Improvement programme for the implementation of a kanban system in a supplier of the automotive industry

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“Perfection is not attainable. But if we chase perfection, we can catch excellence.” – Vince Lombardi

Abstract

The company under study, an established brand in the automotive industry, has existed for a long period of time, and with that long existence comes a constant mentality of continuous improvement. In the case of Renault Cacia, being focused on the production of gearboxes and engine components, the focus of this project will be in the production flows of this factory.

In this specific case, the production department has been struggling to make an efficient production management, allowing for mistakes, when it comes to providing the pieces to its main client: the assembly lines of the gear boxes.

In order to correct this issue, Renault implemented a lean tool, called kanban, that helps to control those production flows and simplify the communication throughout the entire production process, but this tool has been having a few problems with its implementation. The focus of this project will be in the improvement of this tool, allowing for a correct and simple use by the different people that take part in the production lines.

Programa de melhorias para a implementação do sistema kanban num fornecedor da indústria automóvel

Resumo

A empresa em estudo, uma marca de renome no setor automóvel, está presente há vários anos no mercado, onde existe uma constante mentalidade de melhoria continua e de evolução. No caso específico da Renault Cacia, que se foca na construção de caixas de velocidades e componentes de motores, o projeto em análise basear-se-á nos fluxos de produção da fábrica.

Neste caso específico, o departamento de fabricação tem tido dificuldades em fornecer peças para a linha de montagem, o seu principal cliente. De forma a corrigir este problema, a marca está a implementar uma ferramenta lean, o kanban, que permite controlar os stocks de produção e a comunicação entre todo o fluxo de produção. No entanto, esta ferramenta tem tido alguns erros e falhas de implementação, que origina a dificuldade na viabilização da ferramenta.

Assim, o foco deste projeto versará na melhoria da implementação da ferramenta, de forma a permitir um uso correto e simples, de modo que a ferramenta se torne transversal e fiável para todo o fluxo de produção.

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List of acronyms

APW – Alliance Production Way

AVP – Advance in Production

BPS – Black Piece Sector

CUET – Chefe de Unidade Especifica de Trabalho

EKS – Easy Kanban System

FIFO – First In, First Out

FOS – Folha de Operações Standard

LUP – Lista Única de Problemas

MRP – Materials Requirement Planning

MTO – Make to Order

MTS – Make to Stock

OEE – Overall Equipment Efficiency

RFID – Radio Frequency Identification

RSF – Reporting Standard de Fabrication

TPS – Toyota Production System

TTS – Thermic Treatment Sector

VSM – Value Stream Mapping

WIP – Work in Progress

WPS – White Piece Sector

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1 Introduction

The automotive industry was born in the end of the 19th century, being one of the most competitive and high revenue industries that man has faced throughout his existence. The Group Renault plays an important role in this industry, since a large portion of the cars that are sold annually world-wide are produced by this French brand. This company started its activity in 1898, later beginning its production, in Portugal, with the factory in Aveiro in 1981.

The present dissertation, developed at Renault Cacia´s logistics department, focuses on improving the production flows, with the implementation of the kanban methodology. This is a necessity for the Cacia plant, since with the current crisis at the automotive industry, any costs and ways of improving the production flows can help with the longevity of the factory´s life.

1.1 Group Renault

The Group Renault is one of the biggest players in the automotive sector, providing to its clients a vehicle with a good balance between quality and cost. This company (Figure 1) started its production in France in 1898, and throughout these years has grown and developed into one of the strongest companies in the automotive sector.

Figure 1: Renault´s logo (adapted from Renault´s official website)

Today, the Group Renault has 122 factories in 40 locations spread all around the world, employing over 170000 people and has sold over 10,76 million vehicles in 128 different countries. Throughout these years, in order to maintain its competitiveness, this brand has established several partnerships with brands like Nissan and Mitsubishi, allowing for it to reach a vast market and gather a wider variety of clients. Due to this partnership, the Group Renault is responsible for the following brands (represented in the Figure 2): Renault, Dacia, Alpine, Lada, Nissan, Mitsubishi, Renault-Samsung, Infinity, Venucia and Datsun. The brand´s vision is to build clean, affordable and safe cars that can be at the reach of anyone.

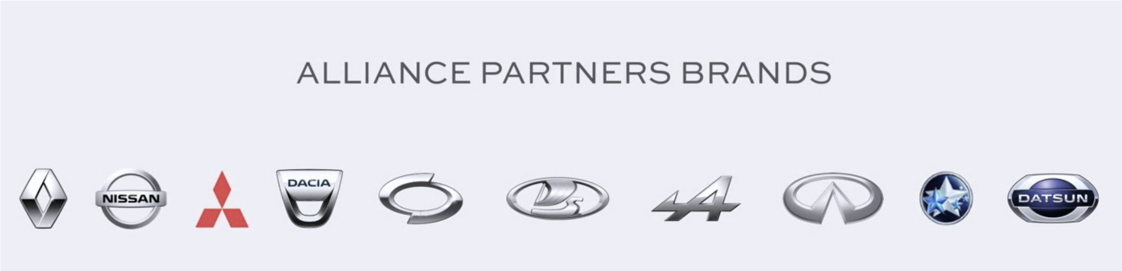

Figure 2: Alliance Group brands (adapted from Renault´s official website)

Currently, the only factory of the group in Portugal is located in Cacia, Aveiro, one of the most important industrial centres in Portugal. This factory is responsible for the production of gearboxes and engine components for several automotive models of the group. The products that are produced in this plant are destined to the several assembly factories of the group in Spain, France, Romania, Turkey, Slovenia, Brazil, Chile, Morocco, South Africa, Iran, and India.

