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Process redesign using design for six sigma - the case of inbound logistics at a pulp and paper manufacturer.

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Master in management of services and technology

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Prof. Teresa Sofia Grilo, Assistant Professor,
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Resumo

A metodologia *Design for Six Sigma* (DFSS) é uma abordagem focada na construção de qualidade nos processos, centrando-se na identificação das necessidades dos envolvidos e na incorporação de características que considerem essas necessidades na conceção do processo. O DFSS segue a estrutura *Define, Measure*, *Analyze*, *Design*, and *Verify* (DMADV).

Este estudo foi conduzido no Departamento de Logística da empresa de papel "*The Navigator Company*" que enfrentou o desafio de redesenhar o processo de entrega de guias de transporte entre a equipa e as matas onde se encontravam os camiões de transporte.

O processo existente revelou ineficiências, com a comunicação e partilha de informações a serem realizadas de forma manual e sujeitas a erros. O redesenho desse processo era fundamental para melhorar a eficiência e minimizar possíveis falhas na logística.

Primeiramente, as necessidades e desafios específicos da equipa de logística foram identificados, o que incluiu entrevistas, mapeamento de processos e a priorização das necessidades através de entrevistas estruturadas. De seguida, utilizando a metodologia, as necessidades mais críticas foram identificadas, orientando o design do novo processo.

A solução proposta envolveu a criação de um sistema eletrónico de comunicação e partilha de informações, permitindo atender às necessidades identificadas de forma mais eficaz. Este novo processo de comunicação e gestão de guias de transporte melhorou a eficiência operacional e reduziu os erros associados à comunicação manual.

O estudo exemplifica como a metodologia DFSS pode ser aplicada com sucesso na melhoria de processos logísticos, garantindo uma comunicação eficiente e reduzindo potenciais falhas.

Palavras-chave: Logística; Logística de aprovisionamento; comunicação; DFSS; *Action Research*.

Códigos de classificação JEL: L91; M11

Abstract

The Design for Six Sigma (DFSS) methodology is an approach focused on building quality into processes, focusing on identifying the needs of those involved and incorporating features that take those needs into account when designing the process. DFSS follows the Define, Measure, Analyze, Design, and Verify (DMADV) framework.

This study was conducted in the Logistics Department of the paper company "The Navigator Company," which faced the challenge of redesigning the process of delivering transport notes between the team and the forests where the transport trucks were located.

The existing process revealed inefficiencies, with communication and information sharing being carried out manually and subject to errors. Redesigning this process was essential in order to improve efficiency and minimize potential logistics failures.

First, the specific needs and challenges of the logistics team were identified, which included interviews, process mapping and the prioritization of needs through structured interviews. Then, using the methodology, the most critical needs were identified, guiding the design of the new process.

The proposed solution involved creating an electronic system for communicating and sharing information, enabling the needs identified to be met more effectively. This new process for communicating and managing waybills improved operational efficiency and reduced the errors associated with manual communication.

The study exemplifies how the DFSS methodology can be successfully applied to improving logistics processes, ensuring efficient communication, and reducing potential failures.

Key words: Logistics; Inbound logistics; communication; DFSS; Action Research.

JEL Classification: L91; M11

INDEX

Figure index

Table index

List of abbreviations

BPR – Business process reengineering

CTQ – Critical to quality

DFSS – Design for Six Sigma

DMADV - Define, Measure, Analyze, Design, Verify

ICT - Information and communication technologies

SIPOC - Suppliers, Inputs, Process, Outputs, Customer

TQM – Total quality management

VOC - Voice of the customer

1. Introduction

1.1 Background and Context

Logistics and transportation play a crucial role in the efficient movement of goods and services. The integration of logistics and transportation systems is essential for businesses to meet customer demands and achieve competitive advantage (Modica et al., 2021). Logistics management involves a series of integrated activities, including information processing, freight transport, material handling, inventory storage, and sharing information with supply chain members involved in moving products (Khan et al., 2019). Transportation, as a component of logistics, is identified as an essential component that contributes to the overall efficiency of logistics operations (Zhenjing et al., 2022).

The transportation sector is broad and includes multiple areas such, planning, implementing and storage of raw materials, inventory, transport of finished goods and the information through the supply chain, as it is stated by Kasilingam, R. G. (1998), the major requirements of the transport industry are cost and transit time reduction, on-time delivery, lower variability of transit time, availability of seamless transportation service through a combination of modes, minimum delay, damage and loss reduction and the availability of other options such as storage, pick-up and delivery, adding to that, a strong legal and regulatory frame is also imposed in this sector.

The company's problematic is related to the area of inbound logistics, more specifically related to the waybills process used for the transportation of wood between the forests and the factory. All the factors named above translate into challenges faced by the company and will be addressed in this thesis with the ultimate goal of reducing the occurrence of errors throughout the process and simplifying it. These errors not only lead to delays and disruptions but also jeopardize the process's overall dependability and efficiency. The thesis' main objective will be to address this issue by identifying the sources of errors and explore practical solutions to reduce their frequency.

1.2 Problem statement

The company is seeking a new approach to streamline the creation and distribution of waybills to truck drivers in Portugal. Presently, a third-party individual is subcontracted by the company (guide handler) to retrieve the waybill and hand it to the driver at remote forest locations where internet access is often unavailable. The company thus aims to develop a more efficient solution that simplifies and reduces errors in the process, and also reduces bureaucracy and waiting times, while simultaneously improving supply chain visibility and real-time monitoring. And all this, while also considering cost concerns. Additionally, since inbound logistics at the Navigator Company is 100% subcontracted, the new solution to be proposed should be easily implemented and standardized across all subcontracted companies to ensure seamless integration into their operations.

The objective previously addressed requires identifying the constraints and challenges associated with the current process and conducting an analysis to explore potential solutions. The goal is to propose a well-suited redesign of the current process, complete with specific recommendations on how and where to implement the new approach.

1.3 Research question

Within this setting, the research question addressed in this project can be stated as follows: How to redesign the current process employed by The Navigator Company for the formulation and delivery of the waybills to the wood truck drivers in the Portuguese territory, so as to make it more efficient and easier to track?

To answer this research question, several partial objectives should be pursued:

What is the current process?

What problems exist with current process?

What needs need to be fulfilled when redesigned the process?

What solutions exist for this problem?

Evaluation and selection of the most suitable solution.

1.4 Project structure

The framework of this research project is divided into five chapters:

- First, the main topic of the research project and its aims, as well as the scope of the research and its methods, are discussed.
- Second, a Literature Review is presented to support the research proposal discussion.
- Third, a Methodology in which the research project's course is detailed, including the phases and tools utilized to collect and analyze data.
- Following the methods outlined, the Case Study is described below. This depicts the effort done at the logistics Department to create and execute a process redesign.
- Finally, a chapter will describe the conclusions and limitations of the research project.

2. Literature review

Keeping in mind the overall goal of this project, which is primarily focused on the design of a logistics process for a transportation process, various design approaches, such as, design thinking, design for six sigma, total quality management (TQM), and business process reengineering (BPR), are addressed. Examples regarding this topic will be presented throughout the chapter. After the address of this design approaches is concluded a further approach to Design for Six Sigma is made as it is the methodology.

2.1 Logistics, Inbound Logistics and Communication

Logistics can be defined as the management of the storage and transport of goods through the supply chain, being the transportation one of the main characteristics of the logistics as it is established by Kearney (2004), which estimates that transport presents approximately 40% of all logistics costs. Also, as it is stated by Kasilingam (1998), the major requirements of the transport industry are cost and transit time reduction, on-time delivery, lower variability of transit time, availability of seamless transportation service through a combination of modes, minimum delay, damage and loss and the availability of other options such as storage, pick-up and delivery and so on. Transport logistics is not only a reason for the flow of goods it is part of integrated logistics. It is a part of adding value, which is included in strategic management and decisions through transport logistics (Topolsek, et al., 2018). This enhances the importance of a consistent and reliable inbound logistics process.

In a legal frame regarding waybills, as it is in, decreto-Lei n.º 147/2003 de 11 de julho, it's a mandatory document when in the transport of any type of material. All goods in circulation in national territory, whatever their nature or type, which are the subject of operations carried out by persons liable for value added tax must be accompanied by documents of transportation processed under the terms of this diploma.

Communication plays a crucial role in the logistics and inbound logistics processes, particularly in the transportation of goods and the management of waybills. Effective communication ensures that information flows smoothly between different stakeholders, such as suppliers, manufacturers, and truck drivers, enabling them to coordinate their activities and make informed decisions (Winch, 2003). In the context of inbound logistics, communication is essential for coordinating the transportation of goods from suppliers to manufacturers. It involves the exchange of information regarding shipment schedules, delivery instructions, and any potential issues or delays that may arise during transit (Winch, 2003).

According to Micieta et al., (2019) whenever there is a disruption to the material flow, there is a high chance that financial losses might occur. One of the main tasks is to strive for a consistent material flow that creates more reliable delivery and greater value for customers, teams of employees and all stakeholders.

