raw materials, improve operational efficiency, minimize the environmental impact of its activities, and enhance working conditions for its employees

4. DMAIC

In response to the operational challenges faced by J. Baptista, the DMAIC methodology has been introduced, offering a structured approach to addressing process inefficiencies and enhancing operational sustainability.

In this context, DMAIC serves as a strategic framework for identifying root causes, analysing data, implementing targeted improvements, and establishing control measures. By systematically applying DMAIC principles, J. Baptista aims to reduce waste, enhance efficiency, minimize environmental impact, and improve working conditions, ultimately ensuring long-term sustainability and growth.

In the first phase, the techniques to be used for each of the following steps were defined to achieve the intended objectives. These techniques are presented in the following Table 15 - Techniques applied at the "Improve" phase.

Table 15 - Techniques applied at the "Improve" phase

Define	Measure	Analyse	Improve	Control
SIPOC	VSM	Ishikawa's Diagram	5S	Kamishibai
	Questionnaire	GUT priority matrix	Layout redesign	KPI's
	KPI's	Flowchart	Visual Management	
		A3 report	Standard Work	
			OPL	
			Kanban Board	

4.1. Define

The Define phase of DMAIC is a crucial milestone on the path towards continuous process improvement. At this stage, we turn to the SIPOC (Figure 16 - SIPOC) to gain a comprehensive and detailed understanding of J. Baptista's internal operations. The primary objective is to meticulously identify problems requiring in-depth analysis and strategic interventions to optimize operational efficiency and foster sustainability within the organization.

During the development of the SIPOC, a series of issues emerged at various stages of the process. From communication between departments to issues related to materials management, raw material storage, production processes, and technician deployment, several obstacles were identified.

Regarding communication between production and the commercial department, it became evident that communication channels are outdated, with a lack of established standard procedures and high variability, leading to misunderstandings and detrimental errors. Concerning material availability verification, difficulties in locating necessary raw materials were observed, resulting in excessive movement and significant time spending, indicating inefficiencies in inventory management and storage systems.

In raw material storage, an inefficient layout and absence of formal procedures were noted, leading to space wastage and difficulties in locating and accessing materials when needed. In the production phase, issues such as inefficient planning, a shortage of skilled labor, and outdated processes were identified, directly impacting productivity and product quality.

Finally, in technician deployment for necessary interventions, inefficiencies in planning and a shortage of qualified labor were noted, potentially resulting in delays in problem resolution and service delivery to customers. These challenges represent significant obstacles to the operational efficiency and sustainability of J. Baptista.

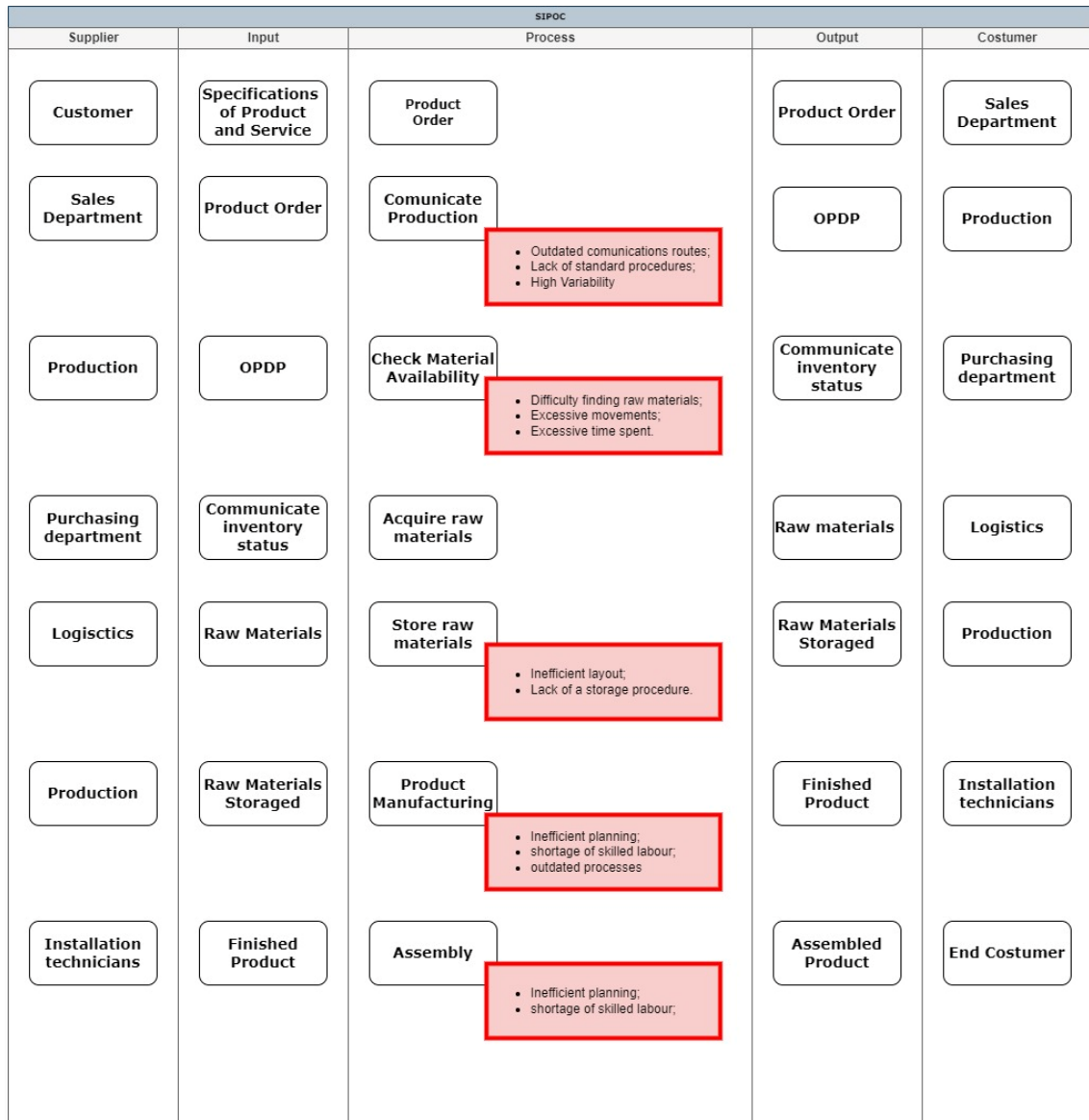


Figure 16 - SIPOC

Considering the various economic, social, and environmental aspects, the issue of sustainability emerges as a crucial point for the company J. Baptista. The identified challenges, from inefficiencies in production flow to inadequate working conditions and environmentally harmful processes, underscore the urgent need to address these issues to ensure not only the long-term viability of the company but also its responsibility to stakeholders and the environment (Figure 17 - TBL problems).

Economically, inefficiencies in production flow pose a direct threat to the company's profitability, increasing operational costs and decreasing overall profitability. Investing in

improving production processes is essential to ensure efficient use of resources and maximize the company's profit.

Socially, the company faces challenges related to inadequate working conditions and a shortage of qualified labor. Inadequate working conditions not only pose risks to the safety and health of employees but can also lead to increased stress and job dissatisfaction. Additionally, a shortage of qualified labor can create instability in the work environment, negatively impacting employee well-being and team cohesion.

In terms of the environment, inefficient processes and the company's inadequate layout contribute to higher energy consumption and a more significant environmental footprint. Reducing diesel consumption, minimizing waste, and adopting sustainable practices are essential to mitigate the environmental impact of the company's operations and promote environmental responsibility.

In summary, addressing these challenges comprehensively is essential to ensure the long-term sustainability of the company J. Baptista. By investing in improving production processes, ensuring safe and healthy working conditions, and adopting environmentally responsible practices, the company can not only enhance its operational efficiency and economic profitability but also promote the well-being of its employees and protect the environment for future generations.

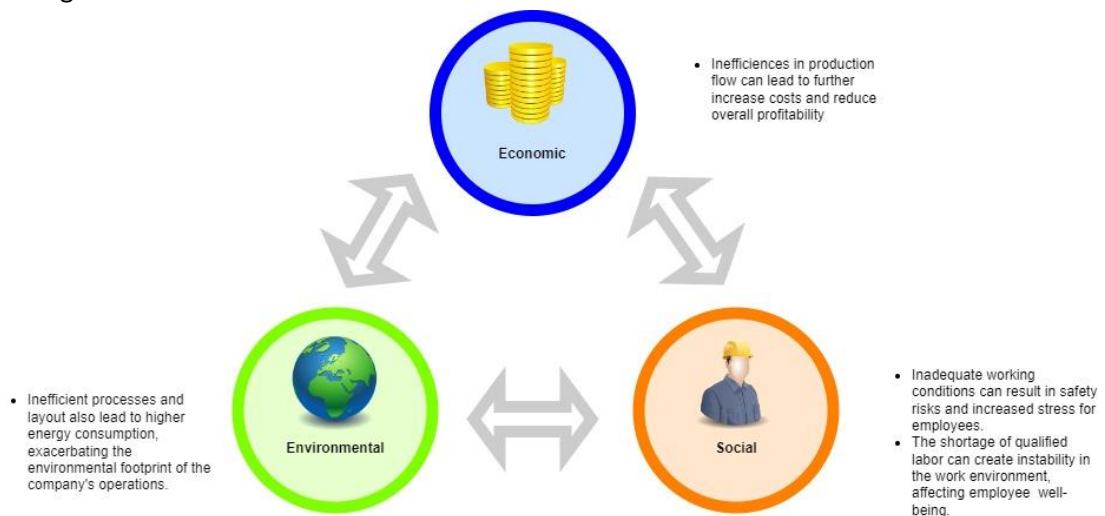
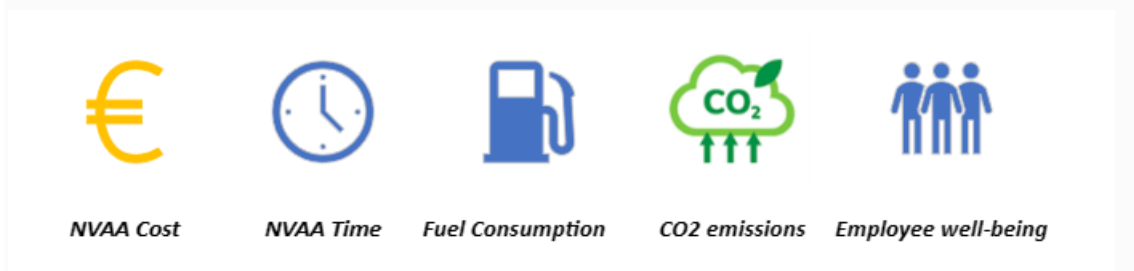


Figure 17 - TBL problems

After a thorough analysis of the challenges faced by J. Baptista company, relevant KPI's were defined to assess its situation and guide improvement initiatives. These KPIs were carefully selected to address different key aspects of the company's economic, social, and environmental performance. The introduction of these KPIs is essential to provide a solid framework for evaluating and analysing the company's current situation, as well as to guide future actions and improvement initiatives.

Additionally, KPI's related to the company's economic aspects, such as expenses on non-value-added activities, were defined. These KPIs are fundamental for evaluating the company's financial health and identifying opportunities to maximize profitability and economic efficiency. Regarding social aspects, KPIs were established to assess employee satisfaction and well-being. Finally, KPI's related to the company's environmental impact, such as emissions and fuel consumption, were defined. These KPI's help the company assess its environmental impact and

identify opportunities to reduce its environmental footprint and adopt more sustainable practices.



The introduction of these KPI's aims to provide a solid foundation for evaluating the situation of J. Baptista company and guiding the identification of areas for improvement and intervention. By monitoring these KPI's, the company can make informed decisions and implement improvement initiatives that promote its long-term sustainability and success.

4.2. Measure

In the Measure phase of DMAIC, a detailed analysis of the current situation was conducted. Initially, the production process was represented on vertical flowcharts and a VSM was used to map the flow of operations' value, allowing for a better understanding of processes, and identifying areas of waste and inefficiency. Next, a spaghetti diagram was created to analyse the movements of materials and personnel, aiming to identify and reduce unnecessary movements that contribute to time and resource losses. Additionally, a questionnaire was administered to employees to assess their satisfaction and perception of the work environment, providing valuable insights into potential areas for improvement in human resource management. These quantitative and qualitative analyses were crucial for establishing a solid understanding of the company's current situation.

4.2.1. Flowcharts

Considering the inherent variability in J. Baptista's production process, it is important to recognize that there is no defined order for the execution of certain tasks. Given this complexity, measures have been adopted to better understand the workflow and identify improvement opportunities. One approach involved collecting execution times for critical tasks, such as conveyor belts with profiles and component placement. With this, vertical flowcharts were developed to visualize the flow of operations, highlighting not only the time required for each step but also the distance travelled and other relevant variables. Vertical flowcharts provide a detailed view of the process, allowing for a thorough analysis of each step and identifying potential bottlenecks or inefficiencies.

Process Flowchart

Process:			Execution of the splices					Description
Steps	Distance (m)	Time (min)	Operation	Transport	Inspection	Waiting	Stock	
1	60	25	●	➔	■	⌒	▲	Search for rolls in the warehouse
2	30	5	●	➔	■	⌒	▲	Take the roll to production
3	30	5	●	➔	■	⌒	▲	Measure the roll
4	30	10	●	➔	■	⌒	▲	Cut
5	5	10	●	➔	■	⌒	▲	Place one end on the table
6	5	60	●	➔	■	⌒	▲	Perform the first splice
7	2,5	5	●	➔	■	⌒	▲	Remove the end from the table
8	10	10	●	➔	■	⌒	▲	Place the second end on the table
9	5	65	●	➔	■	⌒	▲	Perform the second splice
10	2,5	5	●	➔	■	⌒	▲	Remove the end from the table

Figure 19 - Process Flowchart: Execution of the splice

J. BAPTISTA								
Process Flowchart								
Process:			Preparation of the profiles for screw-mounted profiles					
Steps	Distance (m)	Time (min)	Operation	Transport	Inspection	Waiting	Stock	Description
2	60	30	●	→	■	⌋	▲	Search for the roll
3	30	5	●	→	■	⌋	▲	Take the roll to the workbench
4	0	20	●	→	■	⌋	▲	Measure profiles
5	0	30	●	→	■	⌋	▲	Cut the profiles
6	0	20	●	→	■	⌋	▲	Mark the profiles
7	0	90	●	→	■	⌋	▲	Drill the profiles

Figure 20 - Process Flowchart: Preparation of the profiles for screw-mounted profiles

J. BAPTISTA								
Process Flowchart								
Process:			Preparation of the conveyor belt for screw-mounted profiles					
Steps	Distance (m)	Time (min)	Operation	Transport	Inspection	Waiting	Stock	Description
1	15	45	●	→	■	⌋	▲	Mark the conveyor belt
2	15	115	●	→	■	⌋	▲	Drill the conveyor belt
3	5	5	●	→	■	⌋	▲	Take the profiles to the location where they will be assembled
4	10	5	●	→	■	⌋	▲	Bring the screws, nuts, and washers
5	15	450	●	→	■	⌋	▲	Screw the profiles

Figure 21 - Process Flowchart: Preparation of the conveyor belt for screw-mounted profiles

4.2.2. Value Stream Mapping

After the elaboration of the flowcharts, it became evident that there were excessive movements and prolonged times in certain tasks that did not add value to the final product, in the production of belts with profiles. These observations raised concerns about the efficiency of the process and the need to better understand the value stream of production.

To address these issues, it was decided to carry out a specific Value Stream Mapping for the production process of belts with profiles (Figure 22 - VSM). The VSM would allow for a more detailed analysis of the stages involved, from raw material to finished product, identifying improvement opportunities and areas of waste.

For the construction of the VSM, it was considered that in the last 6 months there was a demand for 119 conveyor belts, with only 29 being belts with profiles and the remaining 90 being conveyor belts without profiles, with the VSM presented on the appendix B. Considering that the shifts are 8 hours long, the available time for each type of product is then calculated: minutes for the belts with profiles and minutes for the belts without profiles.

$$\text{Demand per day (belts with profiles)} = \frac{29}{6 \text{ months} * 22 \text{ days}} = 0,22 \text{ belts/day}$$

$$\text{Demand per day (belts without profiles)} = \frac{90}{6 \text{ months} * 22 \text{ days}} = 0,68 \text{ belts/day}$$

$$\text{Total Demand} = \frac{119}{6 \text{ months} * 22 \text{ days}} = 0,90 \text{ belts/day}$$

$$\text{Available Time (belts with profiles)} = \frac{0,22}{0,90} * 480 = 117,33 \text{ min/day}$$

$$\text{Available Time (belts without profiles)} = \frac{0,68}{0,90} * 480 = 362,67 \text{ min/day}$$

With the daily demand values and available time, the takt time for both products is calculated:

$$\text{Takt Time} = \frac{\text{Available Time}}{\text{Demand}}$$

$$\text{Takt Time (belts with profiles)} = \frac{117,33}{0,22} = 533,32 \text{ min/belt}$$

$$\text{Takt Time (belts without profiles)} = \frac{362,67}{0,68} = 533,34 \text{ min/belt}$$

In the Table 16 - Takt Time, the values necessary for the calculation of takt time are summarized.