The factory at Cacia started its activity in 1981, and throughout these years it has battled to stay in the leadership of the group when it comes to producing automotive gearboxes.

Figure 3: Renault Cacia plant (adapted from Renault´s official website)

The factory has a layout of over 70000m^2 (as can be observed in the Figures 3 and 4) of covered area, being divided in five ateliers:

- AT1 - production sector responsible for the manufacture of gearwheels, primary and secondary trees, that will take part in the automotive gearboxes;
- AT2 - manufacturing area responsible for the production of racks, synchronization axels, clutch mechanisms and crankcases also for the gearboxes;
- AT3 – atelier responsible for the production of oil pumps, engine covers, crankshaft supports and several crankcases;
- AT4 – sector responsible for the production of balancing trees, barrels, ramps and balancing axels;
- AT5 – area responsible for the final assembly of the gearboxes.

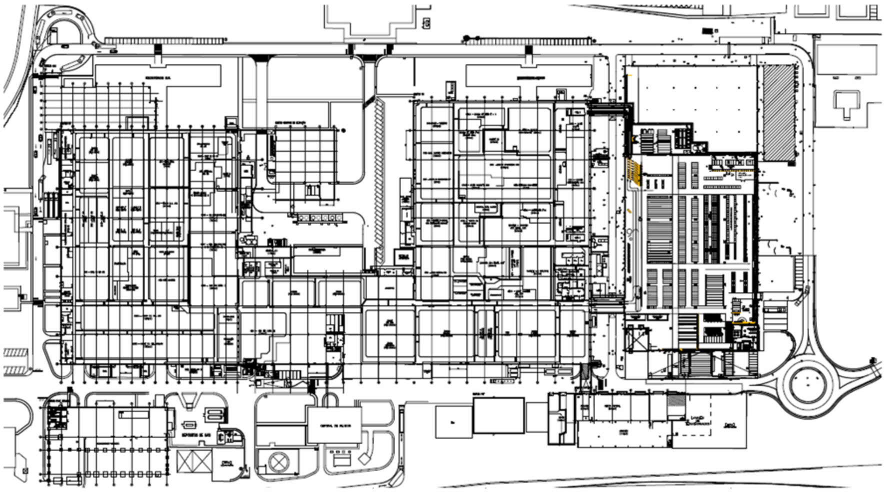

Figure 4: Detailed map of the factory

Internally the factory is divided in nine departments, having each department a chief responsible for the well functionality of its domain:

- Finance/ Purchase;
- Human Resources;
- Engineering;
- Logistics;
- Manufacturing;
- Technical Department;
- Quality;
- APW;
- IT Department.

The present dissertation was developed in the logistics department of the factory.

1.2 Project background

The main objective of the Renault´s plant in Portugal is to stay in the leadership for the production of gearboxes and engine components in the group, and with that, it has to create a production process that is as efficient as possible, capable of providing the needs that the main factories ask for.

The background of this project started with the motivation to improve the production system at the factory. Traditionally working with a Push system, where the production planning is done to produce as many stocks as possible, creating oversized amounts of stock, Renault realised that they could reduce costs, by controlling its production quantities. In the need to solve this issue, Renault implemented a lean methodology, based in the Pull system. This system, using kanban, works by only manufacturing what the following client asks for, allowing for a reduction of those stock amounts. This represents a strong change of production mentality, so the system that is implemented must be as simple and intuitive as possible.

1.3 Problem description

At the initial stage of this project, the kanban system was already implemented, but with a large margin for improvement. One of the most impacting aspects was the lack of interaction between the factory workers with the system.

Aspects like oversized stocks, lack of parts provision to the assembly line, inefficient changes of production types, lack of communication throughout the entire factory, difficulty of knowing the location of the different parts, and the distinct paths that all the parts take, were the main problems found.

1.4 Problem objectives

The main purpose of this project is to improve the kanban´s functionality in the factory, helping to improve the production flows. This improvement in functionality implies the operational aspect of the program, as well as, creating the best possible conditions both for the factory workers and engineers that use the kanban information to manage the production at the factory.

The goal is to create a unique production tool that is transversal to all production sectors and allows for a clear communication and organization in the production flows.

1.5 Methodologies

The present project is divided in five main parts (Figure 5): the representation of the current process, the identification of the observed problems, the analysis and application of improvements and a final measurement of the changes that were made.