With this in mind, the following project as to account that whatever the results come to be, the material flow, in other words the process, can never be endangered otherwise the value provided for the stakeholders will be negatively affected. A disruption in the transport of wood would impact the value chain and so, for a consistent and reliable it´s also important to understand what has been done before and in what molds regarding the redesign of a process and in particular in the transport logistic area. The design process is a series of actions and a set of rules that create a defined beginning point and guide the designer from imagining a product or service to actually realizing it in a methodical way.

2.2 Redesign approaches

The design process is a series of actions and a set of rules that create a defined beginning point and guide the designer from imagining a product or service to actually realizing it in a methodical way (Haik and Shahin, 2011).

To ensure the best redesign approach is chosen the next chapter will do an observation over the various models and choose the most appropriate. Each redesign method will have an introduction regarding its specifications, it will also be presented more than one example and if possible related to logistics or transportation and at the end of each subchapter an overview paragraph of the pros and cons of the approach.

2.2.1 Total Quality Management

After the design, system improvement and control process trends spread in Japan, according to Magdalena (2022) the western world developed its own system of quality management, which was widely adopted and consisted in the continuous process of detecting and eliminating manufacturing errors in supply chain as well as to prepare employes, the TQM (total quality management), that falls under the umbrella of lean process thinking.

According to Hamad (2016) TQM refers to building a culture of quality in which every stakeholder of the organization seeks to improve customer experience and service provided, for that reason Brun (2011) believes that TQM needs a full integration process that involves all departments of an organization including finance, human resources, and manufacturing, working together to meet customers' needs and to achieve the organizational goals.

Powell (1995) recommended the use of Total Quality Management (TQM) as a competitive advantage in transportation systems in his work. This approach provides a thorough examination of TQM principles and practices, emphasizing the main stages required to gain a competitive advantage through TQM implementation. Powell's research describes TQM methodology phases, which include a number of critical steps:

Phase 1: Leadership Commitment

- TQM principles and practices must be strongly supported by top management.
- Goals and objectives for process reform must be clearly defined.
- All staff must adhere to the TQM principle.

Phase 2: Customer-Focused Approach

- Customer needs and expectations, including truck drivers, must be identified.
- Customizing redesign efforts to fit client needs and increase satisfaction.

Phase 3: Continuous Improvement Practices

- Using tools and techniques like process mapping, statistical process control, and employee participation.
- Identification and removal of waste, reduction of variability, and enhancement of transportation efficiency and effectiveness.

Phase 4: Supplier Partnerships

- Collaboration with suppliers to ensure timely delivery.
- Improvements and quality in transportation through supplier collaboration.

Phase 5: Measurement and Evaluation of Performance

- Use of key performance indicators (KPIs) for monitoring and Regular measurement and evaluation.

One study that refers to an application of TQM in the transportation sector is the work of Anca (2015) that presents a TQM implementation case study at British Airways. British Airways adopted Total Quality Management in September 1988 as a result of the technical workshops in an effort to advance and contribute to the organization's success. For that purpose, it was identified key steps for the implementation first they had to conduct a diagnose within technical workshops, then obtaining support from all levels, educating staff for TQM requirements, changes in policies, starting the TQM improvement process and finally reviewing the process. The strategy used by the company to gather quality costs was the breakdown of employee's activities related to quality in three main activities, 1 - "Anticipation - activities that provide performance right first time"; 2 - "Assessment -activities that check if the concept of right first time is done"; 3 - "Failure - activities resulting from the failure of the concept right first time".

A survey of the workers as well as an assessment of the team leaders regarding their staff was done, the data collected was introduced to a diagnostic report and seven improvement activities identified, "1. The way the employees view the company's management; 2. Managerial style; 3. Implementation of changes; 4. Communication; 5. Systems and procedures; 6. Facilities and conditions; 7. Attitude of employees.". After this a set of courses were held for managers into adopting TQM philosophy as well as to employees and a set of projects were conducted for improvement.

In conclusion, TQM can be a valuable methodology for redesigning processes, such as the logistic process of transporting goods and improving communication with all parties. However, it is important to consider the potential limitations and challenges associated with TQM, such as the risk of stifling innovation and the need for strong commitment from management and employees (Mosadeghrad 2014).

2.2.2 Business Process Reengineering

The business (BPR) processes reengineering aims to maximize the efficiency and effectiveness of a company through the use of information and communication technologies to promote new radical organizational structures and processes as stated by David (2000). Or as said by Hammer and Champy (1993), BPR is the fundamental rethinking and the radical redesign of business processes to create drastic improvements in performance. Still the BPR is a general term that can be implemented in different ways.

In the work developed by David (2000) the implementation was made in three phases. Understanding the process by identifying stakeholders, analyzing perspectives, observing the process and understanding goals. Then the radical process redesign phase by developing business visions, radical thinking and reengineering proposals. And lastly the implementation phase by specify new process designs and information and communication technologies (ICT) in detail, implement new structures and continuous evaluation.

In the work of Moço (2018), a development of BPR for application in a logistics company, that aimed to turn Corporate Center's processes more efficient, less costly and as streamlined as possible, through process reengineering. An eight-step process was elaborated, starting with business vision and process reengineering objectives then identifying and selecting processes to be redesigned by focusing on processes that required immediate innovation and a radical approach. The third step "Process AS- IS – understand and measure it" where the process to be worked with must be understood and measured so it's not repeated and to serve as a baseline for future improvements.

The fourth point was to opportunities to change and IT (information technologies) levers, followed by a "Process TO-BE – define the solutions" where the process solution is created through a series of workshops, brainstorming sessions, and other facilitation techniques that encourage participation from all group members in accordance with the guidelines and change possibilities identified in the previous step. Followed by decisions regarding in-house development and work or an outsourced IT solution.

The last two steps regard the development of a case for each of the solutions where benefits are measured, and t an implementation plan is developed and the final step is the implementation.

There is a shortage of current cases for a BPR approach in the transportation area, hence the most appropriate reference for summarizing a paper that employs BPR as a redesign methodology in the transportation area is (Guimaraes & Paranjape, 2013). The purpose of this study, "Testing success factors for manufacturing BPR project phases," is to discover success characteristics for various stages of BPR projects in the manufacturing business. Although the article does not expressly reference transportation, the principles and approaches mentioned can be applied to the transportation sector.

Guimaraes and Paranjape (2013) conducted a detailed analysis of BPR projects in the manufacturing industry in this study to discover success criteria for various project phases. The authors utilized a mixed-methods approach, combining a review of the literature with empirical study. They gathered information from 50 BPR initiatives in manufacturing firms and examined the characteristics that led to the success.

This study's approach included three major phases: planning, execution, and evaluation. The authors did a literature review during the planning phase to identify potential success factors for each project phase. They then created and circulated a questionnaire based on these characteristics to the participants.

During the execution phase, the authors evaluated the questionnaire data to find the success criteria most commonly reported by participants. They also interviewed project managers and team members to acquire a better understanding of the elements that influenced the success of each phase.

During the evaluation phase, the authors validated their findings by comparing the discovered success variables to the available literature. They also carried out statistical analysis to assess the importance of each aspect in determining the success of BPR programs. The study's findings identified various success criteria for each project phase.

When compared to other redesign methodologies, BPR can have associated issues and constraints. Its radical nature is one of the primary issues. BPR seeks to totally redesign and alter existing processes, which frequently results in considerable changes in organizational structure, technology, and job responsibilities (Grover & Malhotra, 1997). Employees may object to this technique because it is disruptive (Zellner, 2011). Furthermore, the time and resources necessary to execute BPR can be significant, making it an expensive venture (Grover & Malhotra, 1997).

2.2.3 Design Thinking

According to Martin (2009) Design Thinking (DT) consists of shaping a context rather than taking it as it is. Taking it as it is, in other words, the concept deals mainly with what does not yet exist. Within this analysis, Brown (2009) proposes that DT is an approach that uses designer's sensitivity and methods to solve problems and meet people's needs with viable and commercially feasible technology. In other words, DT is user-centered innovation, which requires collaboration, interaction and practical approaches to find the best ideas and final solutions.

It's a method that focuses on the work of a heterogeneous team to establish empathy and proximity with users through the use of action-oriented prototyping solutions. This design strategy improves contact with all stakeholders involved and only innovates after passing through various pre-defined processes such as ideation, prototyping, and testing (Altman et al., 2018).

In the work of Sanchéz et al., (2022), a design thinking approach was used to implement condition monitoring system on paper press bearings. For that a six steps approach was elaborated. Empathize; Define; Ideate; Prototype; Test and Implement.

In the first phase meetings with different teams were taken and immersion in the problem by visiting the production process, reviewing the maintenance histories, measurements, interviews with maintenance and IT department and meetings with work teams. For the second step, it was used focus groups and in-depth interviews with the maintenance manager, maintenance planner, lubricator, and IT department staff for problem definition. In this the problem was defined, “The need for a system that allows detecting early failures in press bearings and satisfies the requirements indicated in the results of the empathy stage”.