Table 16 - Takt Time

Total available time	480 min/day
Total Demand	0,90 belts/day
Demand (Conveyor Belt with profiles) per day	0,22 belts/ day
Demand (Conveyor Belt without profiles) per day	0,68 belts/day
Available time (Conveyor Belt with profiles)	117,33 min/day
Available time (Conveyor Belt without profiles)	362,67 min/day
Takt time (Conveyor Belt with profiles)	533,32 min/belt
Takt time (Conveyor Belt without profiles)	533,34 min/belt

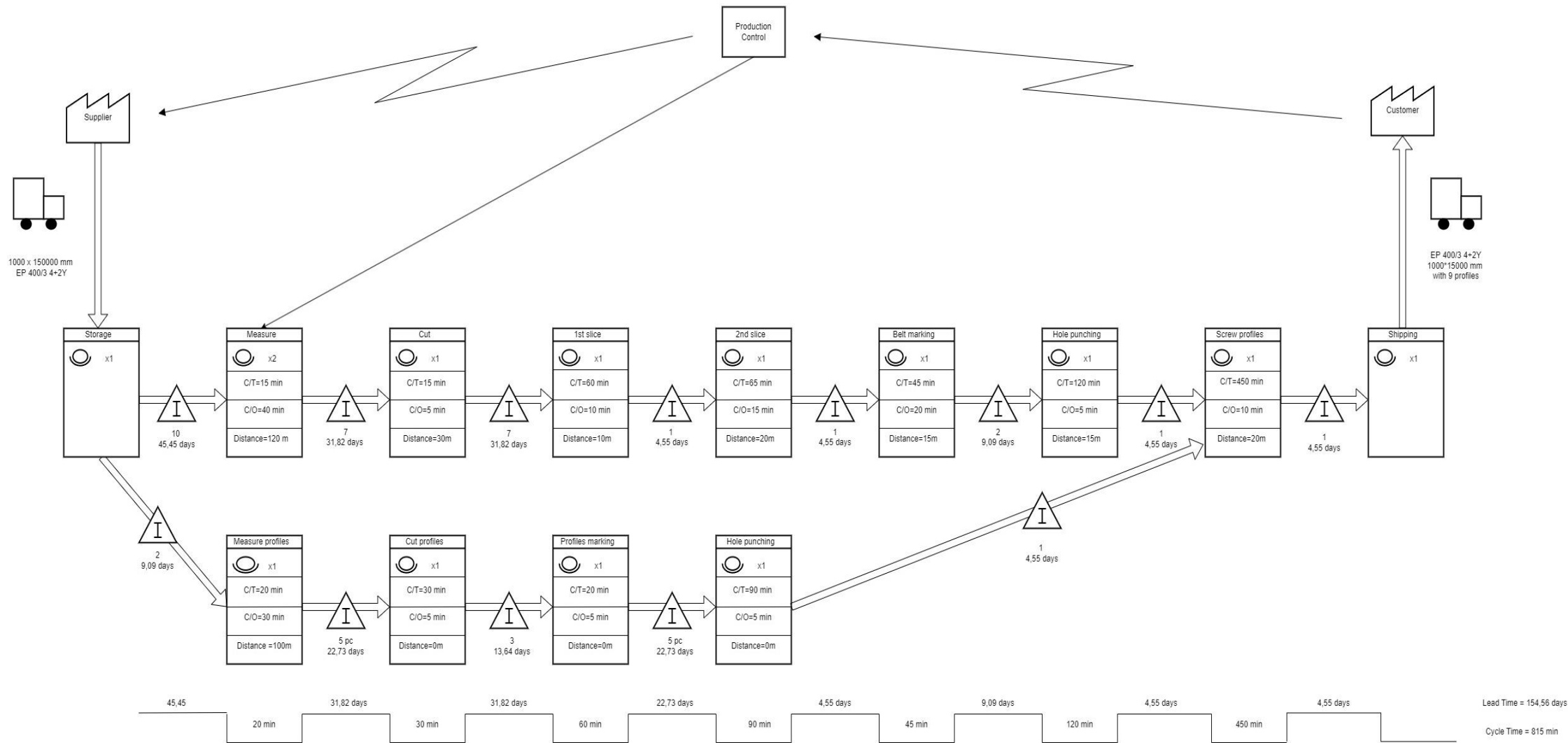


Figure 22 - VSM

During the mapping of the value stream, various aspects were considered, including cycle times, changeover times, movements of materials, and information. This provided a more comprehensive understanding of the activities involved and the interactions between them. The analysis conducted in the VSM revealed a significant finding, a total of 150 minutes dedicated to the setup changeover process (non-value-added activities), a Lead Time of 154,56 days and a cycle time of 815 minutes. This realization holds substantial implications for operational efficiency in the company's production processes. The time allocated for setup changeover represents a critical opportunity for improvement and waste reduction. This time allocation also carries a direct cost for the company. A belt with profiles takes an average of 1080 minutes to be produced, which corresponds to 18 hours of work, equivalent to more than two shifts. 13.89% of the total production time is dedicated to NVAA.

$$\begin{aligned} NVAA \text{ time} &= \sum CO \text{ time} = 40 + 5 + 10 + 15 + 20 + 5 + 10 + 30 + 5 + 5 + 5 \\ &= 150 \text{ min} \end{aligned}$$

$$\begin{aligned} VAA \text{ time} &= \sum CT = 15 + 15 + 60 + 65 + 45 + 120 + 450 + 20 + 30 + 20 + 90 \\ &= 930 \text{ min} \end{aligned}$$

$$Total \text{ time} = VAA \text{ time} + NVAA \text{ time} = 150 + 930 = 1080 \text{ min}$$

$$NVA \text{ time} = \frac{150}{1080} \times 100 = 13,89\%$$

Considering that 1 hour of work costs 10 euros, the production of a conveyor belt with profiles has a labor cost of 180 euros, with 25 euros related to NVAA.

$$NVA \text{ cost} = 10 \times 2,5 = 25 \text{ euros/tela}$$

$$Total \text{ labor cost} = 18 \times 10 = 180$$

On average, a diesel forklift has a consumption of 2.5 Liters per hour. Considering the disorganization of the warehouse, it is used for about 30 minutes whenever a new item is needed because sometimes it's necessary to move other materials to access the required material. 1.25 Liters of diesel are consumed per belt. It emits approximately 600 grams of CO2 per liter, resulting in approximately 0.75 kg of CO2 emissions in this situation.

$$Diesel \text{ Consumption} = 2,5 \times \frac{30}{60} = 1,25 \text{ litros}$$

$$CO2 \text{ Emissions} = 1,25 \times 0,6 = 0,75 \text{ KG} \frac{CO2}{conveyor}$$

Table 17 - Initial state of KPI's

Total labor cost	180 €
NVAA cost	25 €
Total time	1080
NVAA time	150 min
Diesel consumption	1,25 l
CO2 emissions	0,75 Kg CO2
Distance	330 m

4.2.3. Spaghetti Diagram

To better comprehend the setup changeover process and its associated inefficiencies, a spaghetti diagram was employed and is represented on Figure 23 - Spaghetti Diagram. This diagram visually maps the movements of materials and personnel during the setup changeover process, providing a clear illustration of the flow of activities and potential areas for improvement.

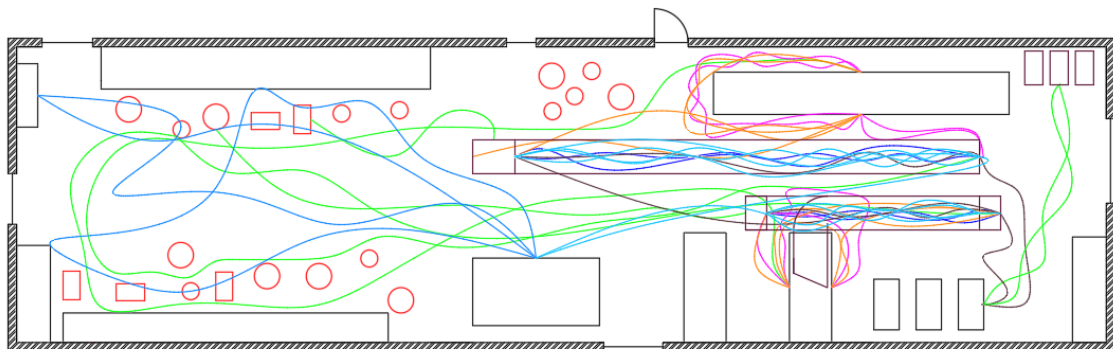
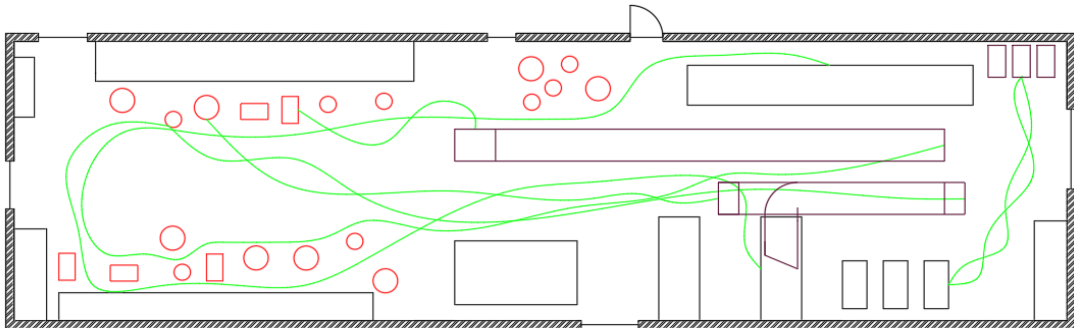


Figure 23 - Spaghetti Diagram

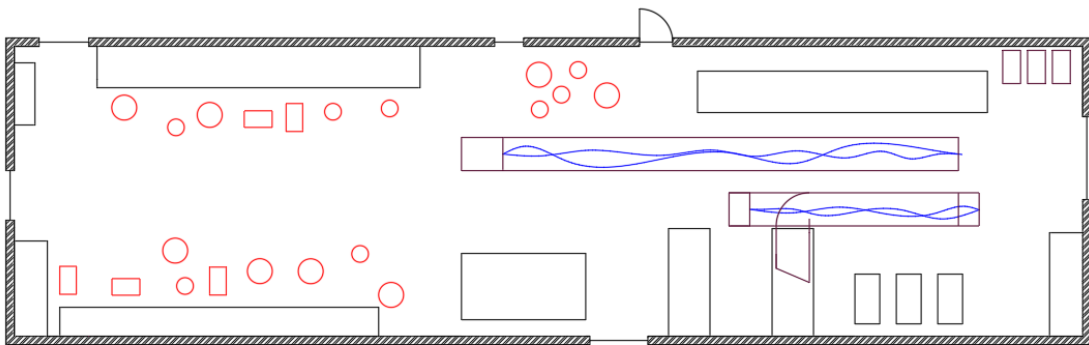
To conduct a detailed analysis of the movements at each stage of the production process, the diagram was broken down into stages. By breaking down the diagram into phases, it was possible to carry out a thorough analysis of the operations at each stage of the production process. This approach revealed that trips to the warehouse for raw material retrieval emerge as a critical point. This is primarily due to the extent of the distances travelled during this process. Additionally, it is observed that the search for essential equipment to perform tasks also impacts movements. This results in significant disruptions in workflow, potentially increasing production time and reducing the overall efficiency of the process. Therefore, understanding and optimizing these stages of movement and resource preparation becomes essential to improve the effectiveness and efficiency of the production process.

Table 18 - Spaghetti diagram decomposition

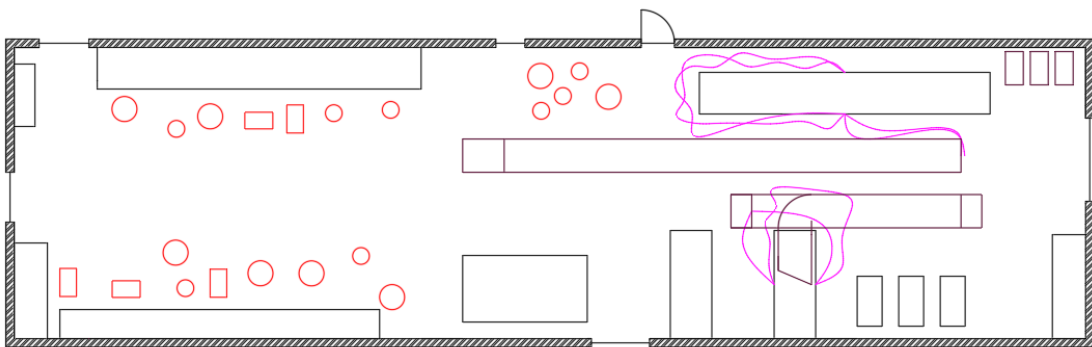
Locate material in the warehouse and transport it to the production area.