In order to represent the current kanban flows, a VSM (Value Stream Map) will be mapped, with a clear and detailed information of the way the production process is done. In addition, several diagrams of action will be represented, in order to show the logic behind the functionality of the kanban system.

The identification of the observed problems will require a detailed analysis of the process, with a detailed explanation of what is not working to its full capabilities.

The analysis and implementation of solutions require a deep investigation of the systems limits and the analysis of the production flows, in order to provide a simple and adapted solution to the reality.

In order to measure the results, a series of tools are displayed, in order to understand the evolution of the solutions and if any changes are necessary.

Figure 5: Method to solve the problem

1.6 Report structure

The present report is structured as follows:

Chapter 2 encompasses a literature review on the automotive industry and the theme of production management, more specifically in production flows. Themes like lean methodologies and tools are explained, focusing on the kanban methodology.

Chapter 3 focus on describing the current process at Renault Cacia. It includes the manufacture flow of the different pieces that take part in the gearboxes. Also, a detailed explanation of the logic behind the functionality of the kanban system is provided.

Chapter 4 focus on describing the changes and upgrades that were made to the current system, explaining the logic behind every decision, as well as providing an analysis of the measurements that were collected.

Finally, chapter 5 serves as a conclusion of this project, with a reflexion of the work that was done and a few suggestions for the future.

2 Literature review

The present chapter aims at providing a literature review of the relevant topics. Firstly, the automotive industry, and its impact in the technology and evolution of the industry 4.0. Production management will be detailed, with its main purpose and principles, focusing on the methodologies Push vs Pull, and their impact in the efficiency of any industry. The lean mentality will be described, alongside with its principles and methodologies. Finally, a detailed analysis on the kanban methodology will be provided, explaining its functionalities and the value that it brings to any manufacturing company.

2.1 Automotive industry

The automotive industry has been around since the 19^{th} century, being one of the fastest in terms of growth and very demanding in terms of competitivity. Throughout these years, the leaders of this industry have intercalated between Europe, United States and Asia. Initially it was in Europe that the industry started to develop, until the beginning of the 20^{th} century, when the United States changed this direction, with the invention of mass production. After the second half of the century, Europe and Asia gained power in this sector, becoming, until now, the biggest producers and exporters of automobiles to the entire world (Nyamwange & Nyamwange, 2014; Parry & Graves, 2008a).

Technology has played an important part in the evolution of this industry, allowing both to develop the vehicles, which started from steam powered engines, involuting to combustion power and know facing a new challenge of electric mobility, as well as the production process of those same vehicles. Initial production started from small factories, using simple and primitive tools, involuting to mass production with the automatization of the processes. After this large evolution, the industry trend is to focus on improving the production organization, in order to cut costs and invest those savings in the development of other innovative technologies, increase safety and reduce pollution (Liu et al., 2020; Nyamwange & Nyamwange, 2014).

2.2 Production Management

As mentioned before, one of the major focus of the automotive industry is to make the production processes as efficient as possible, and with that comes a good production management mentality and practises. “Production management is a process of planning, organizing, directing, and controlling the activities of the production function. It combines and transforms various resources used in the production subsystem of the organization into value added product in a controlled manner as per the policies of the organization” (Kumar & Suresh, 2008). The target is to convert a batch of raw materials into a finished product, ensuring that the manufacturing performance, volume, quality, and time meet the demanded goals (Parry & Graves, 2008).

An effective production management mentality is the result of 6 elements: men, money, machines, materials, methods, and markets. Those elements are interconnected, and when well-balanced facilitate the production of any goods in any industry (Meier & Liker, 2006).

2.2.1 Objectives of the Production Management

The main focus of any production management process is to provide the client with a service or product which has the right quality at the right quantity, at the right time and made with the right production cost (Kumar & Suresh, 2008):

- Right Quality

The quality of any product is determined by the customer needs. This means that not always the best quality is the appropriate one for the client. Aspects like the technical characteristics and the cost of the product associated with the requirements needed, determine the appropriate quality for the customer.

- Right Quantity

The manufacturing process should produce the necessary amount of product. If this happens in an excess situation, there will be an excess in inventory, increasing costs. On the other hand, in shortage situations, the client will not be served with what was defined, implicating a situation of dissatisfaction.

- Right Time

The time when a product is delivered is one of the most important aspects in production management. This parameter helps to evaluate the performance of the production process and should manage all the necessary resources to fulfil this objective.

- Right Production Costs

This aspect ultimately defines the performance of any process and is usually determined before the product is manufactured. The objective of any production manager is to try to keep up with the initial cost, helping to reduce variability in the overall costs.