The third phase, based on data collected, was to create a brainstorming workshop with multiple teams. Followed by the prototype and test were the developed prototypes had to be approved, commissioned and tested in the industry. By last the implementation phase, divided in seven steps so it could be smoothly understood and fully implemented.

Regarding an application of design thinking in transportation area, the work of Villarreal et al., (2016), "Lean Road transportation – a systematic method for the improvement of road transport operations", the methodology used in this case study involves several phases.

First, the authors perform a thorough examination of present road transport operations, identifying inefficiencies, bottlenecks, and places for improvement. This study is critical for identifying current difficulties and laying the groundwork for the redesign process.

Next, the authors apply design thinking principles to generate innovative solutions. Design thinking is a human-centered approach to understanding user needs and preferences. Empathizing with users, describing the problem, brainstorming potential solutions, prototyping, and testing is all part of the process.

In the case study, applied design thinking to develop a set of improvement initiatives for road transport operations. These initiatives included optimizing routes, improving vehicle utilization, enhancing communication and coordination among stakeholders, and implementing performance measurement systems.

The authors also emphasize the importance of involving different stakeholders in the design process. By engaging truck drivers, logistics managers, and other relevant parties, a more comprehensive and effective solution can be developed. This collaborative approach ensures that the redesigned processes align with the needs and expectations of all stakeholders.

Design Thinking has limitations when it comes to rethinking a logistics process. One potential constraint of Design Thinking in this context is its emphasis on empathy and user-centered design. Understanding the needs and experiences of visitors and other stakeholders is vital, but it can lead to a limited concentration on individual viewpoints and ignoring larger systemic challenges (Katzenstein & Lerch, 2000).

Redesigning a logistics process necessitates taking into account not just the needs of individual users but also the overall efficiency, cost-effectiveness, and system coordination (Katzenstein & Lerch, 2000). In addition, Design Thinking frequently entails iterative and experimental approaches, which may not be appropriate for rethinking a logistical process that necessitates precision and conformity to established standards (Gross et al., 2021). Logistics processes require complicated workflows, rules, and multi-stakeholder cooperation, and any changes must be properly planned and implemented to avoid disruptions and ensure smooth operations (Gross et al., 2021). Furthermore, Stewart (2011) suggests that Design Thinking may favor creativity and innovation over practicality and viability.

2.2.4 Design for Six Sigma

Six sigma, a trend that started in the 1980´s first with Motorola and gaining recognition when adopted by GE, that according to Silitonga (2022) as resulted in immense contributions, especially at financial level for companies that adopted it. The six sigma is divided into two big different kinds of implementation the (DMAIC) Define, Measure, Analyze, Improve, Control that has more virtues regarding quality improvement and the DMADV for a more profound action seeking a redesign of the process.

The appropriate way to select which one of the two kinds to use is as stated by Yang et al., (2022) if it´s an existing product/process then the six sigma (DMAIC) is the most appropriated, if its either a non-existing process/product or it's an existing one but just an improvement to it is not enough, then as Design For Six Sigma (DFSS) DMADV is the one to choose.

Cardoso (2022) in her work regarding improvement of communication in an oncology department of a hospital used a fundamental action research approach together with a DFSS – DMADV methodology. To do this, in an initial phase a project charter and a project plan were developed in which details related to project scope, team members roles and project guidelines were provided and also a SIPOC diagram which illustrates the key elements of the process. In the following phase there was data collection with resource to interviews and affinity diagrams to analyses the data; action plan is elaborated, getting client feedback to categorize the needs and development of metrics to measure the design process; creating and putting into practice concepts to address the main needs based on the use of a prioritization matrix; finally verify the redesign process.

DFSS (Design for Six Sigma) is a methodology used for redesigning processes in various industries, including transportation (Mitchell & Kovach, 2016).

Now it will be addressed a logistics/transportation related work in the scope of DFSS, as in the work of Mitchell et al., (2015) a study employing Design for Six Sigma (DFSS) methodology to improve communication and information sharing within a marine transportation supply chain organization. The project addresses the issues of efficiently and successfully delivering essential supply chain information through the development and implementation of a new slate distribution procedure utilizing SharePoint technology.

It is initially stated that in today's global business world, the bigger necessity of supply chain management and information sharing. It emphasizes the importance of synchronizing supply chain tasks and employing technology to facilitate successful communication.

For the case study it was used a DMADV approach, just as it will be used in this thesis project. For the define phase the project goals, including the problem statement (problems with the present slate distribution method) and mission statement (enhancing communication within supply chain operations), are defined. In the second phase, measure, interviews are used to identify user needs, which are then translated into interpreted needs statements. The needs are classified and ranked according to their importance. For the analyze phase metrics are created based on the needs of the highest-rated user needs. To discover opportunities for improvement, baseline metrics for the existing slate distribution procedure are collected. Lastly for the design and verify phases design concepts are produced to meet the needs of consumers while also addressing process restrictions. To build design profiles, brainstorming and benchmarking sessions are held. The new slate distribution procedure is tested and implemented on a small basis. Verification metrics are gathered to assess the process's efficacy in meeting user’s needs.

Overall, by using the DFSS the new slate distribution procedure significantly promotes communication and information sharing within the company. It minimizes confusion, streamlines operations, and improves usability for supply chain stakeholders.

Because it provides a structured and methodical way to ensure that the revised process fulfils the desired objectives and customer needs, the DFSS can be useful for process redesign (Holcomb, 2003). Mitchell and Kovach (2016) found that the DMADV technique is particularly well suited to redesigning service processes. However, the same authors state that there are certain disadvantages to employing DFSS - DMADV for process redesign. One shortcoming of the DFSS technique is that there is no standard framework that guides its implementation, which can lead to variations in its application (Mitchell & Kovach, 2016). Furthermore, the

DMADV technique may necessitate significant time and resources to adopt, which can be difficult for firms with low resources or time constraints (Holcomb, 2003).

2.2.5 Comparing alternative redesign approaches

Since the aim of this project is to rethink the logistics and communication methods currently used in the company, a process that must be redesigned in a more efficient way and that serves multiple intervenient, looking back at the goods and bads of each redesign approaches it can be considered that the DFSS is the most appropriate. In comparison to other approaches such as BPR that presents itself as being too radical and disruptive (Zellner, 2011), something that the company is not looking for even considering a total redesign, it rather seeks something in the same molds as the previous one or when compared to both, design thinking - good to solve more complex problems and innovate in areas where user experience and empathy are crucial (Gross et al., 2021), or TQM - used for continuous improvement and a focus on incremental enhancements (Mosadeghrad, 2014). Considering this DFSS is the methodology that better feats the company's expectation and goals.

Although there are some potential disadvantages to using DFSS, such as the various variations of technique and the need for additional time and money to implement a solution, it is thought to be more appropriate to the company's problem and goals when compared to alternative approaches, such as, that DFSS is extremely versatile and has had multiple uses in different areas and industries, from supply chain information sharing (Mitchell et al., 2015) to new housing design concepts (Johnson et al., 2006), from animal care and use programs (Okpe and Kovach, 2017), construction (Lee et al., 2020) to additive manufacturing (Liverani et al., 2019).

2.3. Design for Six Sigma

Design for Six Sigma (DFSS) is an approach for designing and developing new processes, products, and services with a focus on quality and customer satisfaction. DMADV (Define, Measure, Analyze, Design, Verify) and DMAIC (Define, Measure, Analize, Improve, Control) are two forms of DFSS techniques. These techniques offer systematic approaches to issue solving and process improvement, but they range in the order of phases and the emphasis they place on them.

DMADV takes a methodical approach, beginning with defining project goals and customer requirements, then measuring current process performance, analyzing data to identify redesign opportunities, designing and developing the new process, and finally verifying the new process's performance. This methodology emphasizes an extensive understanding of the goals and requirements of the client, as well as a data-driven approach to process optimization (Radziwill, 2017).

DMAIC, on the other hand, uses a sequential method but focuses more on optimization, without compromising the redesign goal. It begins with establishing the project goals and customer needs, then moves on to designing and building the new process, optimizing the process to attain the targeted performance levels, and ultimately validating the optimized process's performance. This methodology is concerned with developing and applying the most effective design solutions in order to accomplish the intended results (Chakrabarty & Tan, 2007).

As stated, there are multiple applications of DFSS including in services as is the case of animal care and use programs (Okpe & Kovach, 2017) or supply chain information sharing (Mitchell et al., 2015) and in healthcare (Cardoso, 2022). Okpe & Kovach (2017) in their work to improve the services provided by animal care and use programs also used an action research/DFSS-DMADV approach methodology. Initially using SIPOC diagram which illustrates the key elements of the process and to understand the process as whole; interviews and surveys were held on to collect data and to identify the users' needs; matrixes to prioritize the needs and understand the ones the users considered to be more important; metrics for design evaluation and affinity diagrams; creating and putting into practice concepts to address the main needs; finally verify the redesign process.