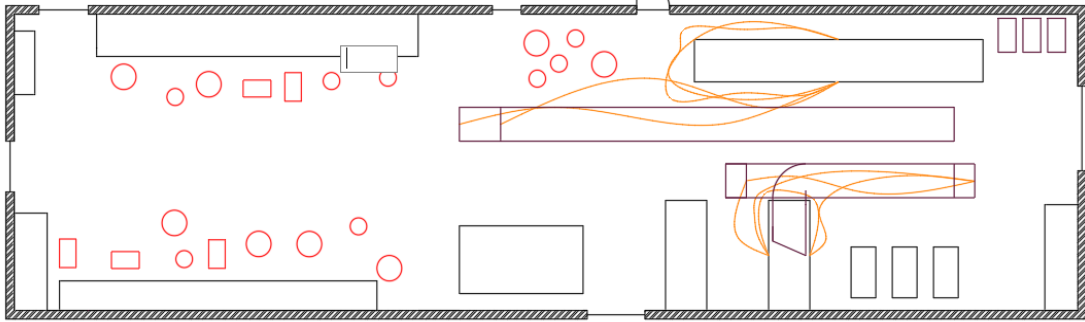
Measure and cut



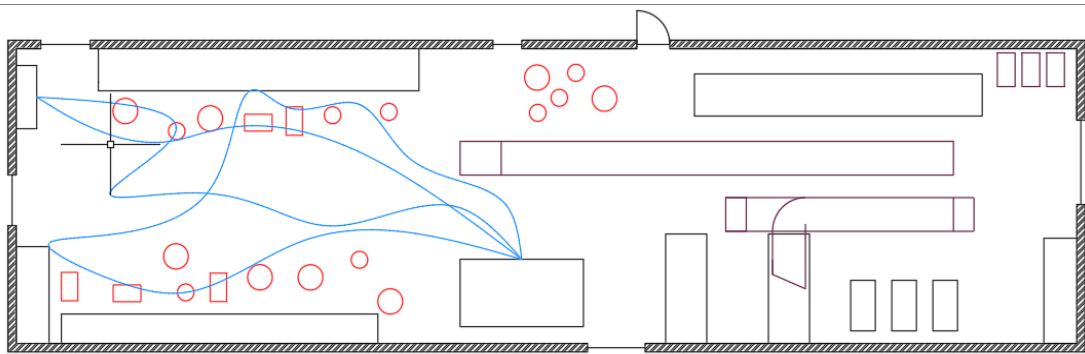
1st slice



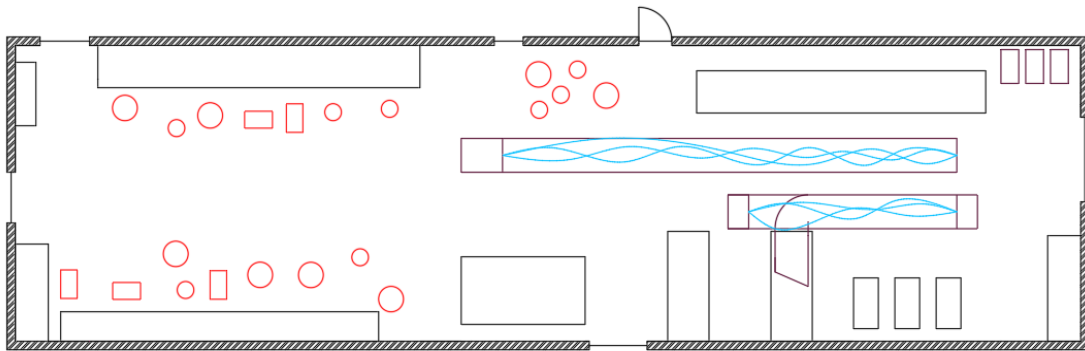
2nd slice



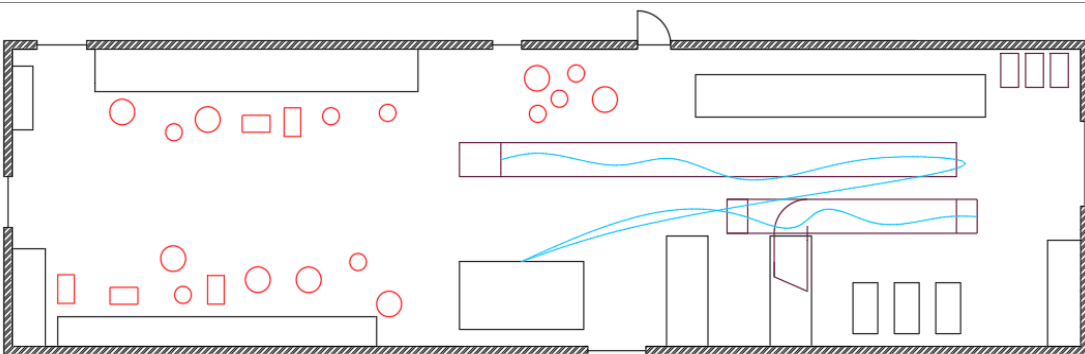
Mark and drill profiles



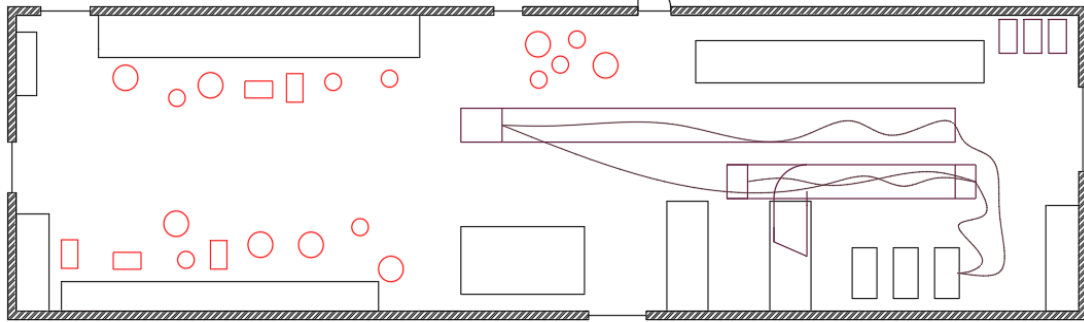
Mark and drill conveyor belt



Screw profiles



Vulcanization



When analysing the spaghetti diagram representing movements throughout the production process, it becomes evident that the warehouse is a critical point with a high number of movements. This phenomenon suggests that there are several underlying issues contributing to these frequent movements. One of the main identified problems is related to the organization of the warehouse. The lack of proper arrangement of materials can lead to difficulties in locating necessary items, resulting in unnecessary movements and loss of time. Furthermore, an inefficient warehouse layout can further hinder access to materials, leading to additional movements to find what is needed. Another point of concern is operational procedures. If there are no clear instructions regarding the storage location of materials or if procedures for optimizing movements are not well defined, workers may spend more time than necessary moving around the warehouse. Additionally, issues related to inventory management may be contributing to the problem. If there is inadequate forecasting of material needs or if inventory levels are excessive or insufficient, this can lead to frequent trips to the warehouse to adjust inventory levels. Finally, internal transportation is also an area deserving attention. If there is inadequate equipment for internal transportation or if transportation routes are not optimized, this can result in inefficient movements and wasted time. Addressing these issues is crucial to reducing movements to the warehouse and improving overall process efficiency. This will not only help save time and resources but also contribute to a more organized and productive work environment.

4.2.4. Employee Satisfaction Survey

Also, a survey was conducted to assess various aspects related to the work environment and employee satisfaction within the company, which is presented on appendix C. Understanding employees' perceptions regarding topics such as job satisfaction, stress levels, internal communication, involvement in company activities and decisions, as well as opportunities for professional development, is crucial for identifying areas of improvement and fostering a more productive, healthy, and harmonious work environment.

The data collected through this questionnaire allows for a comprehensive analysis of employees' perceptions and needs in different areas, providing valuable insights for human resource management and organizational improvement strategies.

The questionnaire was designed to cover a variety of relevant topics, from academic background and professional experience to perceptions about the work environment and development opportunities. Employee participation in this process is essential to ensure an accurate and comprehensive representation of diverse perspectives and experiences within the organization.

Through this initiative, it is expected to promote an open and transparent dialogue between the company and its employees, encouraging collaboration and engagement for mutual success.

In terms of longevity in the company, the data indicates a significant division. Approximately 37.5% of employees are relatively new, with less than a year of service, while another 25% have been with the company for over 20 years.

As for educational level, half of the employees have only completed the 2nd cycle of education. Regarding job satisfaction, responses are divided. While half of the employees express a certain level of contentment, a similar proportion, 25%, report feeling "somewhat dissatisfied."

Regarding stress, a majority declare facing moderate levels, but a significant portion, 37.5%, consider it high, which can impact both performance and well-being at work.

There is also a widespread perception of lack of inclusion in company activities and decisions and deficiencies in internal communication. However, many employees seem to overlook the direct impact of this on their work and personal satisfaction.

Additionally, a notable proportion of employees, 12.5%, point out that the organization of the work environment negatively affects their well-being and performance. They also express a perception of a shortage of opportunities to develop new skills. These indicators suggest potential areas for improvement and development within the organization.

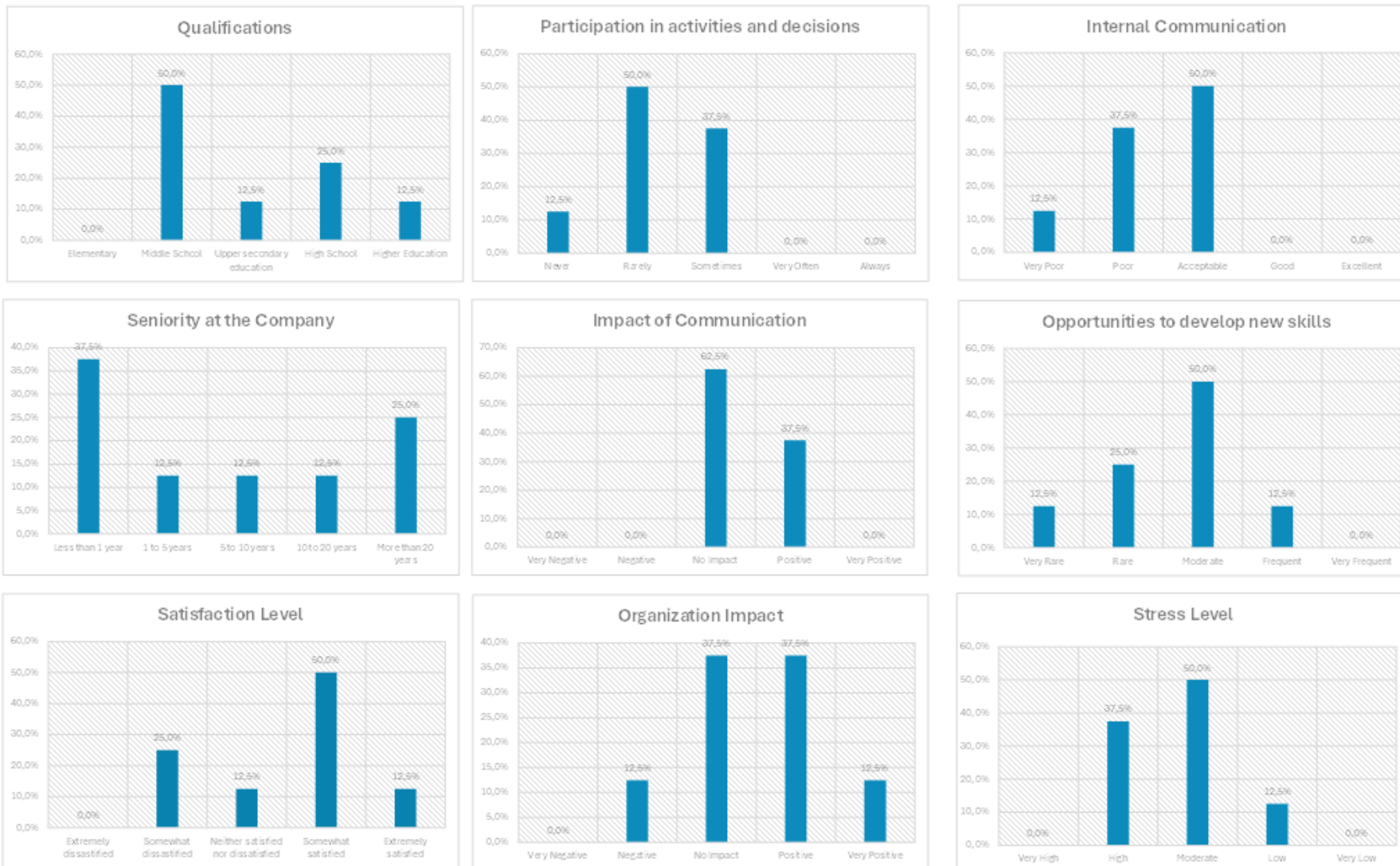


Figure 24 - Survey Results

4.3. Analyse

In the DMAIC Analyse phase, it is essential to deeply understand the problem in question and identify its root causes, in order to detect improvements that can be implemented in the next phase. At this stage, a root cause tree diagram was first developed to identify, in general, the causes that are affecting the sustainable development of J. Baptista.

4.3.1. Process Flowchart

To better understand the intricacies of the process and identify potential inefficiencies, a detailed process flow diagram was created based on the SIPOC analysis conducted during the Define phase of the DMAIC methodology at J. Baptista. This comprehensive examination aimed to uncover underlying issues requiring targeted interventions to enhance operational efficiency and promote sustainability within the organization.

Throughout the development of the SIPOC and subsequent process flow diagram, several critical issues emerged across various stages of the operation. These challenges spanned from communication breakdowns between production and the commercial department to shortcomings in materials management, raw material storage, production processes, and technician deployment.

Communication gaps between production and the commercial department were identified as a significant concern, characterized by outdated communication channels, lack of standardized procedures, and high variability. These deficiencies led to misunderstandings and errors, highlighting the need for improved communication protocols and clearer lines of communication.

In terms of materials management, challenges in verifying material availability were observed, resulting in excessive movement and time expenditure. These inefficiencies underscored shortcomings in inventory management and storage systems, necessitating improvements to streamline material tracking and accessibility.

Issues within raw material storage were attributed to an inefficient layout and the absence of formal procedures, leading to space wastage and difficulties in locating and accessing materials when needed. Addressing these challenges requires redesigning storage layouts and implementing standardized procedures to optimize space utilization and facilitate material retrieval.

Within the production phase, inefficiencies in planning, a shortage of skilled labor, and outdated processes were identified as key obstacles impacting productivity and product quality. These issues highlight the need for process optimization, workforce development, and technology upgrades to enhance operational effectiveness and meet customer demands efficiently.

Lastly, challenges in technician deployment were linked to inefficiencies in planning and a shortage of qualified labor, potentially resulting in delays in problem resolution and service

delivery. Improving workforce scheduling and investing in training programs can help address these challenges and ensure timely interventions to meet customer needs.

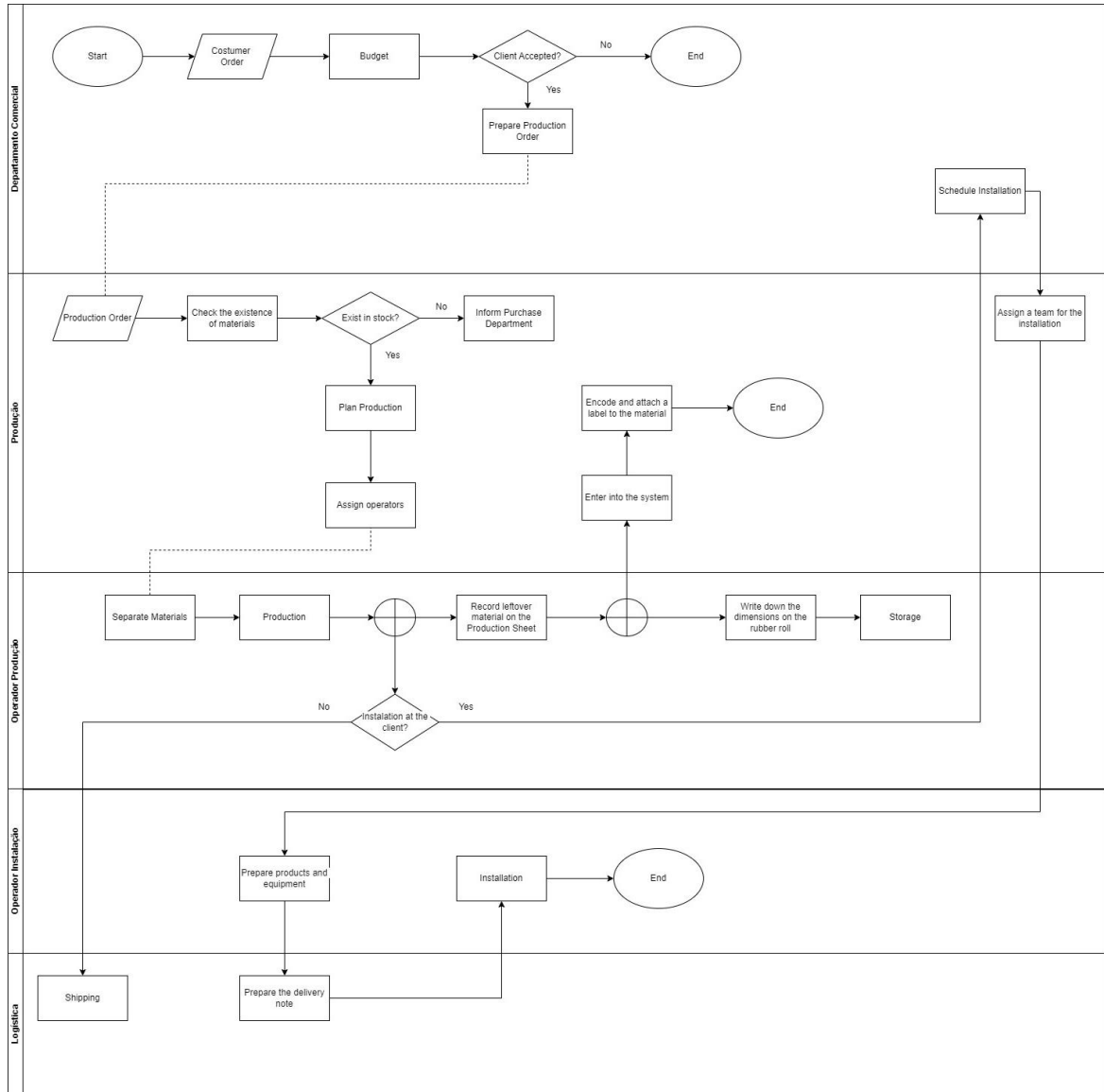


Figure 25 - Process Flowchart

A tree root cause analysis diagram (Figure 26 - Tree root cause analysis) was developed to examine how each pillar of sustainability is impacted within J. Baptista's operations. This comprehensive analysis aimed to uncover the underlying causes of sustainability challenges across economic, environmental, and social dimensions, providing insights into areas for targeted interventions and improvement efforts. Upon analysing this diagram, it is observable that the primary reasons for sustainability issues are high operational costs, excess movements, and high stress levels. However, it is necessary to analyse these causes in more detail to identify potential improvements. For this purpose, Ishikawa diagrams were prepared.