In order to achieve the desired objectives mentioned before, when implementing a production operation, there are several rules that must be followed to fulfil this level of efficiency and success. First, by implementing shorter and well planned set up times, to ensure the longevity of the machines and to reduce the time spent changing the output of the manufacturing lines. Second, with small-scale production, allowing for cost reduction and production based on demand. Third, by empowering the workers, providing people with the tools and responsibility to do their own job and to do it with the highest success. Fourth, by implementing equipment maintenance, again improving the machines longevity and overall efficiency. Fifth, by implementing a mentality of producing only what is demanded, reducing unnecessary costs. Last, by involving the suppliers with the production process, helping with the several problems that usually happen in a manufacturing process (Kumar & Suresh, 2008; Meier & Liker, 2006; Parry & Graves, 2008a).

2.3 Push vs Pull approach

The production flow of any industry depends on an effective supply chain of communication, that provides the products throughout the entire production line. These approaches can vary from a Push or Pull system.

2.3.1 Push system

This first strategy bases its demand on a prevision of what is necessary, having its fundability in the MRP. The Material Requirement Planning (MRP) is a system used to calculate the necessary materials and components to produce any product. This approach tends to create work in progress (WIP), producing bigger quantities of stock and may not always be accurate. This type is usually used when we are dealing with complex and high variety products, which tend to have a big quantity in the production lines. Products usually have long lead times and/or the factory is working to make stock of some products (Geraghty & Heavey, 2005; Takahashi & Nakamura, 2004).

2.3.2 Pull system

This second strategy is influenced mainly by the demand. The finished goods are only prepared if there is an order in place. This type minimizes WIP and is used when there is a high demand and relatively small variety of products (Geraghty & Heavey, 2005; Takahashi & Nakamura, 2004).

The application of these approaches should be adapted to the industry under analysis. Despite this, the evolution observed in several industries shows that a hybrid version between these two systems has been becoming stronger and more appreciated by the industry.

2.4 Lean

This is a concept based on the efficiency and sustainability of the manufacturing processes, that was adapted out of the Toyota Production System (TPS). It bases its philosophy on the definition of value from the customer’s perspective, and the continuous improvement of the way this value is delivered to the customer. The lean mentality focuses on preserving value with less work, by providing perfect value to the customer through a process that eliminates the different sources of waste, or actions that do not contribute to the desired goal (Gorecki & Pautsch, 2013; Meier & Liker, 2006).

The lean mentality aims to maximize human potential by motivating workers to continuously improve their work. This process of putting responsibility and encouraging pride in their job stimulates the personal growth and allows for a better contribution to the organization. This represents a fundamental value of the lean mentality, which is focused on the respect of the others, going from the workers, to the customers and the entire ecosystem that surrounds the organization (Gorecki & Pautsch, 2013).

The process of continuous improvement, as mentioned before, is a basic principle of the lean mentality. It was originated from the expression Kaizen, which means “change for the better” (Moskvicheva et al., 2020). This principle focuses on eliminating waste, a concept being explained further down. It defends that the analysis of any process should be done at the place where it happens (Gemba), encouraging all the people that part in that process to identify problems and suggestions of improvement (Chiarini et al., 2018).

2.4.1 The beginning of the lean mentality

The lean philosophy was initially developed by the Japanese in the 1950’s and it is currently implemented in several areas, from the industry to the service sector. The concept is based on the Toyota Production System, and it had its origin with the Toyota brand, in the years after the Second World War. The event that originated this approach was a tour to Ford’s car manufacturing plant, at that time the biggest car manufacture in the world. Ford was the first to truly integrate a production system called “mass-production”, which produced large quantities of standardized products (became famous for the quote: “choose any colour as long as it is black” (“MILESTONES - Henry Ford,” 1994)). Ford created a production flow which involved continuous movement of elements through the production process. This allowed the company to reduce the fabrication time from hours to minutes. After studying Ford’s production system, the Japanese manufacturer realized that Toyota was too small and did not have enough money to invest in so many machines like Ford. However, Toyota adapted the car production to its reality by achieving higher productivity with more flexible processes, while eliminating waste activities in their processes. These experiments led to developing several innovative ideas that became known as the “Toyota Production System”. This allowed a revolution in the production industry, empowering an incredible development and innovation to manufacturing that we know nowadays (Gorecki & Pautsch, 2013; Meier & Liker, 2006; Murdock, 2021).

2.4.2 Toyota Production System

The Toyota Production System (TPS) was developed based on two concepts. The first is called "Jidoka", which defends that when a problem happens in a process, the process should stop immediately, preventing the production of defective products. The second is the concept of "Just in Time" which each process produces only what is needed by the next process, in a continuous production flow.

The “Jidoka” concept “is a stop and respond approach, either machine or human, to halt production and address product defects or quality issues as they are encountered in a process” (Gorecki & Pautsch, 2013). This allows the workers to visually monitor and control several machines, helping with a quicker and specific control of the problem, originating a successful quality control at the root cause of the problems (Meier & Liker, 2006; Murdock, 2021).

The concept of Just in Time (JIT) “refers to supplying what is needed, when it is needed, and in the amount that is needed” (Gorecki & Pautsch, 2013). By applying this rule, companies can produce high quality products efficiently through the elimination of waste (Meier & Liker, 2006; Murdock, 2021).