2.3.1 Design for Six Sigma: Applications in logistics

A collaborative working approach was designed in one case study to optimize logistics operations using DMADV (Carvalho et al., 2016). The first phase, Define, involved determining the logistics system's primary objectives and requirements. Understanding client needs, such as on-time delivery and inventory management, was part of this. The second phase, Measure, entailed gathering information on current performance measures such delivery lead time and order correctness. This information was utilized to create a baseline and identify areas for improvement.

The third phase, Analyze, dealt with determining the root causes of problems and bottlenecks in the logistics process. This included data analysis, process mapping, and the use of techniques such as value stream mapping to identify waste and inefficiencies. Potential solutions were identified based on the analysis.

The fourth phase, Design, entailed creating and implementing solutions to the identified problems. This could entail revamping the warehouse layout, introducing new inventory management technologies, or improving transportation routes. In a controlled environment, the solutions were tested and validated.

The fifth phase, Verify, involved assessing the efficacy of the deployed options for resolution. The impact of the improvements on logistics performance was assessed using key performance indicators (KPIs). This stage also included gathering input from consumers and stakeholders to ensure that the changes fulfilled their expectations.

DMADV was employed in another study to improve the performance of an extrusion process in the logistics industry (Aggogeri et al., 2009). During the Define phase, the critical-to-quality aspects of the process, such as product dimensions and surface finish, were identified. During the Measure phase, data on current process performance was collected and a capacity analysis was performed to determine the process capability. The Analyze phase concentrated on determining the root causes of process problems and variances. This required identifying the elements contributing to the variances using statistical tools such as cause-and-effect diagrams, pareto analysis, and hypothesis testing. Potential solutions were created based on the analysis.

The solutions were turned into specific process adjustments and enhancements throughout the Design phase. This may entail revamping the equipment, changing process parameters, or installing new control mechanisms. In a controlled environment, the adjustments were applied and tested. The Verify phase required assessing the efficacy of the implemented solutions. The Verify phase required assessing the efficacy of the implemented solutions.

2.4 Conclusion

This chapter confirms that several different redesign approaches, such as Design Thinking, TQM, Business Process Reengineering, and Design for Six Sigma have been used in previous studies, with DFSS representing the one that better fits the purposes of this project given that the goal is to redesign a process rather than simply improve it and that the type of configuration required by the company is better full field by the DFSS - DMADV methodology.

3. Methodology

3.1. Action Research

The project will follow an action research methodology. The contact with people from organization is fundamental to the work to be developed, in action research, data come from engagement with participants during action cycles (Coghlan and Brannick, 2014) and so observations made during action cycles collect data and simultaneously generate learning for researchers and participants. Lessons in this section use analysis of data collected in formal settings, focus groups, storyboarding workshops and individual consultations as stated by (Balthu and Clegg, 2021) in which the quality of relationship between members of the system and researchers is paramount (Coughlan and Coghlan, 2016). So, the developed work in the organization has to be teamwork, where the researcher and the human resources of the company make an effort to reach a common goal (Shani et al., 2008). It is fundamental to recognize that action research is focused on change (Slack and Lewis, 2015).

3.2. Design for Six Sigma - DMADV

The DFSS (methodology, specifically the DMADV (Define, Measure, Analyze, Design, Verify) process, is chosen as the approach for the redesign process in this thesis. DFSS is a management strategy that focuses on improving the quality of products and processes by reducing defects and variability (Alexander, 2001). DMADV is a structured approach within DFSS that is used for the development of new products or processes when the existing ones are unable to achieve the desired business objectives (Aboelmaged, 2011).

DFSS - DMADV as was stated before is chosen over other methodologies such as TQM, BPR, and design thinking for several reasons. TQM focuses on continuous improvement and customer satisfaction, but it may not provide a structured approach for new products or process development like DMADV does (Sahoo, 2018). BPR, on the other hand, is a radical redesign of core business processes, but it may not be suitable for the specific redesign needs of the company in this thesis (Kwadade-Cudjoe, 2021). Design thinking is a human-centered approach that emphasizes empathy and creativity, but it may lack the statistical and analytical rigor provided by DFSS - DMADV (Piller, 2022).

DFSS - DMADV methodology has been widely recognized and applied in various industries, including manufacturing and service organizations (Aboelmaged, 2011). It provides a structured and data-driven approach to process redesign, ensuring that the redesigned process meets customer requirements and achieves business objectives (Radziwill, 2017). By following the DMADV process, organizations can systematically identify and address process inefficiencies, leading to improved quality, efficiency, and customer satisfaction.

The figure 3.1 shows the sequence of the five phases of the DMADV methodology, following that each of the phases is briefly presented and explained.

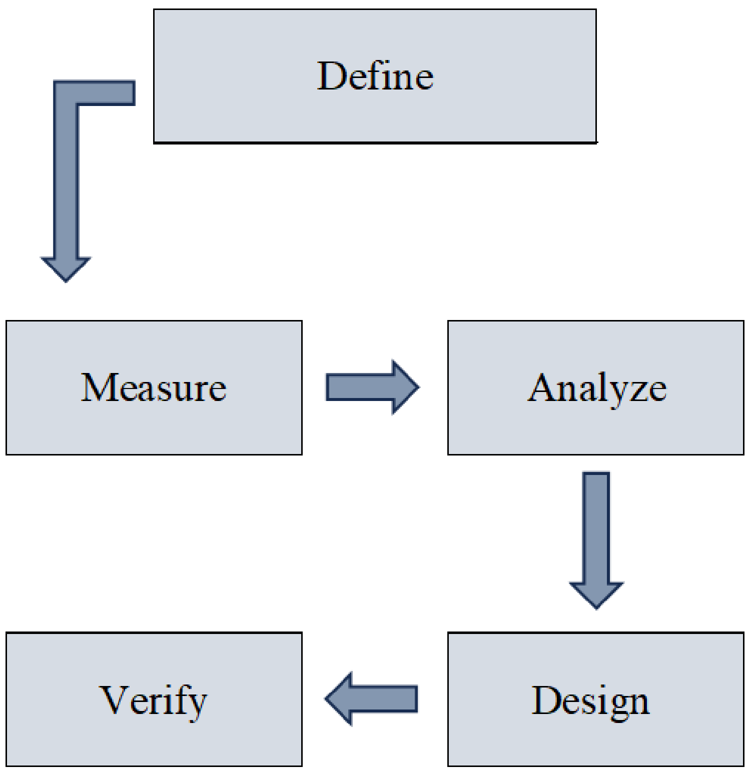


Figure 3.1 - DMADV Phases

Define

For the first phase it is fundamental to assemble a team, creating a project charter and developing a project plan. The team must first of all create the charter to outline the project requirements and opportunity for improvements. The charter must include a scope for the project as well as a team members role (Okpe et al., 2017). In order to capture the essential of the project, the team must document the process through the use of a suppliers, inputs, process, outputs, and customers (SIPOC) diagram, that illustrates the main elements and maps the flow of goods, information and actives, and to better document the flow of the process by a step-by-step representation of it, a swim-lane diagram is used (Okpe et al., 2017).

Measure

In the measure phase the goal is to develop a data collection plan, measure it to identify customer needs and compare data to determine issues (Kwak et al., 2006) During the measure phase, the "voice of the customer" is integrated into the design process by obtaining data on consumer requirements translate it to define those needs into clear need statements (Okpe et al., 2017).

To collect data needed for the project interviews with the members of the process, in this case the logistic team members, drivers and guide handlers so, parts of different stages of the process were held with the following questions. Q1: “What is your job and what functions do you have?”; Q2: “What difficulties do you face in your day-to-day activities/in the process?”; Q3: “What are the positive aspects of the process?”; Q4: “Given your experience, how could this process be improved?” so the critical to quality (CTQ) characteristics can be identified from those needs. Afterwards the needs previously identified in the interviews were organized into aggregated needs to simplify and minimize the long list of needs, in an affinity diagram. Next a needs prioritization survey is made where the main intervenient categorizes which ones are the most and least important of those needs, this is important so that when developing a solution, it´s easier to know what the points of importance are (Okpe & Kovach, 2017).

An Ishikawa diagram (fishbone diagram) was also used, in this case the goal was to reach the root causes of the main fundamental disruptions identified on the case. After the identification of the respective root causes for the disruption of the process, another prioritization survey was elaborated and where the intervenient of the process are asked to rank them in a 1 to 5 Linkert scale.

Analyze

At the analyze phase the data collected previously is analyzed and the action plan is elaborated (Hahn et al., 2000) The work done here focuses on gathering client feedback to rank the identified needs, translated in CTQs, and those with the highest priority are used to steer the remaining redesign project. The project team produced metrics in this phase to measure the design process and advise what should be done to carry out a specific demand based on the survey results from the previous phase (Okpe and Kovach, 2017). Regarding the Ishikawa diagram ranking results, it follows the same method as the CTQ, after the feedback is received, a set of metrics are elaborated to measure the process and based on the survey results from the previous phase, advise on what should be done to carry out a specific demand.