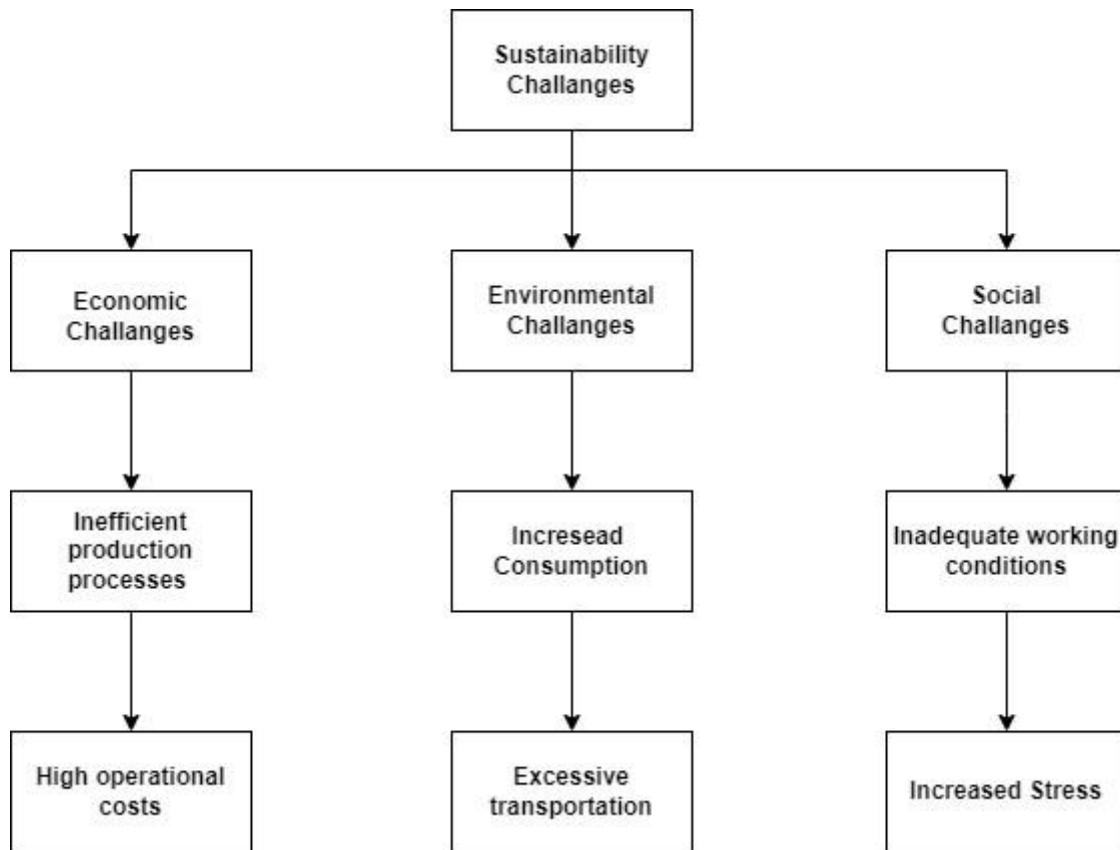


Figure 26 - Tree root cause analysis

The fishbone diagrams reveal that many of the identified causes are common across various issues. A careful observation suggests that these causes essentially reside in related areas such as inefficient layout, absence of standard procedures, inefficient planning underlying communication problems between departments, and lack of skilled workforce. We observe that inadequate workspace layout, lack of organization in material storage, and lack of process standardization are some of the underlying causes of excessive movements, compromising operational efficiency and impacting operational costs. Additionally, other causes contributing to high operational costs are identified, including resource mismanagement, material waste, rework, and inadequate equipment maintenance.

Disorganization in the workplace can cause workflow inefficiencies, wasting both time and resources. When tasks lack clear processes and designated spaces, employees may struggle to work effectively, driving up operational expenses. Poor workspace layout can hinder productivity by misplacing equipment and materials, causing unnecessary delays. The absence of standardized procedures leads to inconsistent quality and productivity as employees use different methods. Inadequate inventory management can inflate costs through overstocking, stockouts, or obsolete inventory. Without proper controls, resources may be misallocated, resulting in unnecessary spending.

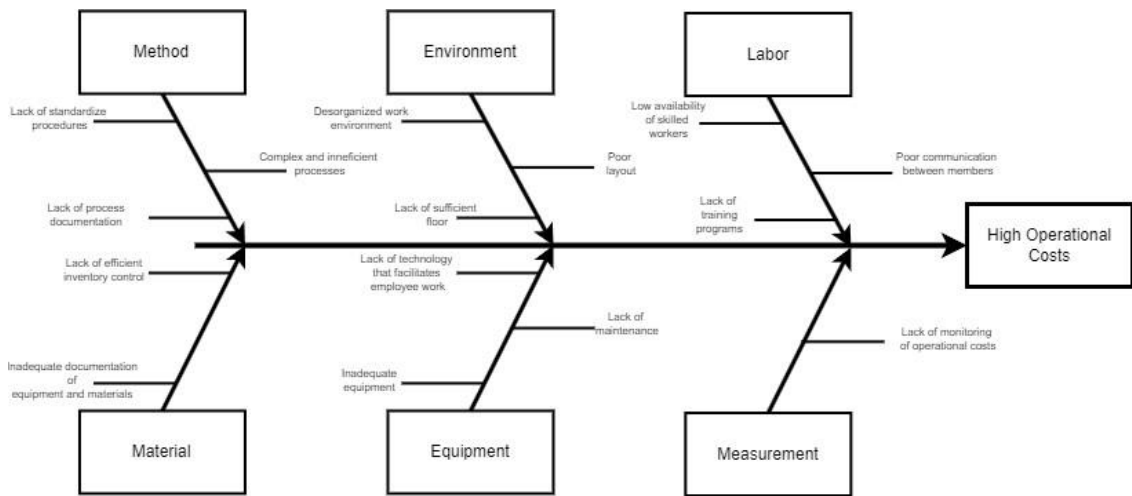


Figure 27 - Ishikawa's Diagram: High operational costs

Ambiguous work processes can cause inefficiencies and unnecessary movements in production or operations. This lack of clarity often leads to backtracking or rework, increasing transportation requirements. Poor planning and scheduling of production activities can disrupt material flow and resource allocation, resulting in additional transportation to manage shortages or surpluses, thus driving up costs. Bulky materials further complicate logistics and transportation, adding to expenses. Just as with operational costs, the absence of standardized procedures exacerbates transportation challenges. Without clear guidelines for material handling and transport, inefficiencies emerge, requiring more transportation resources. A cluttered workspace disrupts material flow, necessitating extra transportation to maneuverer, highlighting the importance of clear pathways and organized storage to minimize unnecessary transportation.

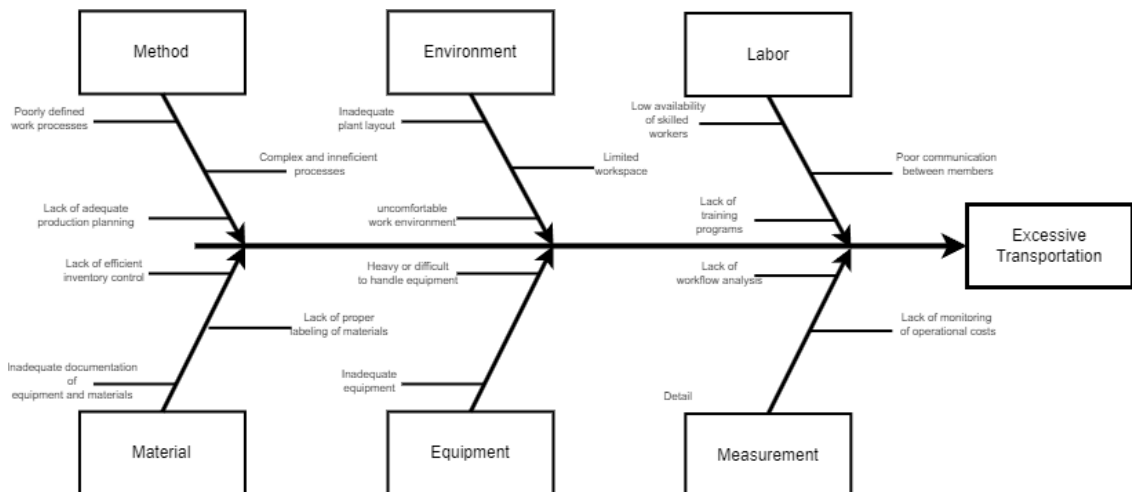


Figure 28 - Ishikawa's Diagram: Excessive transportation

Procedures lacking clarity breed uncertainty and confusion among employees, elevating stress levels. When expectations or guidelines are unclear, employees struggle to perform effectively, heightening frustration and anxiety. A cluttered workspace adds to stress, fostering a chaotic

atmosphere. Difficulty finding tools or materials increases pressure and distracts from tasks. Communication barriers lead to misunderstandings and conflicts among team members. Insufficient sharing of information or feedback exacerbates stress and hampers collaboration. Shortages of skilled personnel or inadequate staffing led to overwork and burnout, further diminishing morale. Increased workloads without adequate support amplify stress and decrease overall morale among employees.

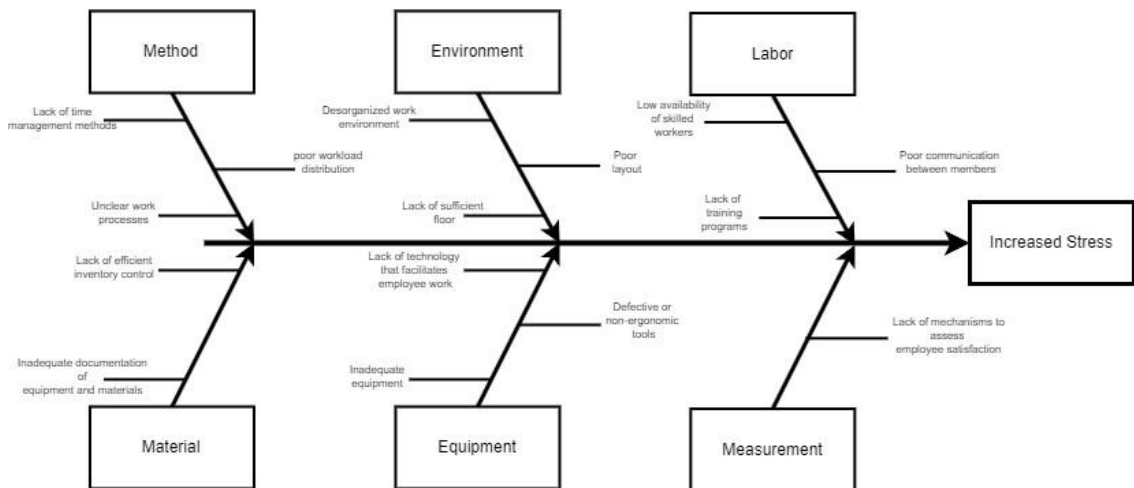


Figure 29 - Ishikawa's Diagram: Increased stress

4.3.2. GUT Priority Matrix

The main aspects were then assessed in a GUT matrix to establish priorities. Based on the analysis of Ishikawa diagrams, we proceeded to prioritize actions using the GUT matrix. This approach allowed us to assign weights according to the level of importance of each factor, helping us identify areas that require immediate attention. The highest priority concerns layout problems and lack of inventory control. Following are communication issues, workspace organization, shortage of qualified workers, and difficulty in resource allocation. Subsequently, it is necessary to review processes as they are outdated and reformulate them to standardize.

Table 19 - GUT priority matrix

Problem	Gravity	Urgency	Trend	G*U*T	Rank
Inadequate Layout	5	5	4	100	1
Desorganized environment	4	4	4	64	3
Lack of inventory control	5	5	4	100	1
Outdated processes	3	3	3	27	6
Lack of standard work	3	3	3	27	6
Poor communication	5	4	4	80	2
Lack of skilled workers	5	4	3	60	4
Lack of equipments documentation	3	3	2	18	7
Inadequate equipments	3	3	3	27	6
Difficulty in resources management	4	4	3	48	5

The following table outlines key improvements implemented during the Improve phase of the DMAIC process, aimed at addressing sustainability issues and enhancing organizational processes.

Table 20 - Improvements

Improvement	Description
New Layout	<p>Redesigning the layout is a fundamental aspect of optimizing operations. Based on principles of efficiency and accessibility, the new layout aims to streamline material flow and minimize unnecessary movements. This involves grouping materials according to frequency of use or production flow, implementing clear labelling and signage systems, and optimizing aisle widths to accommodate equipment and personnel movement. The goal is to minimize travel distances, reduce congestion, and facilitate smooth material flow.</p>
Implementation of 5S	<p>Implementing the 5S is crucial to improve efficiency, safety, and quality while reducing waste and fostering a more pleasant and productive environment. In summary, implementing the 5S is essential to create a culture of operational excellence and ensure satisfaction among both employees and customers.</p>
Create a system to track inventory	<p>Creating a system to track inventory is essential for businesses to efficiently manage their stock levels, monitor product movement, and prevent stockouts or overstock situations. By implementing such a system, businesses can streamline their operations, minimize errors, and make informed decisions regarding purchasing, production, and sales.</p>
Standardize Procedures	<p>It ensures that operations are carried out uniformly, reducing errors, increasing efficiency, and facilitating employee training. Moreover, standardization promotes continuous improvement, facilitates collaboration with partners and customers, and contributes to the company's reputation by ensuring the consistent delivery of high-quality products and services</p>
Training	<p>Thorough education is essential for providing staff with the necessary knowledge and skills to effectively implement and maintain the new procedures. Training should encompass various topics, including the reasoning behind the changes, navigating the updated layout, correct utilization equipment, adherence to 5S principles, and addressing common challenges. Continuous training and reinforcement guarantee sustained engagement and dedication to upholding the standardized process over time.</p>

Improvement	Description
Kanban Board	A Kanban board is extremely effective for improving planning and communication within a team or organization. It offers a visual and intuitive way to organize tasks and projects, ensuring that everyone is on the same page. By providing a clear visualization of work to be done, in progress, and completed, Kanban facilitates prioritization, collaboration, and transparency, promoting more efficient and integrated project management.

4.3.3. A3 Report

The A3 Report plays an essential role during the Analysis phase in the DMAIC process. In this critical stage, where detailed understanding of the issues is paramount, the A3 Report provides an effective framework to summarize and communicate the analysis results clearly and concisely. It has condensed the information presented so far in a way that all collaborators can prioritize the key data points, highlighting the identified issues, their root causes, and the impact on the organization's sustainability. Additionally, the A3 Report facilitates clear communication by visually and directly presenting the identified issues and the proposed action plan. This helps ensure that all stakeholders understand the situation and the next steps, promoting a proactive approach to resolving operational issues. Finally, the A3 Report serves as a formal record of the findings and the agreed-upon action plan. This is valuable for future reference, progress tracking, and evaluation of the effectiveness of the implemented measures. The Figure 30 - A3 report, represents the A3 report related to company's situation.

1. Background

The company is facing challenges with:

- Labor Shortages and Scheduling Challenges
- Communication breakdowns between department
- Working Conditions and Employee Well-being
- Operational Inefficiency and Outdated Processes

Which affects the company's Sustainability:

Wich affects the company's Sustainability:

- **Economic**: Efficiency in production can lead to higher income levels and reduce overall production.
- **Environmental**: Inefficient processes and outdated also lead to higher energy consumption, increasing the environmental footprint of the company's operations.
- **Social**: Inadequate working conditions can result in safety risks and increase labor turnover. The shortage of qualified labor can create instability in the labor environment, affecting employee well-being.

2. Current State

Supplier	Input	Process	Output	Customer
Customer	Specifications of Product and Service	Product Order	Product Order	Sales Department
Sales Department	Product Order	Communicate Production	OPDP	Production
Production	OPDP	Check Material Availability	Communicate inventory status	Purchasing department
Purchasing department	Communicate inventory status	Acquire raw materials	Raw materials	Logistics
Logistics	Raw Materials	Store raw materials	Raw Materials Stored	Production
Production	Raw Materials Stored	Product Manufacturing	Finished Product	Installation technicians
Installation technicians	Finished Product	Assembly	Assembled Product	End customer

3. Set the Target

1	Enhance operational efficiency
2	Improve internal communication within the organization
3	Reduce environmental impact
4	Improve working conditions and employee well-being

4. Analyse the Root Cause

5. Develop Countermeasures

**New layout;
5S Implementation;
Create a system to track inventory;
Standardize procedures;
Training;
Kanban Board.**

7. Action Plan

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
New Layout		█	█	█				
5S Implementation				█				
Create a system to track inventory				█	█			
Standardize Procedures						█		
Training							█	█
Kanban Board							█	

8. Follow-up Plan

NVAA Cost **NVAA Time** **Fuel Consumption** **CO2 emissions** **Employee well-being**

NVAA time	150 min
NVAA money	25 €
Diesel consumption	1,25 l
CO2 emissions	0,75 kg de CO2
Distance	330 m

Stress Level

Stress Level	Percentage
Very High	0,0%
High	37,5%
Moderate	50,0%
Low	12,5%
Very Low	0,0%

Figure 30 - A3 report

4.4. Improve

To address the inefficiencies, crucial steps have been outlined. These steps represent a structured and comprehensive process designed to tackle operational challenges and drive improvements in efficiency and effectiveness. By focusing on addressing underlying issues and implementing significant changes, the organization aims to improve its processes and achieve its objectives in terms of sustainability.