The TPS, based on the principles of “Jidoka” and “Just in Time”, being represented in the Figure 6, can efficiently and quickly produce products of excellent quality, at the right time, that fully satisfy the customer needs.

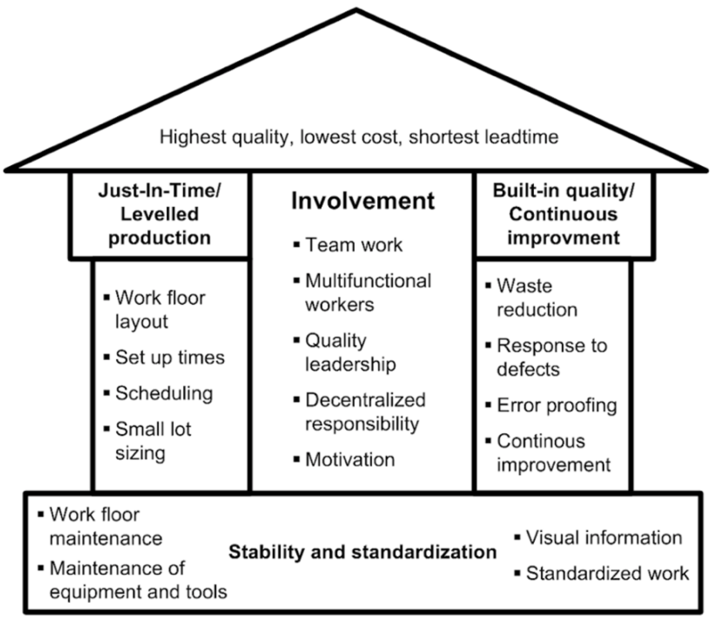

Figure 6: Lean "House" of principles (Höök & Stehn, 2008)

2.4.3 Five lean principles

The lean mentality is based on five principles, which are the basis of this way of thinking (Gorecki & Pautsch, 2013):

- Value

Value is the first step to understand when developing a lean process. "Value can only be defined by the ultimate customer, and it is truly meaningful when expressed in terms of a specific product that meets all the customer's needs and wants" (Gorecki & Pautsch, 2013). By understanding what the customer needs and wants, the correct prices and costs of a process can be defined, eliminating waste, and delivering the best option possible to the client.

- Value Stream

The second concept is identifying and mapping the value stream. This concept uses the customer's value as a reference point to identify the activities that provide the desired values. It identifies value-added and nonvalue-added activities, indicating where the improvements need to be done. This ensures that the customers get exactly what they want, at the right cost.

- Flow

This concept defends that "all of the activities pertaining to the completion of a product or service should be organized in a single, uninterrupted flow" (Gorecki & Pautsch, 2013). It focuses on creating a process flow with no interruptions, where every activity is interconnected with the following one.

- Pull

This principle, as was mentioned before, focuses on producing only what is needed, improving with waste reduction and stocks control. This allows for product creation at the right quantity and at the right time, ensuring a controlled and smooth workflow.

- Perfection

The four principles mentioned before prevent waste, and this last one ensures that the search for a perfect process never stops. It makes lean thinking and continuous process improvement a basic culture, ensuring that every person involved in the process tries their best to deliver the best product/service, improving every day.

2.4.4 Concept of waste

The Toyota Production System, later developed into the lean concept, was developed around eliminating three types of waste:

- Muda

Muda is the most common type of waste, being related to actions/activities that do not bring extra value to a process. There are two types of Muda: Type 1, that includes non-value activities that are necessary to the customer, and Type 2, that still does not bring extra value to an activity but is not necessary to the customer, meaning that it can be eliminated. The Muda type 2 can be divided into seven categories: transport (excess movement of product), inventory (excess stocks), motion (excess movement of machines/people), waiting (time waste), overproduction (excess of production), over-processing (excess of production steps) and defects (faults in the product developed) (Leksic et al., 2020; Wahab et al., 2013).

- Mura

Mura is related to the waste in inconsistency and inequality, translating the irregularity that occur in any process. It is because of these inconsistencies that the seven variations of the type 2 Muda exist. The lean mentality aims at reducing this by regulating the work that is being done, creating a smooth and balanced operation. To reduce this type of waste, can be applied JIT methodologies, in order to control stocks and production quantities (Gorecki & Pautsch, 2013).

- Muri

The Muri type of waste is related to excessiveness and irrationality. It results from the Muda and/or Mura. This type of waste creates situations of overcapacity of both machines and people, originating opportunities for product defects and lack of safety. In order to correct this type of waste, standard processes and rules have to be applied, helping with the levelling of the different processes (Gorecki & Pautsch, 2013).

2.4.5 Lean techniques

There are several lean techniques/indicators that can be applied to a process, therefore only a few are being explained below. All the principles described previously, allied with these lean methodologies, can achieve impactful results in any industry:

- 5S workspace organization

This lean tool helps to organize any working area by following five simple steps: Sort (eliminate what is unnecessary), Set in order (organize), Shine (clean), Standardize (make a model and apply it to everything) and Sustain (regularly apply the developed standards) (Gorecki & Pautsch, 2013; Mazumdar, 2020).