Design

The Design phase consists of developing and implementing concepts to satisfy the primary needs identified in the Analyze phase, with the primary goal of designing and implementing the new design. Brainstorming meetings with the head of department were first held to create design ideas. It is vital to highlight that every proposal is considered valid independent of the factors, no evaluation of ideas is intended at this point. Only after developing several ideas, it´s required to examine them in order to determine which alternative best satisfies the process.

After deciding on a set of ideas, a more rigorous evaluation must be done, for that a triple evaluation was designed. First by doing a comparison on how the different ideas fulfil the CTQs of the process, then a prioritization matrix evaluating the ideas with the root causes of disruption of the process and last a prioritization matrix with multiple criteria evaluation, with criteria not considered yet in the other evaluations.

Verify

For the chosen redesign option in the previous section, an implementation map and a set of guidelines are proposed in the verify section.

The table 3.1 shows in a simple way the tools used in each of the methodology phases.

Table 3.1 - Methodology Tools

Phase	Tool	Carachteristics
Define	Sipoc	Identify target proces
	Swim lane	visualize the process
Measure	Surveys	Identify needs
	Brainstorm	Gather ideas
	Ishikawa diagram	Root analyzis
	Affinity diagram	Group needs into categories
Analyze	Prioritization of metrics	Evaluate metrics
Design	Prioritization matrix	Evaluate ideas
	Solution comparison points	Compare solutions
Verify	----------------------	----------------------

4. Case Study

The main goal of this chapter is to answer the research questions introduced in Chapter 1. To start, a brief introduction of the organization and department where this research was conducted is given in subchapter 4.1. In subchapter 4.2 the details of how the DFSS methodology, as presented in Chapter 3, was applied are described.

4.1 Organizational Context

As a leading force in the international pulp and paper market, the Navigator Company is one of Portugal's strongest brands on the world stage. Its production structure is based on four major industrial sites in Cacia, Figueira da Foz, Vila Velha de Ródão and Setúbal, the company's supply of wood is prevenient from Portugal and Spain (Iberian market) as well as Africa and South America.

4.2 Research steps

4.2.1 Define phase

The project began by identifying the problem and defining the project guidelines, the team, and expected results. As described before, the dependency on paper waybills and inherent problems related to the process and surrounding environment leads to inefficiencies. The focus of the project is to redesign the system in a way that the dependency on paper waybills is eliminated and that can be simplified reducing bureaucracies and inefficiencies. The project team included the head of the department as well as the main intervenient of the process. The project plan consisted of the following steps:

- Map the internal process to be redesign.
- Interview the head of the department, logistic team members, truck drivers and Guide handlers.
- Interpret and organize the needs obtained from interviews.
- Identify the top-rated needs.

- Develop metrics to address the top-rated needs.
- Interpret and organize inefficiencies from interviews.
- Identify the top-rated inefficiencies through a survey.
- Develop metrics to address the top-rated inefficiencies.
- Establish baseline measurements for each metric.
- Conduct brainstorming and feedback sessions.
- Fully develop the final design of the new communication process.

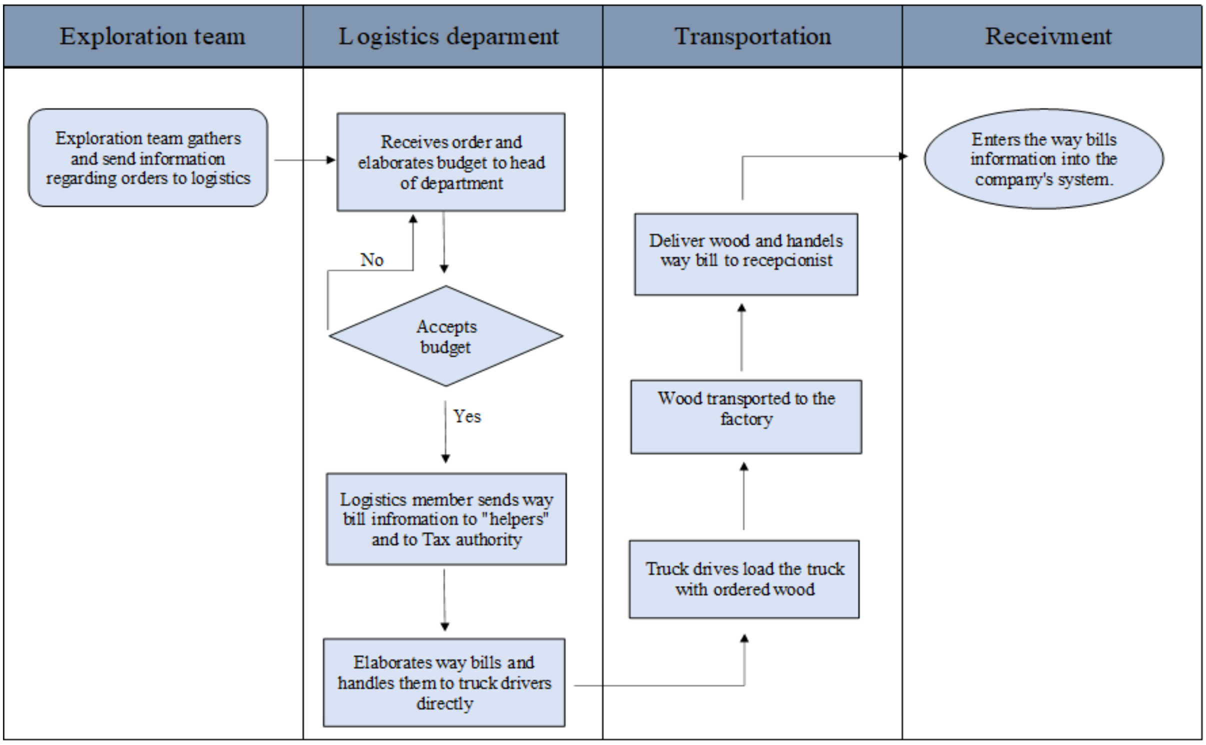
To develop a better understanding of the current process being used at the company a first meeting was taken with the head of the department, the shared information led to the creation of a supplier, inputs, process, outputs, and customers (SIPOC) diagram. This diagram shows who is involved (suppliers and customers), what is involved (inputs and outputs), and how the process functions (the process itself) and is also useful to define the boundaries and scope of the process. As it can be seen the process starts with the logistic team receiving the information regarding the order from the forest exploration department, followed by the budget calculation related to the transport and communication of the budget to the head of the process, after this one of the logistics team members passes the necessary information to elaborate the waybill, with that information the guide handlers create the waybill and delivers it to the truck driver at the wood site. With this the drivers load the wood in the truck and take it to the factory where they load the wood and give the waybill to the receptionist that enters the information in the company systems. The table 4.1 shows the suppliers, inputs, process, outputs, customers (SIPOC) diagram, a visual tool for documenting a business process from beginning to end prior to implementation.

Table 4.2 - SIPOC

SUPPLIERS	INPUTS	PROCESS	OUTPUTS	CUSTOMERS
Exploration department team	Information required from the exploration department	Logistics team receives information regarding the order from the woods exploration department	Paper-based shipment guides prepared by the "guide handlers."	Tax Authority, which receives information from the shipment guides for tax and legal purposes
Logistics team member	Information required for the preparation of shipment guides	Prepare a budget related to the transport of wood and communicate it to the head of department	Legal transportation of the wood carried out by the transportation company.	Company/factory that receives the wood for treatment.
Truck drivers/transportation company	Information required and given to the tax Authority	Logistics team member gives the necessary information to prepare the way bills.	Wood delivered to the factory for treatment.	
Guide handlers		"Guide handlers" draft the way bills on paper based on the provided information.		
		"Guide handlers" deliver the way bills to the truck drivers at the wood loading locations.		
		Truck drivers load the wood onto the trucks and receive the way bills for legal transportation.		
		Truck drivers transport the wood to the factory.		
		Truck drivers deliver the way bills to the receptionist at the factory.		
		Receptionist enters the way bills information into the company's system.		

For a more consistent and detailed view of the process as presented before in the SIPOC diagram, a Swim-Lane charter was developed, the information was obtained through meetings with the head of department and the analysis of the documented process in the company's internal documented processes. The swim lane can be very useful because it provides a clear and structured way to visualize and understand processes, making it easier to identify areas for enhancement and streamlining. The table 4.2 presents the Swim-Lane flowchart of the process.

Table 4.1 - Swim-Lane



4.2.2 Measure phase

Now entering the measure phase, a set of interviews were conducted with the multiple intervenient of the process, this are the logistics team, drivers and guide handlers with the objective of getting to know the experience of the people in every phase of the project. The interviews were hold online and followed the same structure for everyone, all the questions were with open answer about: 1) What´s your name and what job do you have?; 2) What difficulties do you encounter in your day-to-day work and in the process?; 3) What positive points do you find in the process?: 4) What improvements would you like to see implemented in the process?. During interviews, special care was taken to record comments word by word. Finally, the interviewees' imprecise language used to explain their wants was converted into more clear statements representing functional aspects or features for the redesign project. In the table 4.3 it is presented an example of an interview and the needs detected from there.