4.4.1. Layout restructuring

Initially, storage was primarily done in Warehouse 3, adjacent to the production area. This warehouse is depicted in the figure 31. The space was characterized by its inefficiency, with poorly delineated and identified storage areas. As a result, accessing materials was difficult, often requiring excessive material handling. Additionally, this storage method compromised operator safety, as the difficult access frequently necessitated moving heavy materials without the proper equipment. Therefore, it was necessary to rethink the warehouse layout.

Given the lack of space in this area, it was necessary to transform Baptista's underutilized storage space into Warehouse 4, marking a strategic shift in resource allocation. By repurposing the area to store materials with lower turnover, the warehouse optimizes inventory management processes and minimizes the distance travelled by frequently used items.

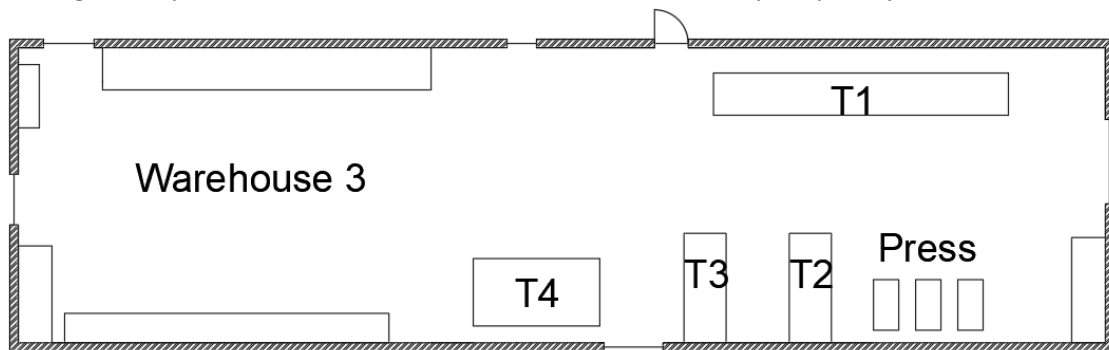


Figure 31 - Layout

In Warehouse 3, whose layout is represented on the figure 32, the delineation of four distinct aisles serves as the backbone of operational efficiency. Each aisle is meticulously organized to fulfil a specific role in streamlining processes and optimizing productivity. Aisle 1 stands out with its six storage areas, thoughtfully designed with two levels to ensure systematic and efficient product arrangement. This layout not only maximizes space utilization but also facilitates easy access to stored items, minimizing retrieval time and enhancing overall workflow efficiency. Moving on to Aisle 2, its twelve individual areas are tailored to accommodate larger-sized rolls that defy conventional shelving standards. This specialized arrangement acknowledges the diverse nature of materials handled, providing a bespoke solution that caters to unique storage requirements. By dedicating specific spaces for such items, the warehouse ensures proper organization and prevents clutter, promoting a safer and

more organized working environment. Meanwhile, Aisle 3 offers a dynamic storage solution with its twelve areas, each boasting three levels of storage capacity. This versatility allows for the efficient storage of materials based on their characteristics and demands, enabling the warehouse to adapt seamlessly to changing inventory needs. Whether it's bulky items or delicate components, the layout ensures that every product is housed appropriately, reducing the risk of damage and expediting retrieval during order fulfilment processes.

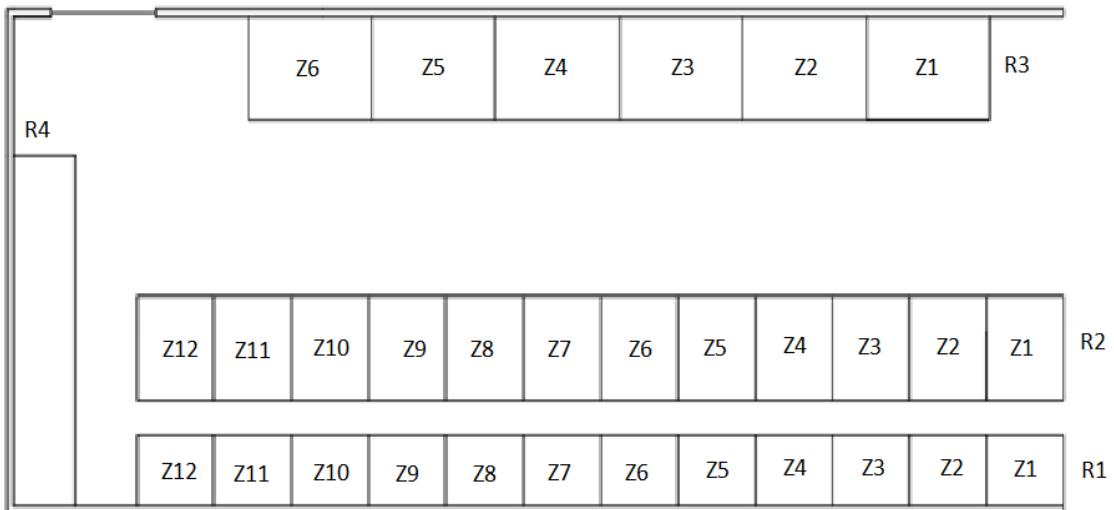


Figure 32 - Layout: Warehouse 3

Warehouse 4, whose layout is presented in the figure, is composed of three distinct aisles. Aisles 1 and 2 provide eight storage spaces each, while aisle 3 provides six.

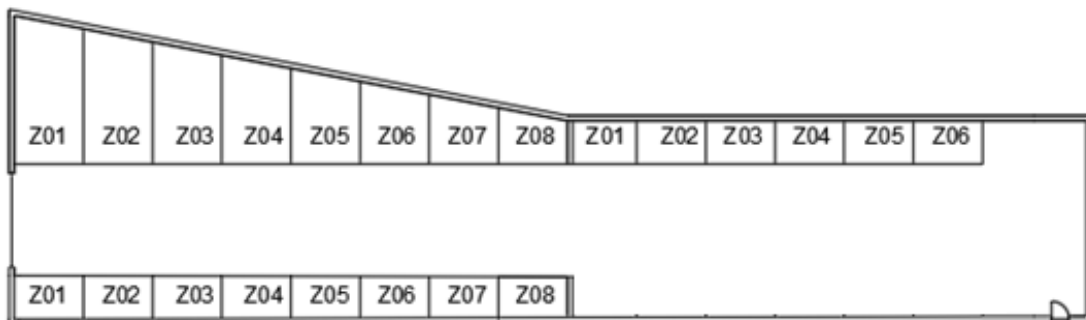


Figure 33 - Layout: Warehouse 4

The layout planning for both warehouses was conducted considering the specific material transportation requirements. While transportation in Warehouses 3 and 4 is predominantly carried out by forklifts, a gantry crane is also incorporated in Warehouse 3, specially designed to facilitate the handling of heavier loads, ensuring efficient and safe material movement. It is essential to note that, due to the large dimensions of the conveyor belts, the warehouse aisle is occasionally temporarily used for production operations. Therefore, the layout was flexibly designed to accommodate this dynamic, prioritizing the maximization of storage capacity and ensuring easy and safe access to materials, thus contributing to an efficient and hassle-free logistics operation.

In the production area, a significant restructuring was carried out aiming to improve operational efficiency and maximize available space. This initiative stemmed from a detailed analysis of existing processes and identified opportunities for improvement. One of the main focal points of this restructuring was workstation 1, which proved to be excessively large and occupied more space than necessary. This excessive occupancy hindered the passage of the forklift and the materials flow.

Considering these findings, immediate and decisive actions were taken. Firstly, the redundant workstation was removed, thereby freeing up considerable space. Subsequently, workstation 1 was replaced with a more suitable version tailored to the specific operations of the workstation. This change not only allowed for better space utilization but also facilitated workflow and material movement. Furthermore, a designated space was created for storing finished products awaiting shipment, providing a more efficient organization of the factory floor. This reorganization improved internal logistics. Additionally, it is worth noting that workstations one and two are now characterized by their flexibility and thus designated for profile preparation and other additional operations, while the remaining workstations are exclusively designated for splice execution.

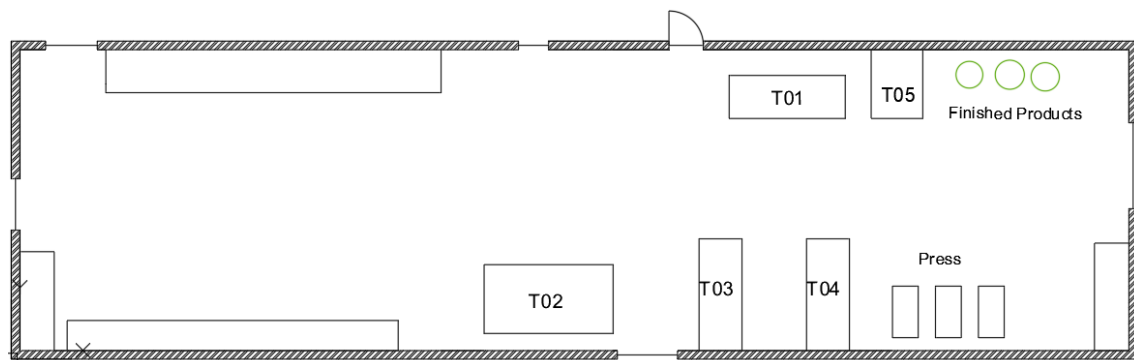


Figure 34 - Layout: Production area

4.4.2. 5S

The implementation of the 5S method in our organization is not only a response to the need for improving operational efficiency but also a strategic decision aligned with our commitment to environmental and social sustainability. By adopting the five phases of 5S we are not just reorganizing our workspaces but also redefining our approach to natural resources and the environment, as well as employee well-being and safety.

The first phase, Seiri, leads to deeply reflect on what is truly necessary in daily operations. By filtering out and removing obsolete equipment, unnecessary materials, and items that do not contribute to our mission, we are reducing not only excess physical clutter but also the burden on resources. This initial action sets the tone for the entire process, establishing a mindset of responsible and efficient resource usage.

The following phase, Seiton, challenges to organize workspaces to maximize efficiency and accessibility. By assigning specific locations for each item and improving workflow, we are not

only reducing wasted time searching for materials but also minimizing energy and resource waste associated with unnecessarily complicated processes.

Regular cleaning, or Seiso, is not just a matter of aesthetics or hygiene, it is a fundamental practice for safety and equipment preservation. By removing dirt, dust, and debris from our workspaces, we are not only creating a safer and healthier environment for our employees but also prolonging the lifespan of our equipment and reducing the need for premature replacements.

Standardization, as seen in Seiketsu, is essential for ensuring consistency and efficiency in our operations. By establishing clear standards for organization, cleanliness, and maintenance, we are creating an environment where sustainability is incorporated into our daily processes. This standardization not only helps to avoid waste and errors but also empowers to identify opportunities for continuous improvement in work practices.

5S warehouse

With the aim of improving warehouse organization and establishing a standardized storage process, the decision was made to adopt the 5S methodology as the central approach. This methodology aims to promote efficiency and quality through five stages of 5S. Initially, a thorough analysis of the warehouse inventory was carried out, identifying unnecessary, obsolete, or excess items that were taking up space and hindering operations. These items were carefully removed, resulting in optimization of the available space, and reducing clutter in the work environment, as previously mentioned.

Most of the rolls were strategically stored on pallets, a measure that not only optimizes space but also aims to reduce the risks associated with transportation and handling by the employees. By using pallets to store the rolls, we minimize the need for direct handling of materials, which can result in musculoskeletal injuries due to repetitive efforts or improper movements. Furthermore, the use of forklifts and pallet jacks for the transportation of these materials contributes to employee safety, as they provide a more controlled and stable way to move heavy loads. This equipment is designed with safety measures, which help to minimize the risks of accidents during transportation. By adopting these storage and transportation practices, the company not only protects the health and safety of its employees, but also promotes a safer and more productive work environment, where the risks related to material handling are reduced to the minimum possible extent.

Table 21 - 5S: Warehouse

5S Phase	Description
Seiri (Sort)	In this stage, it is necessary to carefully sort through all items in the warehouse. Unnecessary, obsolete, or unused items should be identified and removed from the storage space. This help free up space and simplify access to essential items.
Seiton (Set in Order)	After classifying the items, it's important to organize what remains efficiently, considering the new layout of the warehouse. Each item should

5S Phase	Description
Seiso (Shine)	have a designated location and be stored logically and accessibly within this new arrangement. This facilitates the quick location of materials and reduces the time spent searching for them, thereby contributing to a smoother and more efficient operation of the warehouse.
Seiketsu (Standardize)	Keeping the warehouse clean and tidy is essential for operational effectiveness. This involves not only regularly cleaning the physical space but also ensuring that cleaning processes are incorporated into the daily work routine.
Shitsuke (Sustain)	To maintain the established standards of organization and cleanliness, it's important to standardize procedures and work practices. This includes creating clear guidelines for material storage, maintaining cleanliness, conducting regular warehouse inspections.
Shitsuke (Sustain)	The final stage of the 5S methodology, is crucial for maintaining and continuously improving the standards established in the previous phases. This stage focuses on fostering a culture of discipline and adherence to the new processes through regular training and reinforcement of 5S principles. This commitment to continuous improvement helps preserve and build upon the initial gains, promoting ongoing organizational excellence.

Following that, we proceeded with the implementation of allocating specific spaces for each type of item, carefully aligned with the new layout, and considering their individual characteristics. This measure allowed us to optimize space utilization and improve the efficiency of material handling operations within the warehouse. Additionally, with the aim of facilitating employees' navigation through the facilities, reducing the time needed to find specific items, and minimizing the risk of errors or delays in the process, the precise locations of the items were recorded in the computer system. Additionally, each storage space was labelled (Figure 35 - Identification of locations) navigation within the warehouse. This visual management system allows everyone, regardless of their familiarity with the warehouse layout, to find quickly and accurately what they need.



Figure 35 - Identification of locations

After this sorting process, a thorough cleaning of the warehouse was carried out, removing any residue that could compromise the quality of the raw materials, thus creating a clean, safe, and conducive environment for warehousing operations.



Figure 36 - Warehouse Cleaning: a) Before; b) After

Additionally, One Point Lessons were designed to address the challenges often encountered in the daily tasks of the warehouse. These lessons were meticulously structured with the purpose of emphasizing fundamental procedures, such as recording the new location of materials when they are stored and proper handling within the warehouse.

Through these clear and specific guidelines, it is expected that workers develop a comprehensive understanding of material handling and storage processes, while acquiring consistent and uniform skills in their roles. This approach not only aims to improve operational efficiency but also to reduce the risk of errors and accidents in the workplace, ensuring a safe and productive environment. Furthermore, by promoting the standardization of operations, One Point Lessons aim to ensure that all team members are aligned with the same procedures and practices, regardless of their level of experience. This uniformity fosters a cohesive and collaborative work culture, where all employees contribute to the overall success of the warehouse, thus strengthening the efficiency and quality of operations. Furthermore, comprehensive training sessions were conducted to underscore the significance of standardization and encourage adherence to established standards. This approach aimed to promote discipline and commitment among employees to the fundamental principles of 5S.


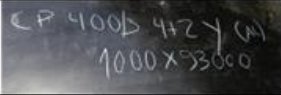


 One Point Lesson (OPL)	
Theme:	Warehouse Article Movement
Objective:	Keep the Warehouse Organized
1. Take note of the new measures in the article	
2. Record the location of the article in the operations sheet according to the following code: Y-AXXR,XXZXXNXX Where, Y - represents the initial of the location where the article is located: S - Sintra P - Porto AXX - represents the warehouse number (ex. A03) RXX - represents the street number (ex. R01) ZXX - represents the zone number (ex. Z02) NXX - represents the level (ex. N03)	
3. Transport the roll to the pallet using the overhead crane.	
4. Place the pallet in the location using a forklift or pallet jack	

Figure 37 - OPL

A standard procedure to warehouse storage was established. The first step involves checking the availability of the necessary materials in the company's system. The materials management officer performs the inquiry to confirm the availability of the items required for production. Once the existence of the materials in the system is confirmed, the next step is to physically locate the materials. After locating the materials, the officer records this information on the production sheet, which will be handed over to Operator 1. This individual is responsible for making the materials available to the production operator. Operator 1 receives the sheet and begins the process of preparing the materials for use in production, transporting them to the work area where production will take place. With the materials available in the work area, the production operator initiates production operations according to the product specifications. Upon completion of production, the operator records the updated measurements of the remaining material on the production sheet and on the material itself. Operator 1 receives the unused materials back and returns them to the storage location in the warehouse. They record the new location of the materials on the sheet, which will be handed over to the production manager. Finally, the materials management officer receives the completed control sheet and updates the system with information on the quantity of material used and its updated location.