- VSM (Value Stream Mapping)

This method provides a visual map of the production flow under analysis. It displays the current and future state of the processes, highlighting opportunities for improvement (Abideen & Mohamad, 2021; Gorecki & Pautsch, 2013; Mazumdar, 2020).

- PDCA (Plan; Do; Check; Act)

This is a methodology used to implement improvements in any type of operation. It is based on four principles: Plan (establish a plan and predict results), Do (implement that plan), Check (analyse if the expected results were achieved) and Act (review and assess, repeating the process all over again) (Gorecki & Pautsch, 2013; Mazumdar, 2020).

- SMED (Single minute exchange of dies)

The SMED technique aims at reducing setup times to less than 10 minutes. Some of the action points focus on converting setup steps from internal to external (done while the process is running), simplifying internal setups, eliminating non-essential operations and creating standardized work instructions. This technique allows the manufacturing process to work with smaller lots, reducing inventory and improving customer responsiveness (Gorecki & Pautsch, 2013; Mazumdar, 2020).

- TPM (Total Productive Maintenance)

This lean methodology defends the active maintenance of the equipment, in order to achieve the best operational efficiency of the production lines. It gives the production workers the responsibility to maintain their working sectors, increasing responsibility and productivity, by creating involvement with the operation (Gorecki & Pautsch, 2013; Mazumdar, 2020).

- Kanban

This last lean tool aims at regulating the flow of products in any operation. It works with the circulation of cards, signalling the need for new products and reenforcing the mentality of producing only what is necessary. It helps to reduce excess inventory and over production (Gorecki & Pautsch, 2013; Mazumdar, 2020).

2.4.6 Lean indicators

- SMART Goals

These are goals that are Specific, Measurable, Attainable, Relevant, and Time-Specific. They help to ensure that the goals established to a specific project are effective and adequate (Gorecki & Pautsch, 2013; Mazumdar, 2020).

- KPIs (Key Performance Index)

These indicators are used to measure the progress of an operation. Its objective is to evaluate if the goals that were established are being accomplished, and if not, understand why. They have a great impact in any project because they are effective at exposing and quantifying waste (Gorecki & Pautsch, 2013; Mazumdar, 2020).

- OEE (Overall Equipment Effectiveness)

This lean indicator is used to measure the productivity of any operation. It uses three parameters of evaluation: Availability (downtime), Performance (slow cycles) and Quality (rejects). It provides a way to measure progress in eliminating waste from a manufacturing process. A result of 100% of OEE corresponds to a perfect production process, manufacturing only good parts, as fast as possible, with no downtime (Gorecki & Pautsch, 2013; Mazumdar, 2020).

2.5 Kanban

One of the lean tools mentioned above, and the one which is the focus of this project is the kanban methodology. The kanban system is a lean tool that can achieve minimum inventory without putting at risk the production capacity (Wakode et al., 2015). It helps to improve the company's productivity while, at the same time, minimizing waste in production and improving the flow of information through the production process. Its functionality is based on only requiring the production when the demand for the products is requested (Gorecki & Pautsch, 2013; Romeira & Moura, n.d.).

2.5.1 Origins of the Kanban system

The essence of the kanban system goes back to the 17th century in Japan, after the military conflicts that happened in the country. At that time, the local business developed colourful signs/boards to create attention and awareness for their clients. The word Kanban (*Kahn-Bahn*) stands for "visible record", meaning that the goal of those signs was exactly to communicate their content clearly and concisely (Rahman et al., 2013).

This concept was later adapted by an engineer at Toyota, to solve a few problems that the manufacturing company was facing. Their main problem was overproduction, which was then considered as waste, because their customer demands could change very fast, and keeping a large inventory of raw materials was not considered viable. The solution found for this problem was to produce what was demanded when it was requested. This method implicated keeping the stocks to a minimum while ensuring a smooth and effective flow of work through the production processes. Inspired by the japanese example, signs/cards were implemented to signal and track the demand in the factory, allowing for a clear view of the pieces that needed to be manufactured and a clear communication throughout the process. This system was later called kanban (R. et al., 2015; Wasserfallen, 2010).

The kanban cards were attached to each product and would circulate through the process alongside the products. The cycle of production would only start if the factory workers received the cards signalling the demand for a new piece. This technique of managing production flows has been implemented in several industries, because it saves costs by eliminating oversized production, developing flexible workstations, reducing waste, minimizing the waiting times and reducing inventory stock levels (Gorecki & Pautsch, 2013).

Due to the evolution of technology, the traditional kanban system through cards has evolved to an electronic system, where the essence of the system is the same, but with the ability of integrating a wider variety of information, providing this lean tool with multiple possibilities of utilities and applications.