Table 4.3 - Interview

Entrevistas			
Entrevistados	Perguntas:	Resposta:	Necesidades identificadas
Joel - Técnico de logística	Que dificuldades encontra no trabalho do dia-a-dia e no processo?	"O processo por vezes toma-se mais muroso, mas existe essa necessidade, e por conta da existencia de alguns problemas como a dificuldade de acesso as matas por parte dos motoristas e da quase inexistencia de rede nesses locais precisamos de um ajudante, que nos ajude a nós e aos motoristas (...) por vezes existem erros no preenchimento das guias porque a informação sai de nos mas passa por várias pessoas".	A necessidade de contratar passa guias.
			Ajuda para navegação dentro das matas.
			De resolução de erros em guias que passem despercebidos.
			De comunicação com as mata.
	Pontos positivos do processo	"Tendo em conta que as guias são preenchidas manualmente, na existência de erros, há facilidade de alteração e correção de erros (…) por vezes os passa guias pode auxiliar na correção de erros".	A existencia de um passa guias pode facilitar na retificação de erro bem como ajudar motoristas
	Que melhorias propõe	"Acredito que está na altura de avançar para a parte tecnológica".	Atualizar e informatizar o processo

During these interviews a padrone was detected, a difficulty in communication between the different members of the team and the need to do it in a more effective way many of them originated by human errors of many kinds and other disruptions.

From these interviews and through communication with the team it was possible to understand that the process was having some inefficiencies that was negatively affecting the performance of the team and the process so, to better understand the causes of those inefficiencies two Ishikawa diagrams were created to reach the root causes of two topics, human error, and general inefficiencies, as presented below.

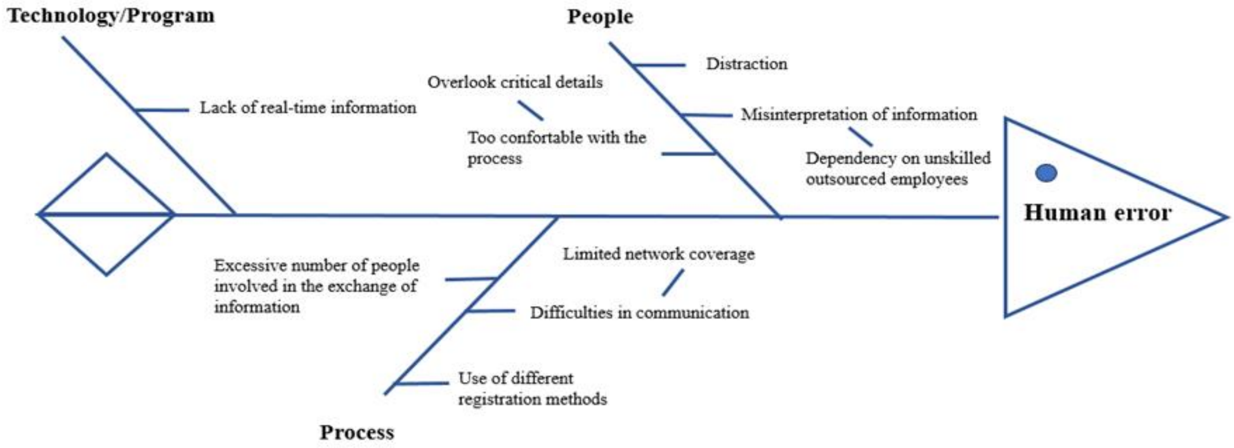


Figure 4.1 - Ishikawa diagram for Human Error

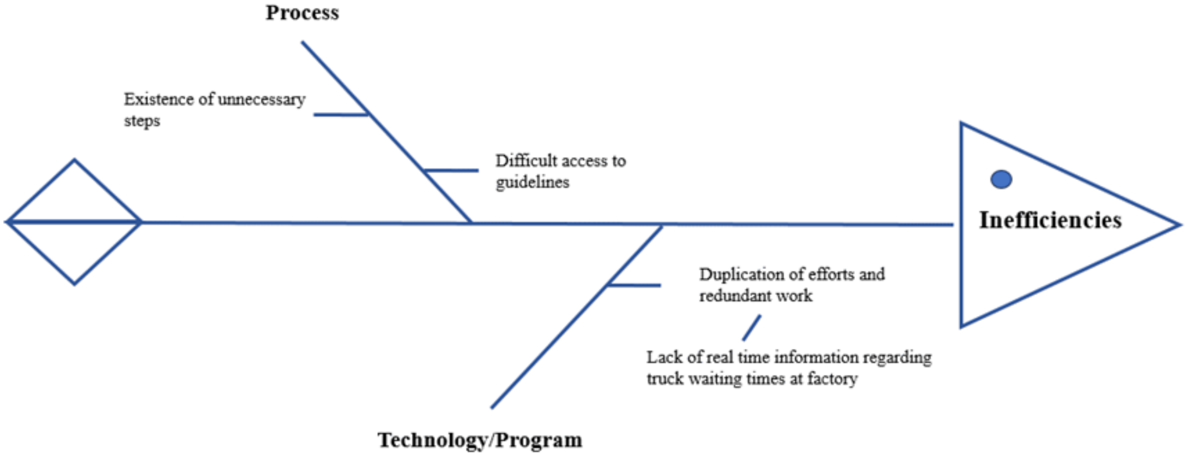


Figure 4.2 - Ishikawa diagram for General Inefficiencies

All the other needs detected from interviews is organized into groups with common themes using an affinity diagram, as shown in table 4.4, the groups that emerged are a total of 6 that were given names reflecting the needs they represent.

Table 4.4 - Affinity Diagram

Informatization	**reliance on subcontractors**	**Dificulties in accessing the woodlands**	**Maintain subcintractors to assist in certain situations**	**Network conections**
Moving towards technology.	Reduce the human error when filling in the forms.	Access to the forests is sometimes quite complicated...	The existence of guideposts facilitates communication with truck drivers and helps to guide them through the forests.	Remote woodlands with difficult access and network
Adoption of devices to aid the process	The need to sub-contract someone to help us pass the guides on to the drivers.	Remote forest areas that are difficult to access	Keep them beacause they help with navigation in the woods.	Access to the woods is sometimes quite
Real-time information system	The need to sub-contract someone to help us pass the guides on to the drivers.	**Simplify and debureaucratize**	Resolving errors in guides that go unnoticed.	Sometimes it's difficult to cover the entire area where
End the use of archaic registration methods		Reduction of human errors	Proveide help with difficult access to the forests.	
Computerization of some stages of the process		Reduce steps in the process		
		Reducing stakeholders in the process		

Given the complexity of changing a process to properly meet a large number of requirements, it was selected the needs considered to be the most relevant to the redesign project based on the understanding of the department, the process, and the number of times they have been mentioned in the interviews. From that selection a total of 11 needs were chosen and the those needs were translated into CTQs (Critical to Quality), following that, a table was created to further prioritize these 11 CTQs. As stated in figure 4.3 the CTQ were prioritized based on knowledge of the process and the feedback gotten with the interviews with the team and meetings done with the head of the department.

Rating of how relevant each of the following CTQs are for the process as it is currently.

1. Need describes an irrelevant feature to be consider.
2. Need describes an unimportant feature to be consider.
3. Need describes a relevant feature to be consider.
4. Need describes a very important feature to be consider.
5. Need describes a fundamental feature to be consider.

Rating		CTQ
-	1.	Get information in real time.
-	2.	Information sharing between all stakeholders in the process.
-	3.	Stop the use of "guide books" to fill the waybills.
-	4.	Use of technological equipment in steps of process
-	5.	Lower number of tasks performed by guide handlers.
-	6.	Lower the land coverage done by guide handlers.
-	7.	Creating a place with secure access to the network.
-	8.	Use of subcontractors for tasks such as location recognition and drivers assistance.
-	9.	Lower amount human errors
-	10.	Less steps in the process
-	11.	Lower number stakeholders in the process

Figure 4.3 - CTQ evaluation

As the Ishikawa diagram have also been made considering the root causes it was decided that a prioritization of those same root causes would be helpful to better understand and identify what was perceived as the main and so to be taken in consideration when redesign the process. As it is shown in the next figures 4.4 and 4.5, a table similar to the one seen before was elaborated regarding the most impactful disruption causes, one of them related to human error disruptions and the other one regarding multiple inefficiencies in the process.

Rating of how relevant each of the following disruption root causes related to human error are for the process as it is currently.

1. Cause describes an irrelevant feature to be consider.
2. Cause describes an unimportant feature to be consider.
3. Cause describes a relevant feature to be consider.
4. Cause describes a very important feature to be consider.
5. Cause describes a fundamental feature to be consider.