Subsequently, they print a label with the material data and affix it so that it is properly identified.

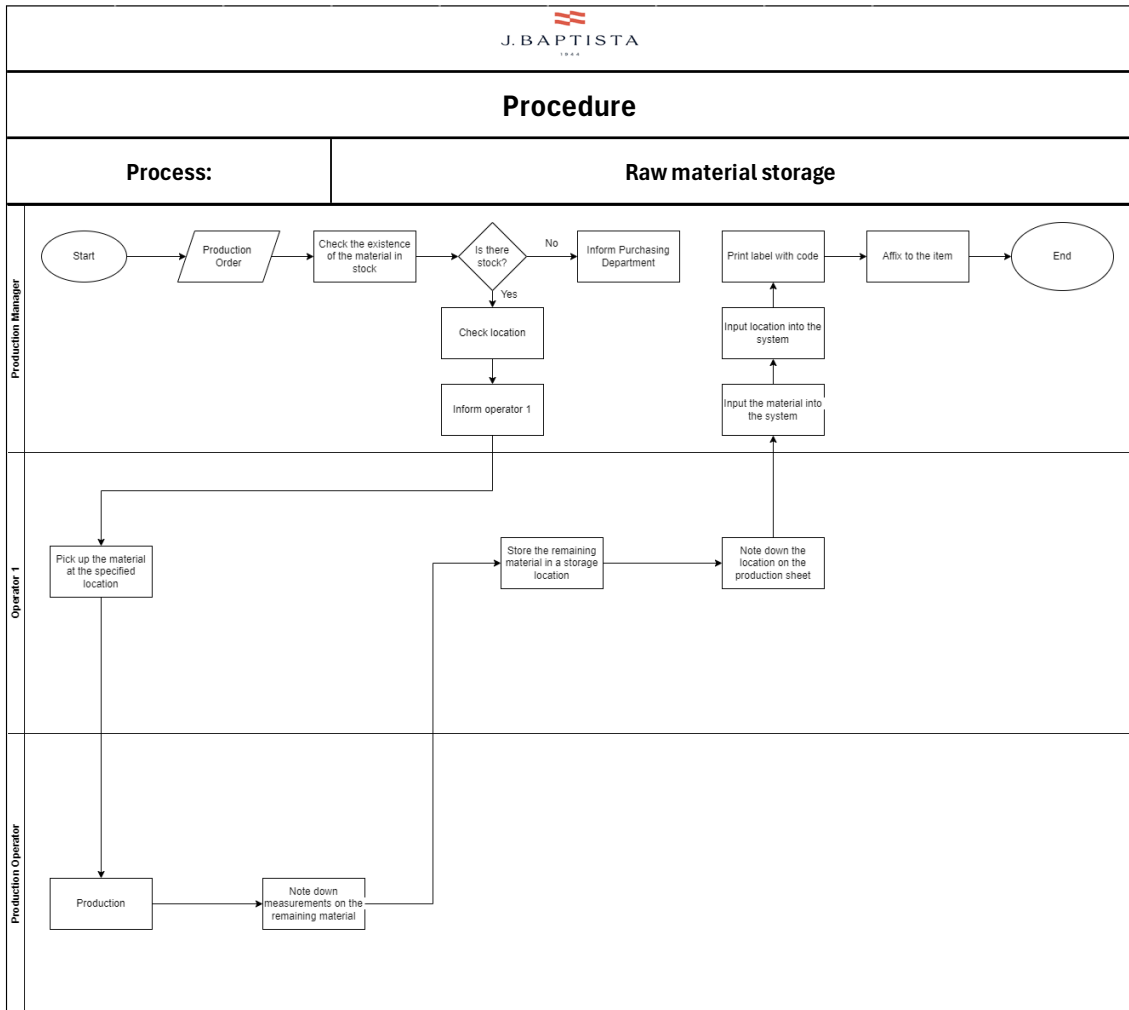


Figure 38 - Procedure: Raw Material Storage

In the following figures (Figure 39 - a) Warehouse 3; b) Warehouse 4), it is possible to observe the arrangement of raw materials in Warehouses 3 and 4.



Figure 39 - a) Warehouse 3; b) Warehouse 4

5S Production

After implementing the 5S in the warehouse, this tool was also adapted to the work zones. In this context, a detailed analysis of the application of the 5S in the workstations follows, highlighting how each phase contributes to optimizing processes, promoting safety, and increasing productivity. The following table outlines the stages of the 5S method and their specific relevance in the production phase, providing a comprehensive view of the practices implemented to achieve significant improvements.

Table 22 - 5S: Production Area

5S Phase	Description
Seiri (Sort)	Filtering equipment and materials that are in unsuitable working and safety conditions and removing them from the workspace. This involves a thorough assessment of all items present in the work environment, identifying what is necessary and useful for operations and what is unnecessary or obsolete. Items that are no longer used should be discarded or relocated to ensure a clean, efficient, and safe workspace.
Seiton (Set in Order)	Organizing the necessary materials for each workstation efficiently and accessibly, facilitating daily work. This includes assigning specific locations for each item based on its frequency of use and importance. Proper organization of materials reduces search time, minimizes errors and accidents, and promotes a cleaner and more orderly work environment.
Seiso (Shine)	Cleaning workstations regularly, removing dirt, dust, and other debris to ensure a safe and organized environment. Cleaning is not limited to equipment surfaces and work areas but also includes maintaining a clutter-free and hazard-free environment. Regular cleaning practices contribute to employee safety, equipment preservation, and operational efficiency improvement, ensuring better joint bonding.
Seiketsu (Standardize)	Creating a list of equipment standards and procedures for each workstation, establishing a foundation for operational consistency and efficiency. This involves defining clear guidelines for organizing, cleaning, and maintaining workspaces, as well as standardizing processes to ensure the quality and safety of operations.
Shitsuke (Sustain)	This phase involves developing an organizational culture that values discipline, responsibility, and commitment to excellence. Regular practice of maintaining established standards is essential to sustain the gains achieved with 5S and promote a culture of continuous improvement.



Figure 40 - Cleaning worktables: a) Before; b) After

When developing a standardized equipment list, we are establishing a solid foundation for implementing operational improvements. This list clearly outlines the necessary resources at each workstation, ensuring that employees have quick and easy access to essential tools and materials to perform their tasks. With this simplification of the workflow, we expect not only to reduce time wasted searching for equipment but also to increase overall production efficiency. Another significant benefit of creating a standardized equipment list is facilitating the training and integration of new employees. With a clear list of equipment required for each role, new hires can quickly grasp the requirements of their job and begin contributing effectively to production.

Additionally, standardizing equipment can help reduce operational costs by eliminating unnecessary duplication of tools and materials. By identifying essential equipment and ensuring it is available at all relevant workstations, we optimize the use of company resources. In the figure 41 an example of the various lists is shown; the complete lists are presented in the attachments.




			
Workstation Equipment List (Splices)			
001	X-Acto Knife		
002	Pincers		
003	Knife		
004	Gripper		

Figure 41 - Workstation Equipment List (Demonstration)

4.4.3. Procedure for the use of molds

In the production of profiled conveyor belts, the use of Molds is essential to ensure the precision and quality of the final product. However, the absence of an identification system for these molds has generated several operational challenges at J. Baptista company. This gap results in duplication in mold construction, leading to significant waste of material and labor resources. The lack of mold identification also negatively impacts the efficiency of the production line. The time spent searching for and constructing existing Molds contributes to increased tool changeover time. This increase in setup time reduces operational efficiency and line productivity, directly affecting costs and the quality of the final product.

In the VSM, this lack of organization and mold identification is represented as a waste of time, hindering the overall efficiency of the production process. This is an area of opportunity where the implementation of a mold identification system and effective storage organization could significantly reduce setup time and improve overall process efficiency.

To address this issue, it is imperative to implement an identification system and a standard process for manufacturing profiled belts. The introduction of a clear and precise identification system will allow for a complete record of which molds are in use and their specific location. This will help avoid unnecessary construction of new molds and reduce resource waste.

Initially, existing molds were collected and separated by customer, with all information recorded in an Excel file and a unique code assigned to each mold. However, there were some gaps in the information for each mold, highlighting the need for continuous updating of the record as the molds are used.

The molds were then stored in an organized manner on a shelf in warehouse 01, sorted by customer to facilitate identification. When a production order for profiled belts is received, an immediate check of the existence of the required mold is made, ensuring a quick and efficient response to production demands. The flowchart representing this procedure is presented in the image (Figure 42 - Procedure: Molds).

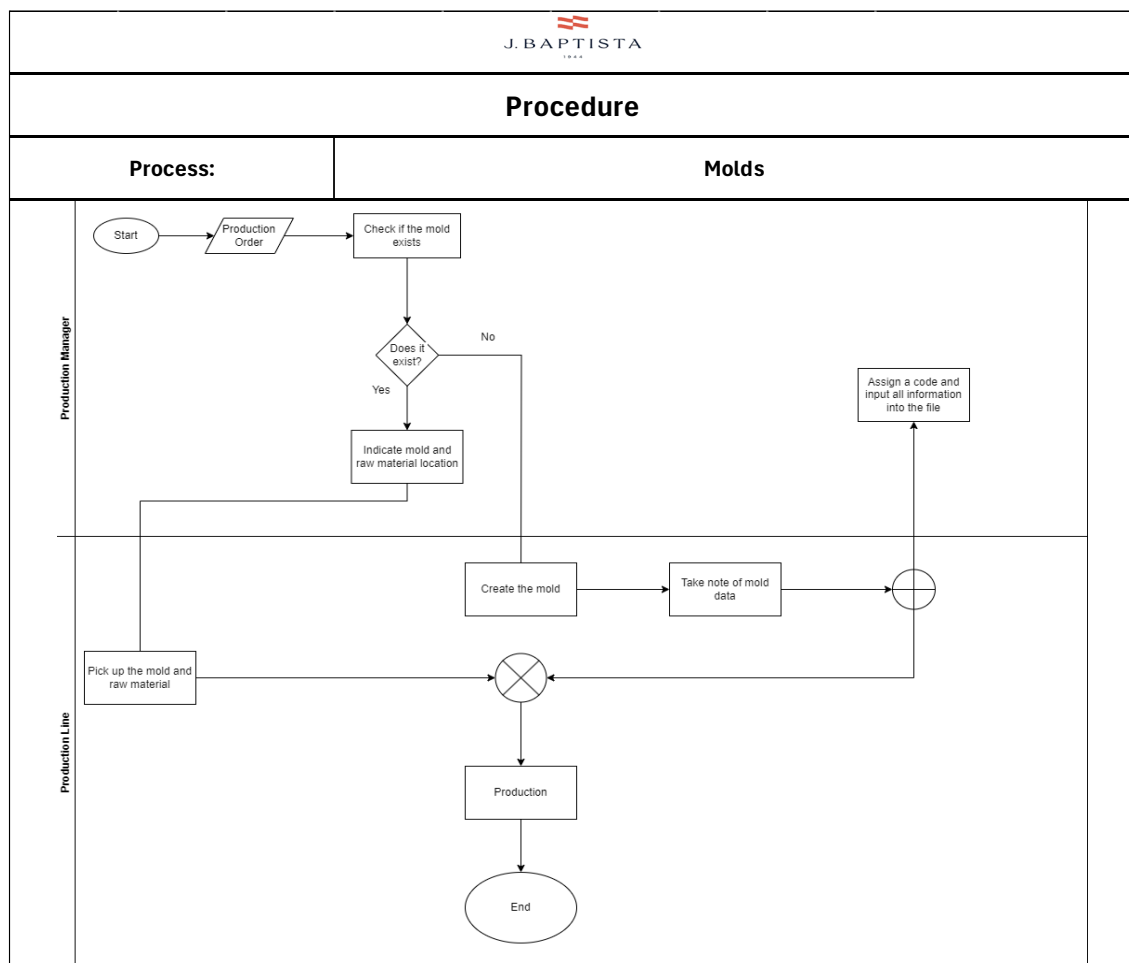


Figure 42 - Procedure: Molds

a competency matrix (Figure 44 - Skills matrix). This tool provides a systematic approach to identify, assess, and develop the skills and knowledge necessary for success in each role within the organization.

This allows for a clear understanding of the skills required for each role within the organization. It helps ensure that employees are assigned tasks and responsibilities that match their skills and experiences, thereby increasing job satisfaction.

Furthermore, it is possible to identify gaps in employees' skills and provide objective criteria for evaluating employee performance and determining which competencies need to be developed for job performance.

The competency matrix is also essential for production planning, as it allows visualization of which tasks operators can perform. Additionally, it enables grouping less experienced operators with more experienced ones into teams, thus developing their abilities.

		Skills Matrix																						
		Splices										Technical Skills												
Operator	Identify Material	Measure	Cut	Dimension Slice	Remove rubber on the splice area	To sand the splice area	Apply glue and connection rubber	Use the press	Cold Vulcanization	Interpret drawings	Make the mold	Cut profiles	Mark profiles	Hole punching profiles	Mark conveyor belt	Hole punching conveyor belt	Screw profiles	Glue profiles	Coat rollers			Repairs	Insulation	
																			Determine necessary material	Apply glue	Coat the roller			
001	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
002	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
003	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	4
004	3	4	3	3	3	3	3	2	3	2	4	4	4	4	4	4	4	4	4	2	4	4	4	4
005	2	3	3	2	3	3	2	2	2	1	1	4	4	4	4	4	4	4	4	1	4	3	3	3
006	1	2	1	0	1	2	0	0	0	1	0	3	2	3	2	2	2	2	2	1	2	1	1	1
007	0	1	1	0	1	1	0	0	0	0	0	1	2	2	2	2	2	1	0	0	1	0	0	0
008	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4
009	1	1	2	1	2	2	0	0	0	0	0	2	2	2	2	2	2	2	0	2	1	0	0	0
010	3	3	3	3	3	3	3	2	2	2	2	3	3	3	3	3	3	3	2	3	3	3	3	3

Figure 44 - Skills matrix

4.4.6. Kanban Board

To mitigate planning and communication issues between departments, a Kanban board was developed. This allows for a graphical visualization of the workflow, clearly showing the status of each order from receipt to completion. This facilitates the identification of bottlenecks and areas that need immediate attention. With a Kanban board, it is possible to set priorities in a visual and intuitive way. Urgent orders can be highlighted and moved to the top of the queue, allowing the team to easily see which tasks need to be expedited. The visual and dynamic nature of Kanban allows for a quick response to changes in customer priorities and urgencies, without losing control over other orders. This is crucial to maintain flexibility in the Just in Time environment. A Kanban board contributes to a more organized and less chaotic work environment. This can reduce employee stress, as everyone knows exactly what to do and when. Implementing Kanban facilitates communication between departments, as everyone has access to the same visual information. This can improve collaboration and alignment among

employees. This board is divided into five stages, which are described in the table (Table 23 - Kanban Board Stages).

Table 23 - Kanban Board Stages

Stage	Description
Backlog	New orders received that have not yet been started. Each card represents an order with the necessary specifications.
Awaiting Materials	Orders waiting for the necessary materials to start production. This ensures that all materials are ready before starting.
Work in Progress	Orders that are currently being manufactured. This helps monitor progress and identify any delays in the production line.
Blocked Work	Orders that are temporarily halted for some reason, such as lack of materials, technical issues, or changes in priorities. This helps quickly identify blockages in the process.
Ready for shipment	Orders that have already been sent to customers. This helps keep a record of all finalized and shipped orders.

Additionally, this board allows for classifying the urgency of orders into four different levels (critical, high, medium, and low) through the colour assigned to the sticker where the order will be recorded (Figure 45 - Urgency level).