2.5.2 Kanban dimensioning

For the kanban to function properly, it is necessary to calculate the number of cards that need to be circulating through the circuit. This number is obtained using a simple formula, represented in the Figure 7:

Number of Kanban cards = [DD * LT * (1 + % SS)] / Q

DD =Daily Demand
LT = Lead Time
SS = Safety Stock
Q = Quantity in the transportation vehicle

Figure 7: Kanban dimension calculous (Braglia et al., 2020)

The number of kanban cards translate the specific number of products that will be circulating in the production flow. This total amount should not vary, unless there are changes in the initial input variables, which can happen if there is a change in the factory, for example, in the daily demand or the lead time of a specific machine in a production line (Braglia et al., 2020; Yurdakul et al., 2020).

2.5.3 Advantages and limits of the kanban system

In order to understand the full capabilities of this system, its advantages are presented below (Agarwal & Agarwal, 2020; R. et al., 2015):

- It is simple and easy to understand and use;
- Promotes continuous and sustainable improvements in the production systems;
- It is very responsive and does not promote delays;
- Eliminates overproduction and reduces costs;
- Promotes a smother manufacturing flow;
- Allows for a better stock management;
- Reduces WIP;
- It implements feedback loops;

- Improves collaboration between workers.

Besides these, and like with any tool, it has its limits (Romeira & Moura, n.d.):

- If there is a change in demand, it has difficulty to adapt to it;
- It does not stop a possible loss or incorrect delivery of the kanban cards;
- Lacks visibility on the entire production flow;
- It has difficulties in measuring data, since there is not a lot of information in the cards.

2.5.4 Types of Kanban

There are several types of kanbans, being related to production flows and movement of pieces:

- Withdrawal Kanban

The Withdrawal Kanban is responsible for giving the authorization for the movement of the products, from one production area to the following one. This type of kanban is related to the movement of pieces, and it follows the flow of the production line until the last part is manufactured, in each station (Mazumdar, 2020).

- Production Kanban

The Production Kanban is responsible for providing an order to the production lines, explaining the quantity of the specific pieces that need to be manufactured. This type of kanban should have information about the materials and parts required in the production process and the information present in the withdrawal kanban cards (Mazumdar, 2020).

Besides these two types of kanban, there are other which are not used as regularly as the two mentioned before, but still have several applications in the industry: Supplier Kanban, which allows the supplier to contact directly with the production flow, improving waiting times; Emergency Kanban, used to signal an unexpected change in quantity of product demand; Express Kanban, working similarly like the emergency kanban, but signalling the shortage of that specific product; Through Kanban, which functions as a combination of Production and Withdrawal kanbans, combining both cards in just a single one (Mazumdar, 2020).

2.5.5 Electronic kanban

The e-kanban (electronic kanban) was developed to improve the limits that were related to the traditional kanban system with cards (Figure 8). In the manual system, the information is passed using the traditional cards, whereas with this electronic improvement, the information travels in the form of an electronic signal, which allows the system to record and store important information about that specific item throughout the production flow (Houti et al., 2017; Ricky & Kadono, 2020; Sapry et al., 2020).

The introduction of information in the e-kanban system can either happen manually, using a keyboard, or automatically using a bar code reader. This technological improvement to the system allows for the reduction of unwanted time efforts and several types of operational waste (Houti et al., 2017; Jarupathirun et al., 2009; Ricky & Kadono, 2020; Svirčević et al., 2013).

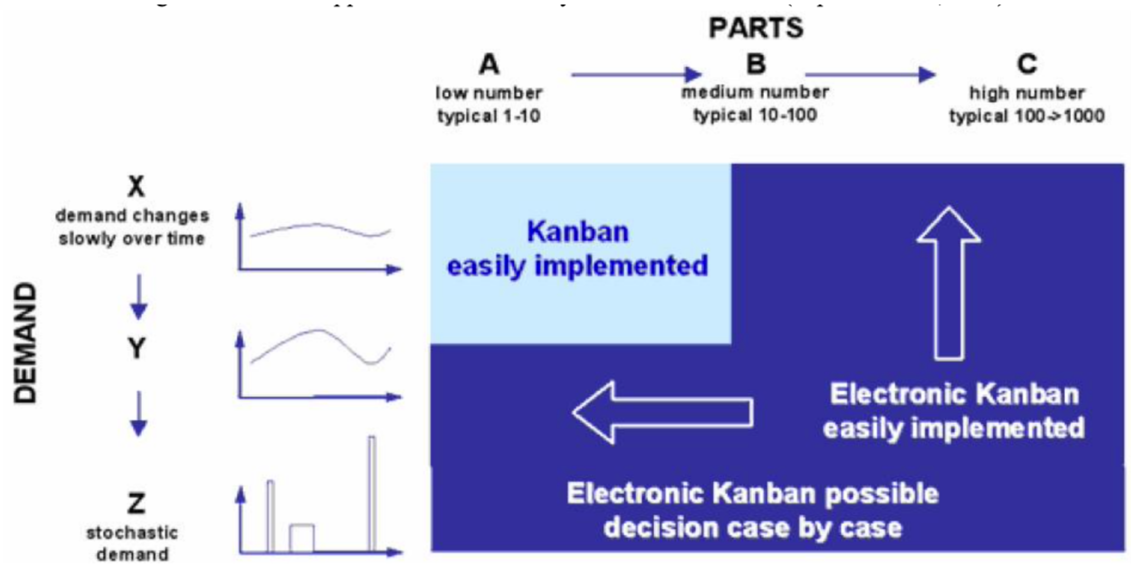

Figure 8: E-kanban advantages (Houti et al., 2017)