Rating	Cause	
_____	1.	Lack of real-time information sharing between the different parties in the process.
_____	2.	Ignoring critical details
_____	3.	Distraction
_____	4.	Limited and inaccessible network coverage.
_____	5.	Use of different registration methods.
_____	6.	Excessive number of people involved in the exchange of information.
_____	7.	Incorrect interpretation of information

Figure 4.4 - Root causes of Human Error evaluation

Rating of how relevant each of the following disruption root causes related to general inefficiencies are for the process as it is currently.

1. Cause describes an irrelevant feature to be consider.
2. Cause describes an unimportant feature to be consider.
3. Cause describes a relevant feature to be consider.
4. Cause describes a very important feature to be consider.
5. Cause describes a fundamental feature to be consider.

Rating	Cause	
_____	1.	Existence of unnecessary steps in the process.
_____	2.	Difficulty of access to process guidelines by stakeholders.
_____	3.	Lack of real-time information on truck waiting times at the factory.

Figure 4.5 - Root causes of Inefficiencies evaluation

4.2.3 Analyze phase

The work in this phase of the project focused on identifying the most essential metrics to explain more clearly how the redesigned process should perform. In the table 4.5 it can be seen the rating each of the CTQs and root causes got according to the understanding of the process and understanding of what the team seeks to get throughout the interviews held.

Table 4.5 - Metrics rating

CTQ	Rating	Root cause Human error	Rating	Root cause inefficiencie	Rating
1	5	1	4	1	3
2	3	2	3	2	2
3	3	3	2	3	4
4	4	4	5		
5	4	5	3		
6	3	6	3		
7	3	7	4		
8	3				
9	4				
10	4				
11	4				

The results were as shown above in table 4.5, the CTQ with highest ranking (1, 4, 5, 9, 10 and 11), the causes of human error (1, 4 and 7) and the root cause of general inefficiency (3) will have a higher wight at the time of evaluating the impact of the solutions.

Given all the data gotten from the interviews it's also possible to do a 3rd analysis considering other criteria not mentioned yet, adding to the CTQ and root causes analysis.

For this 3rd analysis a set of metrics were selected. M1: "Effort required from the transport company"; M2: "Difficulty of implementation"; M3: "Time of training"; M4: "Added effort/time to the overall process" and M5: "IT investment". The goal of this analysis is not only to do a better and more complete general analysis but also to have in consideration the impact each of the proposals would have on the subcontracted transport company considering that they also must accept it. This metrics will also be analyzed regarding a ponderation previously selected.

4.2.4 Design phase

This phase is divided in two sub-phases, first the developed solutions will be presented and after that a set of evaluations as mentioned before will be done.

To develop ideas for how to address the problem, which is the redesign of a process with the main goal of changing the way the waybills are transported and delivered to the bus driver, a section of brainstorming was held with the head of department were three possible solutions were settled:

- Solution number 1 (S1): The driver fills the waybill electronically in the forest with information the guide handler provides in person and prints it in the local.

- Solution number 2 (S2): The driver gets the information to fill the waybill directly, in the forest, from the logistics team using satellite technology and prints it in the local.

- Solution number 3 (S3): The driver gets the information to fill the waybill directly from the logistics team in a designated place outside the forest from conventional network and prints it in the local.

The table 4.6 shows the three possible solutions with an overview of the specifications of each of them.

Table 4.6 - Solutions comparison

Solutions	Need of the guide handler	Uses satellite technology	Need for a portable printer	Need for a tablet/PC
1	●		●	●
2		●	●	●
3			●	●

Regarding the comparison of the solutions three evaluations were elaborated, first the 11 CTQ analysis with the weight of the most and least important ones, after that an evaluation of the impact each of the solutions would have on the root causes, understanding witch one could be most impactful in eliminating those causes, also considering the most and least important ones as stated before and last a multi criteria analysis where a set of metrics not covered before will be considered for each solution.

As stated before, after completing a detailed examination of the logistics process and brainstorming meetings with the department head, three solutions were designed to address the problem. Solution number 1, In this scenario, the truck driver uses a tablet PC to electronically fill out the waybill with information provided by the guide handler on-site upon arrival at the assigned spot. After completing the digital form, the driver can immediately print the waybill using the truck's portable printer.

As for the solution number 2 is to put in place a satellite communication infrastructure. With this system in place, critical information may be transmitted directly to the truck driver, avoiding the problem of network access in remote places. The driver can then use a portable printer on-site to print the waybill, guaranteeing that no time is lost due to inconsistent network coverage. This method enhances communication reliability and decreases information sharing delays dramatically.

Lastly the solution number 3 entails identifying a strategic meeting site near the selected location with reliable network access. At this site, the logistics staff sends critical information straight to the truck driver. The driver can then electronically fill out the waybill with a tablet/PC and print it with an onboard printer. This method successfully addresses the issue of network access in rural places. In summary, these three different approaches attempt to improve information sharing and waybill management throughout the logistics process.

With the prioritization done of the CTQs and the root causes with a 1 to 5 Likert Scale a translation was done from those values to the weight each of those metrics would have. The table 4.7 shows that translation into a percentage. In the table 4.7 the weights shown were calculated by dividing the rating attributed in that CTQ/Root cause by the total amount of all the rating added. Its also important to mention that the Root causes 1 to 7 are referring to human error and from 8 to 10 to inefficiencies.

Table 4.7 - Metrics prioritization

CTQ	Rating	Weigh	Root cause	Rating	Weigh
1	5	0,125	1	4	0,12
2	3	0,075	2	3	0,09
3	3	0,075	3	2	0,06
4	4	0,1	4	5	0,15
5	4	0,1	5	3	0,09
6	3	0,075	6	3	0,09
7	3	0,075	7	4	0,12
8	3	0,075	8	3	0,09
9	4	0,1	9	2	0,06
10	4	0,1	10	4	0,12
11	4	0,1			
Total	40	1	Total	33	1

The CTQ analysis that is presented in the table 4.8 considers the 11 CTQ directly related to the main needs in first and second columns, the third column "as is" its useful to evaluate the impact of each solution in that same CTQ, the cells of the column that are filled are the ones of binary answer, representing a CTQ that seeks for the implementation of one feature, the "impact" column evaluates the implementation or no implementation of that feature with each solution, the column with ratings for each of the solutions will always translate the "YES" or "NO" answer in a "3" or "1" points, respectively. With the exception of the CTQ 11, as it is possible to accurately calculate the number of intervenient in the process, it is possible to calculate the impact that each solution would have on that CTQ. Regarding the others CTQs it is not possible to accurate calculate a value to understand as "as is" therefore, the ranking of those same CTQs will be done directly using a scale from 1 to 3, "1" being little positive impact and "3" big positive impact.

In the last column it's possible to see the weight that each CTQ has considering the prioritization done in the last chapter. The ones with a rate of "1" would be considered with a weigh of 0%, however none of those had such low rating, the ones with a rating of , 3, 4, and 5 will have a weigh of 7,5%, 10% and 12,5%, respectively. The different weights were calculated according to the results of table 4.7 where the highest rated CTQ/Root causes were given a higher weight in the table 4.8, the percentages and scores were attributed together with the team.

Table 4.8 - CTQ metrics VS solutions analysis

CTQ		As is	Option						Weighting
			Impact	1	Impact	2	Impact	3	
1	Get information in real time	NO	NO	1	YES	3	NO	1	12,50%
2	Information sharing between all stakeholders in the process	NO	NO	1	YES	3	NO	1	7,50%
3	Stop the use of "guide books" to fill the waybills	NO	YES	3	YES	3	YES	3	7,50%
4	Use of technological equipment in steps of process	-------		2		3		2	10,00%
5	Lower number of tasks performed by subcontractors	-------		1		3		3	10,00%
6	Lower the land coverage done by subcontractors	-------		2		3		1	7,50%
7	Creating a place with secure access to the network	NO	NO	1	NO	1	YES	3	7,50%
8	Use of subcontractors for tasks such as location recognition and drivers assistance	NO	YES	3	YES	3	YES	3	7,50%
9	Lower amount human errors	-------		2		3		2	10,00%
10	Less steps in the process	-------		2		3		2	10,00%
11	Lower number stakeholders in the process	6	6	1	5	3	5	3	10,00%
Total				**1,68**		**2,85**		**2,15**	100,00%

In the table 4.8 it can be seen that the most suitable solution is the solution number 2 due to be the one with the highest value score, that value was calculates summing the product of the attributed score in each CTQ with the weight given to that CTQ. Regarding the CTQ1 It would be the only one, by using satellite technology capable of maintaining a stable connection with the logistic team and the factory in every position, special in the forest, this way the connectivity problems would be eliminated, any other solution would be capable of doing so, the same applies to the CTQ2. For the CTQ3 all of the solutions would be positive, by using technology to communicate and share information, there would be no need for the books or any paper until the waybill is printed. Regarding CTQ 4 there's an adoption of more technology regarding solution number 2, the CTQ 5and 6 also are more impacted by the 2nd solution the new technologies would allow to reduce the dependency on guide handlers therefore reduce the land they would have to cover to complete the tasks.