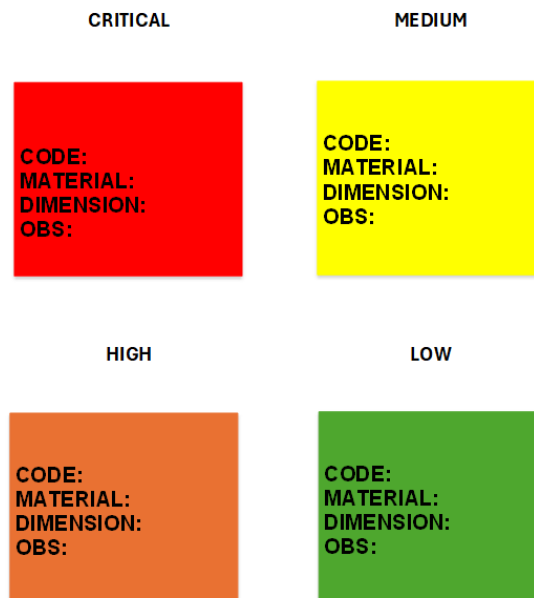


Figure 45 - Urgency level

The commercial department, responsible for receiving customer orders, should classify them according to their degree of urgency and insert them into the Kanban board, in the “Backlog” column. The production manager, after reviewing the orders, should check the availability of the necessary materials. If materials are not available, they should inform the purchasing department to acquire the materials and place the sticker in the "Awaiting Materials" zone. If materials are available, they should plan the production to prioritize the most urgent orders and assign them to operators. If, for any reason, an order is stopped, it should be moved to the "Blocked Work" column. When the product is completed and ready for shipment, it should be moved to the fifth column. The logistics department should then proceed with the shipment and remove the sticker from the board.


 Kanban Board				
Backlog	Waiting Materials	Work in Progress	Stalled Work	Ready for Shipment
<div style="background-color: #f4a460; padding: 5px; margin-bottom: 10px;"> CODE: AA07010210CL004 MATERIAL: EP 400/3 4+2 Y DIMENSION: 800X14000 OBS: </div> <div style="background-color: #66c266; padding: 5px;"> CODE: AA02010010CL008 MATERIAL: TC 40.3 4+2 GM DIMENSION: 600X15500 OBS: </div>	<div style="background-color: #66c266; padding: 5px;"> CODE: AB02060209 SF004 MATERIAL: EP 400/3 4+2 Y DIMENSION: 1000X13000 OBS: </div>	<div style="background-color: #ff0000; padding: 5px;"> CODE: AA02040210CL003 MATERIAL: TC 40.3 3+1.5 GM DIMENSION: 1000X18700 OBS: 148 profiles 125x30 </div>	<div style="background-color: #ffff00; padding: 5px;"> CODE: AC02060210CL004 MATERIAL: EP 400/3 4+2 Y DIMENSION: 500X14000 OBS: </div>	<div style="background-color: #ff0000; padding: 5px;"> CODE: AA07010210CL004 MATERIAL: EP 400/3 4+2 Y DIMENSION: 800X14000 OBS: </div>

Figure 46 - Kanban Board

4.5. Control

The Control phase of DMAIC is crucial to ensure that implemented improvements are sustained in the long term and that processes continue to operate efficiently and effectively. This phase involves the implementation of control and monitoring measures to ensure that the gains achieved during the Improvement phase are maintained and that any deviations from the defined objectives are identified and corrected promptly.

It is essential to maintain regular monitoring of warehouse layout and space utilization to ensure that layout improvements, such as restructuring storage areas and implementing specialized storage solutions, are being maintained and utilized effectively. The 5S system is fundamental for maintaining organization, cleanliness, and standardization in the warehouse. During the Control phase, it is important to conduct regular 5S audits to ensure that established standards are being followed and that any deviations are promptly corrected. Rigorous inventory control is essential to ensure that stock levels are optimized and that materials are stored and managed efficiently.

4.5.1. Kamishibai Board

In this way, a Kamishibai Board was implemented to ensure the sustainability of the improvements made during the Improve phase of DMAIC. This board aims to monitor key areas, including warehouse layout, the 5S system, and inventory control, ensuring that processes continue to operate efficiently and that any deviations are identified and corrected promptly. At the end of each shift, the production manager conducts a brief audit to review the day's objectives and the areas to be audited. The topics to be evaluated are presented in the figure 47. If the task described on the card is found to be completed, a green card is placed; otherwise, it is red. In the figure, the board can be observed. This tool allows for daily monitoring of focus areas, enabling a quick response to problems or deviations, early problem identification, ensuring operational efficiency and effectiveness, and a culture of continuous improvement, with regular adjustments to maintain established standards.



Figure 47 - Kamishibai board tasks

Kamishibai Board									
Monday		Tuesday		Wednesday		Thursday		Friday	
Check if the workspace is clean and free of debris	Check if the unused materials are stored away	Check if the workspace is clean and free of debris	Check if the unused materials are stored away	Check if the workspace is clean and free of debris	Check if the unused materials are stored away	Check if the workspace is clean and free of debris	Check if the unused materials are stored away	Check if the workspace is clean and free of debris	Check if the unused materials are stored away
Ensure that all trash has been deposited into the containers	Verify if all raw materials have been placed in a storage space	Ensure that all trash has been deposited into the containers	Verify if all raw materials have been placed in a storage space	Ensure that all trash has been deposited into the containers	Verify if all raw materials have been placed in a storage space	Ensure that all trash has been deposited into the containers	Verify if all raw materials have been placed in a storage space	Ensure that all trash has been deposited into the containers	Verify if all raw materials have been placed in a storage space
Confirm if the containers are full and need to be emptied	Verify if all locations have been entered into the system	Confirm if the containers are full and need to be emptied	Verify if all locations have been entered into the system	Confirm if the containers are full and need to be emptied	Verify if all locations have been entered into the system	Confirm if the containers are full and need to be emptied	Verify if all locations have been entered into the system	Confirm if the containers are full and need to be emptied	Verify if all locations have been entered into the system

Figure 48 - Kamishibai board

4.5.2. KPI's Analysis

In this phase, it is also important to assess the evolution of the previously defined KPIs to understand if the objectives are being met. For this reason, the VSM of the current state was developed.

It is noted here that the total time to produce a conveyor is 1010 minutes, with the time dedicated to non-value-added activities NVAA being 80 minutes, corresponding to 7.92% of the screen production time. The total distance travelled by operators is now 215 meters.

$$NVAA\ time = \sum CO\ time = 10 + 10 + 15 + 5 + 5 + 10 + 10 + 5 + 5 + 5 = 80\ min$$

$$VAA\ time = \sum CT = 15 + 15 + 60 + 65 + 45 + 120 + 450 + 20 + 30 + 20 + 90 = 930\ min$$

$$Time = CT + CO\ time = 80 + 930 = 1010\ min$$

$$NVAA\ time = \frac{80}{1010} \times 100 = 7,92\%$$

$$Total\ Distance = 60 + 25 + 10 + 20 + 15 + 15 + 20 + 50 = 215\ m$$

Considering that 1 hour of work costs 10 euros, the production of a belt now has a cost of 168.3 euros, of which 13.3 euros represent the labor cost related NVAA.

$$t = \frac{80}{60} = 1,33 \text{ h}$$

$$NVAA \text{ cost} = 10 \times 1,33 = 13,3 \text{ euros/correia}$$

$$t = \frac{1010}{60} = 16,83 \text{ h}$$

$$\text{Total cost} = 16,83 \times 10 = 168,3 \text{ euros}$$

Given the average consumption of 2.5 Liters of diesel per hour for a forklift, with its usage now reduced to 10 minutes, the production of a belt now consumes 0.42 Liters of diesel. As for CO2 emissions, in the production of a conveyor belt, 0.252 kg of CO2 are emitted.

$$\text{Diesel Consumption} = 2,5 \times \frac{10}{60} = 0,42 \text{ liters}$$

$$\text{CO2 Emissions} = 0,42 \times 0,6 = 0,252 \text{ KG de CO2}$$

Taking these new values into account, it is possible to observe through the data presented in the table that the results obtained are positive, both economically and environmentally. The reduction in diesel consumption and carbon dioxide emissions from the forklift movements showed a significant value of 66.4%. Furthermore, the time spent on activities that do not add value to the final product decreased by approximately 46.7%, which implies a reduction in labor costs in the production of a conveyor belt.

Table 24 - KPI's Progress

Metric	Before	After	Progress
Total cost	180 €	168,3 €	- 6,5%
Total time	1080	1010	- 6,5%
NVAA time	150 min	80 min	- 46,7%
NVAA cost	25 €	13,3 €	- 46,8%
Diesel consumption	1,25 l	0,42 l	- 66,4%
CO2 emissions	0,75 Kg de CO2	0,252 kg	- 66,4%
Distance	330 m	215 m	- 34,8%

Furthermore, the reduction in time dedicated to non-value-added activities, as well as the decrease in distance travelled during production, helped alleviate the burden on operators and reduce stress levels. By streamlining processes and optimizing workflows, employees experience less strain and pressure associated with unnecessary tasks or excessive movement. This not only enhances overall well-being and job satisfaction among workers but also fosters a more efficient and productive work environment. Reduced stress levels lead to higher morale, improved concentration, and ultimately better performance in the workplace. Therefore,

beyond the direct economic and environmental benefits, these improvements contribute to creating a healthier and more sustainable work environment for all involved.

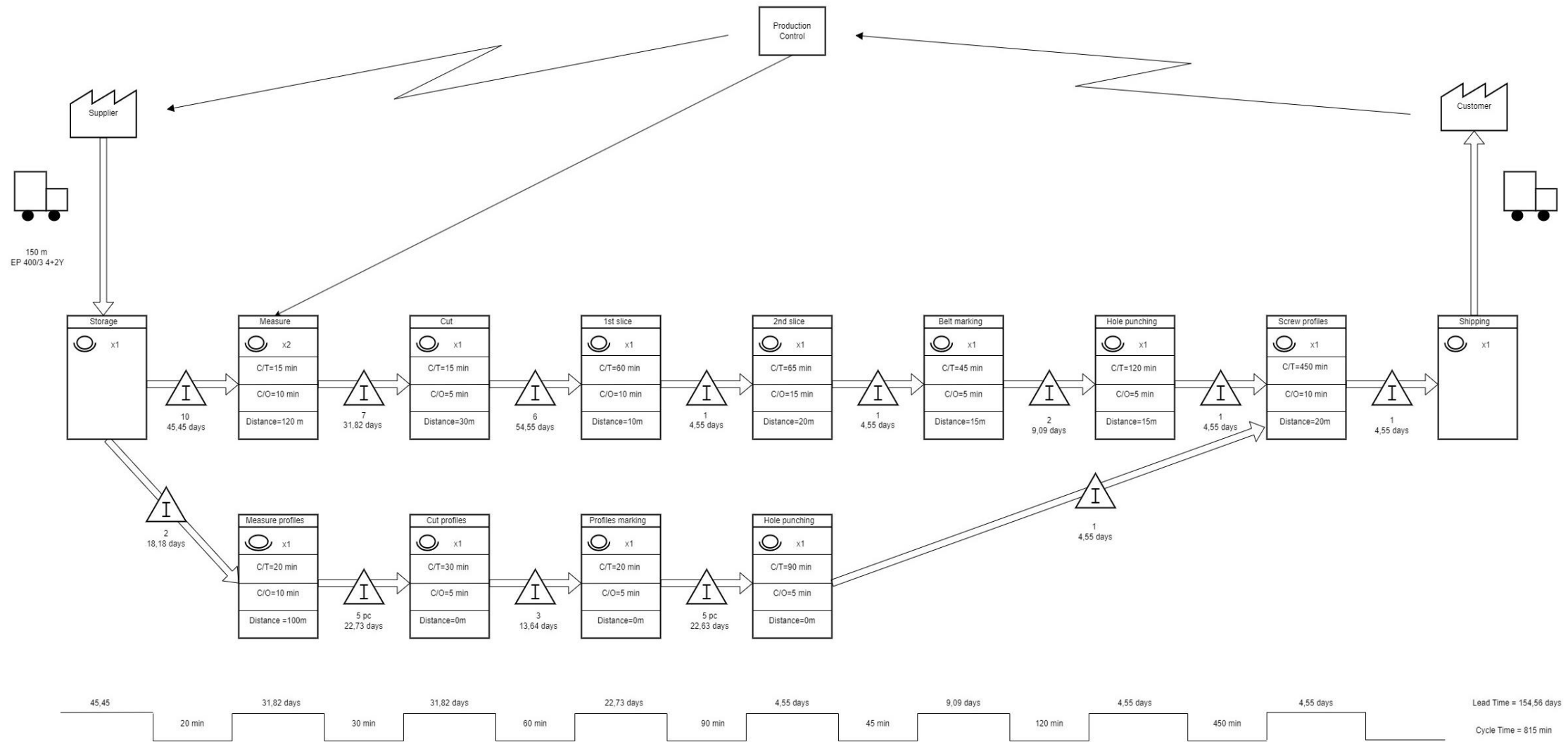


Figure 49 - VSM: current state

4.6. Results Discussion

In this chapter, the outcomes of the implemented strategies and methodologies aimed at enhancing operational efficiency, promoting sustainability, and fostering a culture of continuous improvement within the organization are presented. Through meticulous analysis and comprehensive assessments, we have evaluated the impact of various initiatives across different areas.

The implementation of the 5S methodology has been instrumental in restructuring our workspaces, optimizing resource utilization, and promoting a culture of responsibility and efficiency. Through the phases of Seiri, Seiton, Seiso, Seiketsu, and Shitsuke, we have successfully revamped our organizational practices, leading to streamlined processes, improved safety standards, and reduced waste. By adopting 5S principles in our warehouse management, we have achieved significant improvements in storage efficiency, material handling practices, and employee safety. The strategic use of pallets for storage, implementation of standardized procedures, and introduction of visual management systems have contributed to a more organized and productive warehouse environment. The standardization of equipment lists, implementation of One Point Lessons, and development of Standard Work Combination Sheets have enhanced operational consistency, improved resource allocation, and facilitated employee training and integration. These initiatives have not only streamlined production processes but also contributed to reducing errors and accidents in the workplace.

The introduction of a Kanban board has revolutionized our workflow management, facilitating communication between departments, prioritization of tasks, and quick response to changes in customer demands. This visual management tool has improved overall workflow efficiency, minimized delays, and enhanced collaboration among team members.

Despite the high cycle time to produce belts with profiles, a reduction in the distance travelled throughout the production process has been achieved, as well as a reduction in time spent on non-value-added activities, such as changeover. The metrics evaluated at the Control phase of DMAIC show a significant improvement in several key aspects of operational sustainability after the implementation of strategies and methodologies. The 6.5% reduction in total costs reflects enhanced efficiency in our operations, resulting in significant savings of financial resources. Additionally, the decrease in total production time by 6.5% indicates improved efficiency in the utilization of working time, which may result in reduced energy and human resource consumption.

The dramatic 46.7% reduction in Non-Value-Added Activities (NVAA) time and 46.8% reduction in the cost related to these activities reflect a significant optimization of our processes, minimizing waste of material and financial resources. This not only contributes to the economic sustainability of the organization but also increases efficiency and productivity, freeing up resources for investments in key areas.

The impressive 66.4% reduction in diesel consumption and CO₂ emissions demonstrates a serious commitment to environmental sustainability. This substantial reduction not only helps mitigate our environmental impact but also contributes to the preservation of natural resources and the reduction of the organization's carbon footprint.

Furthermore, the 34.8% decrease in distance travelled during production suggests optimization of workflows and a reduction in the need for resource movement, which may result in further reductions in energy consumption and associated costs.

Overall, these metrics clearly indicate the success of the implemented initiatives in promoting operational sustainability, resulting in tangible benefits for both the organization and the environment.

In this context, the answer to the research question of how the application of lean philosophy can contribute to process improvement and promote sustainability is clear and tangible. By implementing strategies based on lean philosophy, such as applying the DMAIC cycle of Six Sigma, we have achieved concrete results that not only enhance operational efficiency but also promote sustainability on multiple fronts. Comparatively, the literature review revealed that many studies recognize the benefits of lean philosophy in process improvement, particularly in terms of waste reduction, increased efficiency, and resource optimization. However, the distinctiveness of this work lies in the strategic combination of these tools with an explicit focus on sustainability. While existing literature primarily highlights the economic and operational gains of lean, our research goes further by demonstrating substantial environmental outcomes, such as significant reductions in diesel consumption and CO₂ emissions, as well as a notable decrease in distance travelled during production processes.

Furthermore, it integrates traditional and less conventional lean tools to not only improve efficiency and promote environmental sustainability but also enhance social impact and employee well-being. This approach not only fills a gap in existing literature but also provides valuable insights for companies seeking to balance operational excellence with social and environmental responsibility. Thus, the added value of this work is evident in the effective integration of lean practices not only to enhance efficiency but also to achieve robust environmental objectives. This not only validates the effectiveness of lean strategies in industrial contexts but also positions this research as a significant contribution to promoting sustainable practices within the scientific and business community.

5. Conclusion

This chapter aims to present the ultimate conclusions drawn from this dissertation, alongside discussing its limitations, and suggesting avenues for future research.

5.1. Final Conclusions

Considering the main objective of this dissertation, which is to evaluate the impact of Lean philosophy on process improvement and organizational sustainability, it is possible to conclude that this objective has been achieved. Firstly, through a literature review on Lean and Sustainability topics, it was possible to understand the techniques used to address various aspects related to sustainability. In the context of Lean tools, VSM and 5S are frequently employed to tackle sustainability-related issues in organizations, also demonstrating to have the greatest impact. Additionally, it was observed that the DMAIC methodology, when aligned with other Lean strategies and tools, represents a structured approach to deal with process inefficiencies and enhance operational sustainability.

Thus, the DMAIC methodology was applied in the case study of J. Baptista. The implementation of the DMAIC methodology reveals a transformative journey for the conveyor belt production company. By embarking on this structured approach, the company not only addressed immediate operational challenges but also laid a foundation for enduring success and growth. Through the Define phase, the company gained clarity on its internal operations and the imperative for sustainable practices. Key Performance Indicators (KPIs) were established, encompassing economic, social, and environmental dimensions, setting the stage for a comprehensive improvement strategy. In the Measure phase, a deep dive into the company's processes uncovered inefficiencies and areas ripe for improvement. Value Stream Mapping (VSM) and employee questionnaires provided crucial insights into workflow bottlenecks and organizational dynamics, guiding subsequent interventions. The Analyze phase facilitated a granular examination of root causes behind sustainability challenges, paving the way for targeted solutions. The utilization of tools such as Ishikawa diagrams and prioritization matrices enabled the company to pinpoint critical areas for intervention, such as layout optimization and inventory control. In the Improve phase, a series of strategic interventions were implemented, ranging from layout redesign to the standardization of procedures. These initiatives aimed to streamline operations, reduce waste, and foster a culture of continuous improvement, thereby enhancing both efficiency and sustainability. Finally, the Control phase ensured the longevity of improvements through rigorous monitoring and adjustment. The introduction of a Kamishibai Board enabled daily oversight of key focus areas, facilitating prompt responses to deviations and reinforcing a culture of operational excellence. The tangible outcomes show significant reductions in non-value-added activities, fossil fuel consumption, and CO₂ emissions, alongside improvements in production costs and employee workload. These results underscore the transformative potential of Lean philosophy when applied systematically, not only driving operational efficiency but also fostering a culture of sustainability and resilience within organizations. As the conveyor belt production company continues on its journey, it stands

poised to thrive in an ever-evolving business landscape, guided by the principles of Lean thinking and the DMAIC methodology.

Thus, it is concluded that Lean tools, such as SIPOC, VSM, Ishikawa Diagram, 5S, Kanban, among others, play a fundamental role in promoting sustainability in organizations. These Lean tools not only improve the operational efficiency of organizations but also significantly contribute to sustainability by reducing resource waste, minimizing environmental impact, and promoting a culture of social and environmental responsibility. By adopting a Lean approach, companies not only improve their competitiveness in the market but also play a vital role in building a more sustainable future.

5.2. Limitations and Future Work

Although this dissertation has significantly advanced the understanding of the impact of Lean philosophy on process improvement and organizational sustainability, it is important to acknowledge certain limitations that may pave the way for future research and improvements. One limitation of this study is the specific nature of the case study. The results and conclusions obtained may be influenced by unique characteristics of the company, such as its size, sector, and organizational culture. Therefore, generalizing these results to other organizations may require caution and additional analyses.

Another limitation to consider is the limited scope of the Lean tools and strategies addressed in this dissertation. While several common tools, such as DMAIC, VSM, and 5S, have been discussed, there is a wide range of other Lean tools that were not explored. Investigating the impact of these additional tools on organizational sustainability could provide a more comprehensive understanding of how Lean philosophy can be effectively applied.

Moreover, the study may have been influenced by selection and response biases, especially regarding the data collected through employee questionnaires. Employees' perceptions may have been influenced by factors such as past experiences, personal expectations, and the work environment. Therefore, future research may explore alternative data collection methods to obtain a more complete and objective view of the impacts of Lean initiatives.

Another important limitation is the lack of consideration of external variables that may affect the results, such as economic, regulatory, or technological changes. These external factors can significantly influence the effectiveness of Lean initiatives and their sustainability over time. Thus, future research could incorporate sensitivity analyses and scenarios to assess the potential impact of these external variables.

It is also crucial to recognize that the successful implementation of Lean initiatives requires long-term organizational commitment and adequate resources. Resource constraints, such as budget, time, and expertise, can pose significant challenges for many organizations, especially smaller ones. Therefore, future research could explore strategies and approaches to overcome these limitations and promote more effective and sustainable implementation of Lean initiatives.

Additionally, conducting longitudinal studies could observe the long-term effects of Lean initiatives on organizational performance and sustainability, identifying trends and long-term benefits. Comparisons between industries could help understand how specific sector factors

influence the effectiveness of Lean tools and strategies. Investigating the role of organizational culture could examine how different cultural dimensions impact the adoption of Lean. Exploring the synergistic effects of integrating Lean with other process improvement methodologies could provide insights into combined approaches.

Conducting studies on the psychological and motivational impacts of Lean philosophy on employees would help design initiatives that promote a positive work environment. Investigating how digital transformation and emerging technologies can enhance or hinder Lean initiatives could provide a roadmap for integrating Lean with digital strategies. Examining the impact of Lean philosophy on environmental and social sustainability could explore how Lean practices contribute to social responsibility.

Developing and testing customized Lean strategies for specific organizational contexts, such as SMEs and public sector organizations, would reveal insights into necessary adaptations. Conducting comparative studies on the implementation of Lean philosophy in different geographical regions and cultural contexts would help understand the global applicability and regional adaptations of Lean practices.

By addressing these limitations and exploring new research opportunities, we can continue to enhance the understanding and effectiveness of Lean philosophy in promoting efficient, sustainable, and responsible management practices in diverse organizational contexts.

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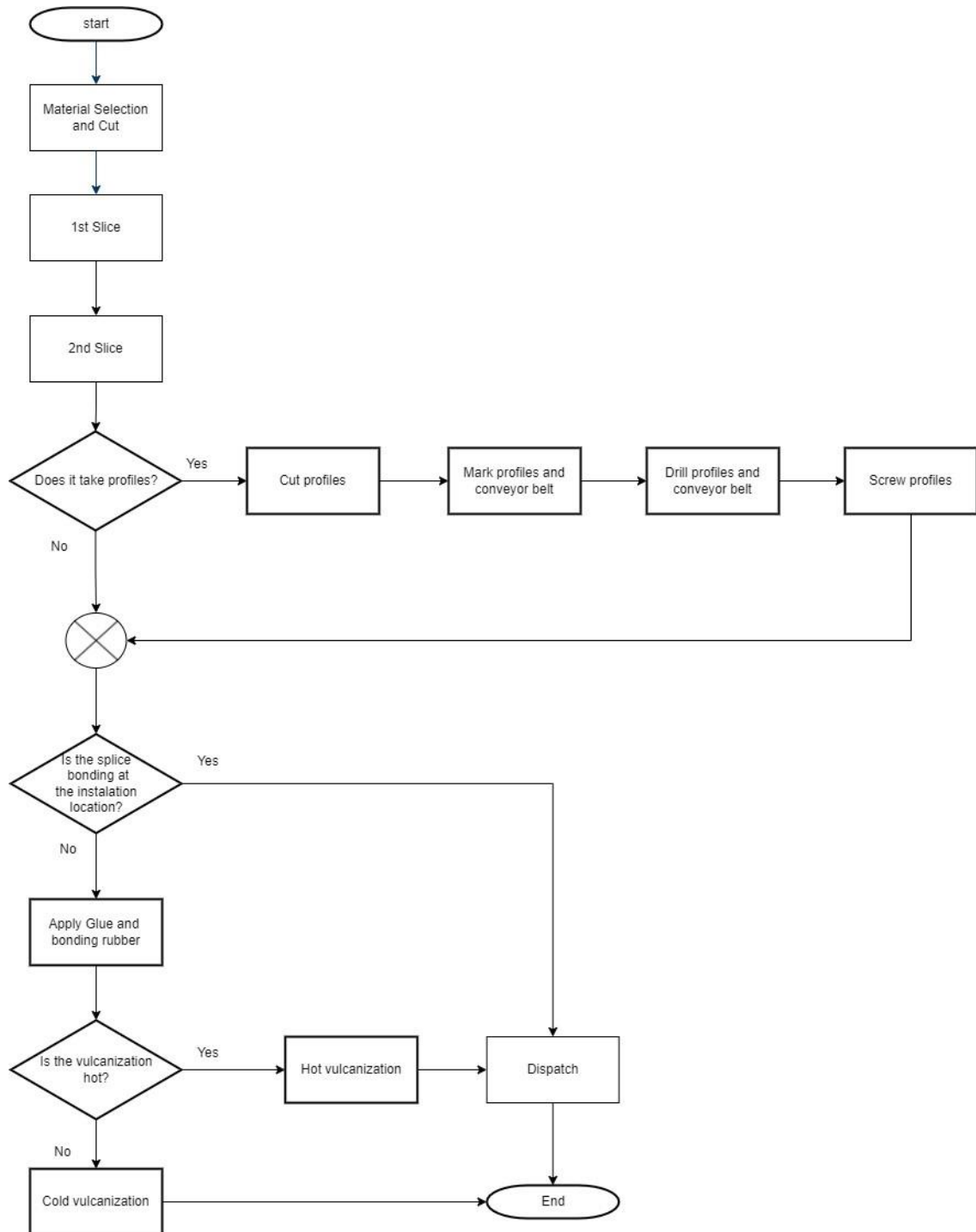
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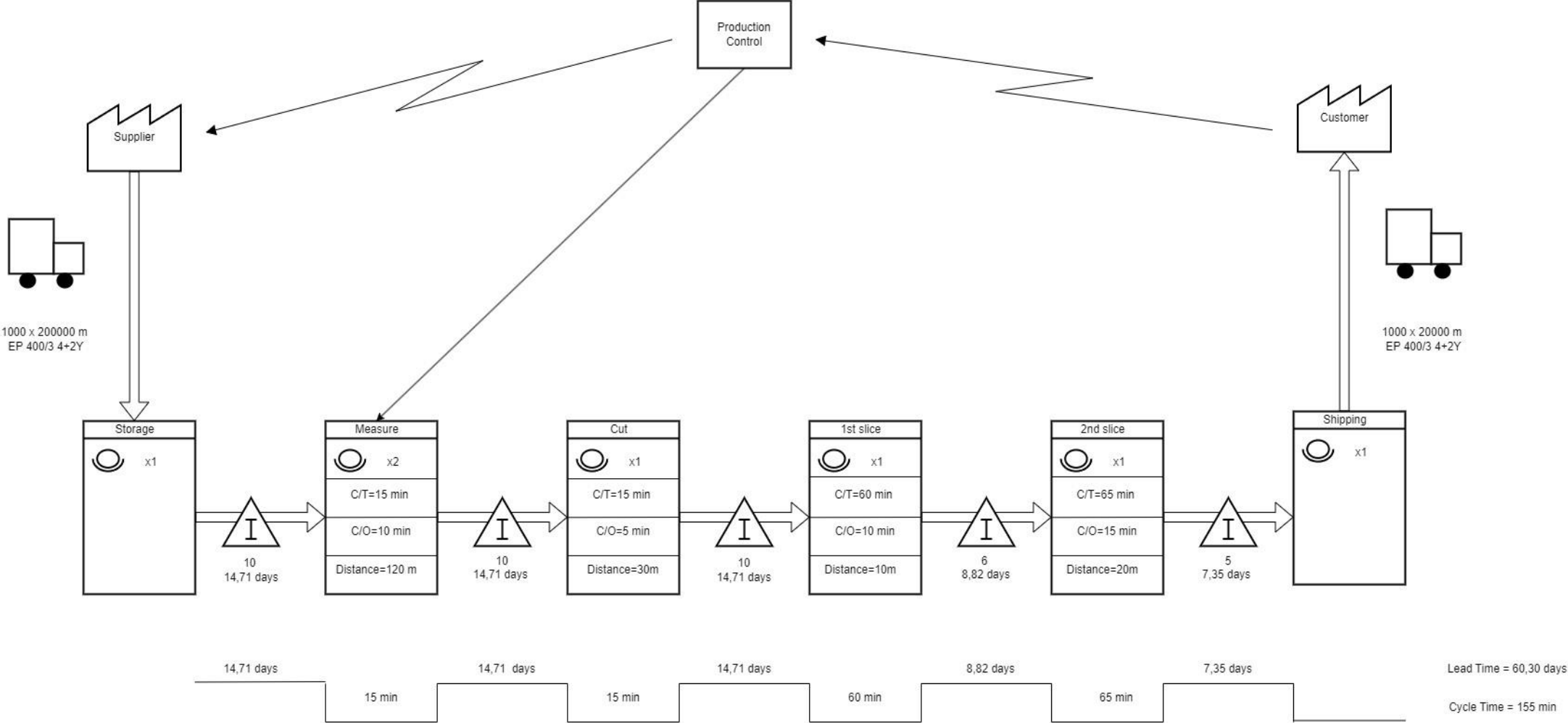
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APPENDIX A – PROCESS FLOWCHART



APPENDIX B – VSM: CONVEYOR BELT WITHOUT PROFILES



APPENDIX C – EMPLOYEE SATISFACTION SURVEY

Employee Satisfaction Survey

* Obrigatória

1. In which department do you work? *

- Production
- Finance
- Sales
- Purchase
- Logistics
- Other

2. What are your academic qualification? *

- Higher Education
- Upper secondary education
- Elementary school
- Middle school
- High school
- Secondary

3. How long have you been working at the company? *

- Less than 1 year
- 1 to 5 years
- 5 to 10 years
- 10 to 20 years
- More than 20 years

4. Overall, what is your level of satisfaction with your current employer? *

- Extremamaly dissatisfied
- Somewhat dissatisfied
- Neitheir satisfied or dissatisfied
- Somewhat satisfied
- Extremaly satisfied

5. How do you rate the level of stress in your workplace? *

- Very high
- high
- Moderate
- Low
- Very Low

6. How often do you feel included in the company's activities and decisions? *

- Never
- Rarely
- Sometimes
- Very often
- Always

7. How do you evaluate the internal communication in the company in terms of keeping you informed about activities and decisions? *

- Very poor
- poor
- Acceptable
- Good
- Excellent

8. What is the impact of communication on your well-being and performance? *

- Very negative
- Negative
- No impact
- Positive
- Very positive

9. What is the impact of work organization, including layout, raw material arrangement, and equipment identification on your well-being and performance? *

- Very negative
- Negative
- No impact
- Positive
- Very positive

10. How do you rate the opportunities to acquire and develop new skills in the company? *





- Very Rare
- Rare
- Moderate
- Frequent
- Very frequent





11. Observation





Este conteúdo não foi criado nem é aprovado pela Microsoft. Os dados que submeter serão enviados para o proprietário do formulário.



APPENDIX D – WORKSTATION EQUIPMENT LIST

 Workstation Equipment List (Splices)				
001	X-Acto Knife			
002	Pincers			
003	Knife			

<p>004</p>	<p>Gripper</p>			
<p>005</p>	<p>Sander</p>			
<p>006</p>	<p>Cutting Machine</p>			
<p>007</p>	<p>Measuring Tape</p>			

 Workstation Equipment List (Profile Preparation)			
001	Punch		
002	Hammer		
003	Cutting Machine		

 Workstation Equipment List (Vulcanization)		
001	Hammer	
002	Paint Brush	
003	Roller	
004	Press	

APPENDIX E – SKILLS MATRIX

Skills Matrix																						
Operator	Technical Skills																					
	Splices						Vulcanization			Conveyor belt w/profiles								Coat rollers			Repairs	Installation
	Identify Material	Measure	Cut	Dimension Slice	Remove rubber on the splice area	To sand the splice area	Apply glue and connection rubber	Use the press	Cold Vulcanization	Interpret drawings	Make the mold	Cut profiles	Mark profiles	Hole punching profiles	Mark conveyor belt	Hole punching conveyor belt	Screw profiles	Glue profiles	Determine necessary material	Apply glue		
0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2
001	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
002	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
003	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0
004	3	4	3	3	3	3	3	2	3	2	2	4	4	4	4	4	4	4	2	4	4	4
005	2	3	3	2	3	3	2	2	2	1	1	4	4	4	4	4	4	4	1	4	3	3
006	1	2	1	0	1	2	0	0	0	1	0	3	2	3	2	2	2	2	1	2	1	1
007	0	1	1	0	1	1	0	0	0	0	0	1	2	2	2	2	2	1	0	1	0	0
008	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4
009	1	1	2	1	2	2	0	0	0	0	0	2	2	2	2	2	2	2	0	2	1	0
010	3	3	3	3	3	3	3	2	2	2	2	3	3	3	3	3	3	2	3	3	3	3