On the other hand, the guide handlers would still be needed to aid in certain situations such as land recognition and help more inexperience truck drivers, due to their knowledge of the area. It's also understood that they all would have a positive impact regarding the human error in the tasks and decreasing steps/effort in the process due to adoption of new technologies.

Just like it was done in the previous analysis, now it will be analyzed how each of the solutions can have a positive impact in overcoming the root causes, as it can be seen in the table 4.9, all the root causes are being evaluated together, as before the different weights were calculated according to the results of table 4.7 where the highest rated CTQ/Root causes were given a higher weight in the table 4.9, the values of the percentage were chosen together with the team. Again, there was no cause with a rating of "1" in prioritization therefore every single root cause was considered. The percentages and scores were attributed together with the team.

Table 4.9 - Root causes metrics VS solutions analyses

Root causes		Solution			Weighting
		1	2	3	
1	Overlook critical details	1	2	2	13%
2	Ignoring critical details	1	2	1	8%
3	Distraction	1	3	2	8%
4	Limited and inaccessible network coverage.	1	3	2	13%
5	Use of different registration methods	2	2	2	8%
6	Excessive number of people involved in the exchange of information	1	3	3	8%
7	Misinterpretation of information	1	2	2	13%
8	Existence of unnecessary steps	1	3	2	8%
9	Difficult access to guidelines	2	3	2	8%
10	Lack of real time information regarding truck waiting times at factory	1	2	1	13%
Medium value		**1,16**	**2,45**	**1,87**	100%

Locking at the root cause 1, solutions 2 and 3 are the ones with higher impact, both have a higher adoption of communication technology or method, this translates in a better information sharing possibilities. In root causes 2 and 3 all the options have an overall positive impact due to more straight forward and direct communication that allows to simplify the process and reduce these types of inefficiencies except root cause 3 solution 1 that maintains possibilities for distractions to happen due to maintain higher number of involved people in the process. Regarding root cause 4, as it's seen before, solution 2 overcomes the lack of network while the solution 3 only bypasses it.

The root causes 6 and 7 are interconnected with a lower number of direct intervenient in the process and more direct communication it's possible to reduce the chances of misinterpret the information. Once again root causes 8 and 9 are interconnected the simplification of the process and better communication allows to access guidelines in a more direct and reliable way.

Lastly ensuring a secure connection with logistic team and factory, solution 2 is the one that would better improve root cause 10.

The last analysis to be done is the multicriteria analysis, in the table 4.10, it can be seen the new added metrics. Those 5 metrics were considered to be relevant to the process but haven't been considered neither in the CTQ or in the root cause analysis.

First, the metrics "Effort required from the transport company" and "IT investment" were given a 5% weight due to the bigger importance they have, one because it specifically considers what each solution will represent for the transport company the other because considers the financial investment the company will have to do so it can implement each of the solutions. Then the "added effort/time to the overall process " because the goal is also to simplify the process if possible therefore it was given a weight of 4%, lastly the remaining two metrics "Difficulty of implementation" of the process and "time training" and adaption time the truck drivers and the rest of the team would need until feel comfortable with the process, its considered important to understand if there will exist resistance to change.

The bottom two metrics are the root causes and the CTQ with the results previously gotten, both of this metrics have a much higher weight, 35% and 45% respectively. This comes due to the importance they have for the team as overall project goals. The distinction between the root causes and CTQ happens, since the CTQ is a natural translation of the teams needs and the root causes were only after evaluated from two disruption causes identified, "human error" and "general inefficiencies". The percentages and scores were attributed together with the team.

The rating was once again from 1 to 3, being 1 the lowest rating and 3 the highest rating.

Table 4.10 - Multi criteria VS solutions analyzes

Multi criteria	Solution			Weighting
	1	2	3	
Effort required from the transport company	2	1	2	5,00%
Difficulty of implementation	3	2	3	3,00%
Time of training	3	2	3	3,00%
Added effort/time to the overall process	2	3	1	4,00%
IT investment	2	1	3	5,00%
Root causes improvement	1,24	2,52	1,97	35,00%
CTQ adjustments	1,675	2,85	2,15	45,00%
Total	1,65	2,50	2,13	100,00%

In the first metric, the effort required both solutions 1 and 3 have the same rating, considering that both solutions are easier to implement therefore not requiring many efforts, on the other hand solution 2 requires the adoption of more new technology and so it was rated as 1 in this scale. The same goes for the second and third metrics, both solutions 1 and 3 are considered easier to implement on many levels and solution 2 would need more time, coordination and training therefore got a rate of “2” while the others got rated as “3”. In the fourth metric the same doesn’t happens, solution 2 would make the process simpler and improve communication and process time while the other solutions would have a lower impact on this level, especially solution number 3. Lastly on level of investment solution number 3 is rated at the highest value not only because it requires less investment but also eliminates the need of guide handler, and associated costs, while solution number 1 only requires lower investments but keeps the guide handler, solution number 2 is rated at the lowest due to high IT investments in a communication technology.

Finally, the results for solutions number 1, 2 and 3 are, respectively, “1,65”, “2,50” and “2,13”. The solution number 2, requiring a satellite communication equipment, was the winning solution in both CTQ and Root causes analysis and second in multi criteria analysis after solution number 3. This translated in a final wining of the solution number 2 with a total score of “2,50”.

The chosen solution is solution number 2, adoption of a satellite communication system.

4.2.5 Verify phase

In this section a verification of the process would be made, unfortunately given the lack of time for implementation and complexity of the process there were no opportunity to do it in time for the thesis delivery. However, a plan to a better implementation is presented.

Since the chosen solution is the implementation of a satellite communication system, research on already existing systems and understand if there is one that better satisfy the metrics already selected is advised. After a selection of the system create a plan on what are the requirements of the system and how they apply to the team, invest in technology that supports it and train the members of the team and intervenient of the process on how to use the system. Lastly verify the results gotten from the implementation.

4.3 Conclusions of the chapter

This chapter describes how to use the Design for Six Sigma methodology with Swim Lane, SIPOC (Suppliers, Inputs, Process, Outputs, Customers) diagrams, affinity diagrams, and selection criteria tools. These analytical tools were critical in undertaking a thorough analysis of the current processes in accordance with the key objectives and research questions of this thesis project.

Several techniques were used in the study methodology, such as brainstorming sessions, interviews, and process observations. These techniques collectively identified certain areas that needed to be improved. The highlighted areas for improvement resulted in practical recommendations that were then approved by the logistics team. Using the DAMDV technique aided in identifying essential required characteristics for a new communication and information sharing process among all stakeholders involved.

Then after defining multiple possible solutions, it was carried an evaluation using a set of metrics previously established as baseline, although no implementation was made it was possible to predict general effects each of the solutions would have on the process, therefore it was possible to select the one that would better satisfy the needs of the team and overcome the root causes of disruptions in the process. Finally, after getting the winning solution a plan was established to better implement the solution.

5. Conclusion

The current case illustrated a problem felt in one of the main companies in Portugal regarding a logistic process of communication, the information sharing of a waybill between the logistics department and the truck driver in the forest. The process had multiple constrains as stated throughout the thesis. It can be stated the main goal of this thesis was to redesign that process making it more secure, reliable, meeting department needs and overcoming constrains.

A literature review was conducted to support the implementation methods proposed to achieve this goal and respond to the research question. The Design for Six Sigma approach was presented in the literature review chapter because it achieves the outlined objectives of rethinking the Logistic process related waybills by deeply engaging with the department and developing a design based on their individual needs. The DMADV approach was then developed in order to improve the project as a whole as well as all of the components necessary for its success.

The case study employed a variety of methodologies, including brainstorming sessions, interviews, and process inspections. These strategies revealed specific areas that needed to be improved. The logistics team accepted practical recommendations based on the highlighted areas for improvement. Then, after defining multiple possible solutions, an evaluation was carried out using a set of metrics previously established as a baseline; although no implementation was made, it was possible to predict general effects each of the solutions would have on the process, allowing the team to select the one that would better satisfy their needs.

To answer the research question: "How to redesign the current process employed by The Navigator Company for the formulation and delivery of the waybills to the wood truck drivers in the Portuguese territory, so as to make it more efficient and easier to track?" A process redesign solution was elaborated in order to perfectly meet the research question, by following a methodology and pursuing the several partial objectives.

To summarize, this study adds to the already existing studies in the literature on logistics, which were built using the DFSS approach and have proven to be effective in satisfying the needs for which the process was redesign.

5.1 Limitations and Recommendations

This chapter has some limitations that should be noted. First and foremost, the study lacks a "verify" phase, owing to time restrictions and a misalignment with the company's implementation timeline. Another limitation is the lack of a specific communication technology option for the selected redesign, which led from challenges linked to alignment with the company's ambitions regarding time of implementation. Furthermore, the study's generalizability is limited because it is highly specialized in a certain business and may not provide thorough insights for other fields or problems.

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