This computerization of the traditional kanban allows for several improvements when comparing with the traditional system (Houti et al., 2017; Romeira & Moura, n.d.; Sapry et al., 2020):

- Allows for the collection and analysis of data;
- Increases the speed of information transmission;
- Increases the transparency of the system;
- Supports the existing kanban processes;
- Allows for a faster adjustment in kanban quantities;
- Promotes the continuous improvement of the kanban system.

3 Current process

In order to better understand the application of the kanban system to the production process, as well as the difficulties that cum with it, all the relevant production processes are described and analysed.

The present chapter starts by describing the production process, represented in a VSM, followed by an illustrated explanation of how the kanban system works in the specific application to the factory production. The operational system of the kanban system is mapped and then studied. Finally, improvement opportunities are identified.

3.1 Production process

The factory at Renault Cacia, being one of the multiple factories from the Group Renault, works directly to the main assembly plants, where the automobiles are assembled and prepared to be delivered to the final customers.

Since the kanban system is only being applied to the factory's gearbox division, the focus will be on that specific plant. The assembly line is responsible for the production of the newest project of the JT4 gearbox, that will fit several models in the fleet of vehicles from the Group Renault.

This is a crucial component of a vehicle (Figure 9) since it allows the utilization of the momentum rotation of the engine, transferring that energy to the axels and wheels, moving the vehicle.

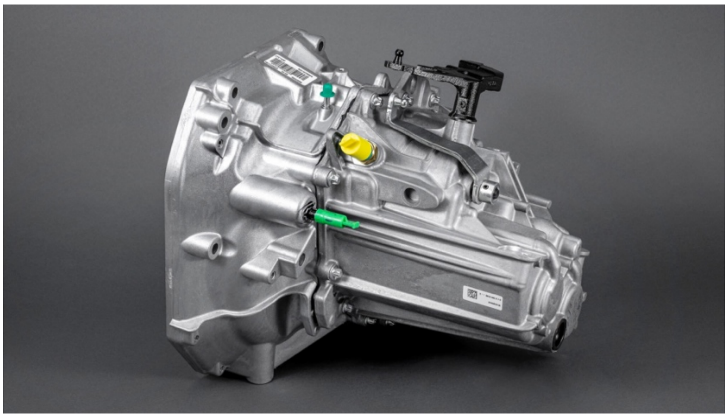

Figure 9: JT4 Gearbox (adapted from Renault´s official website)

This product is composed of several pieces, including clutch shafts, counter shafts, main shafts, gear selecting forks, bearings and multiple gears (as can be observed in the Figure 10).

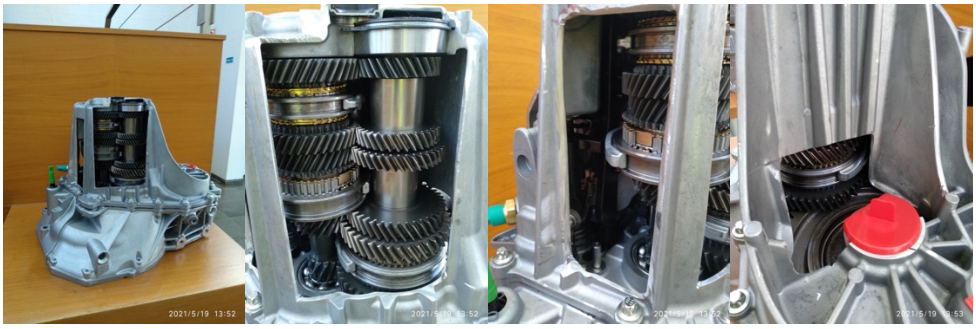

Figure 10: Different perspectives of the JT4 Gearbox

Despite the several components that take part in the gearbox, the focus of this project will be in the production lines of the gears and axel trees/shafts.

Table 1 gives a better description of the different types of parts that are produced in the production flows, with a more detailed description of the piece's varieties.

Table 1: All the pieces produced in the flow

Products	Rapports	Products	Rapports
AP	11x45	**PL4**	35x39
	11x43		38x39
AS	15x58	**PL5**	41x35
	14x63		43x32
	14x59	**PL6**	43x29
	14x69		50x28
ASH	15x58	**PL Mar**	45x44
	14x63		43x42
	14x59	**PFx3**	26x41
	14x69		29x43
PL1	11x45	**PFx4**	35x39
	11x43		38x39
PL2	17x41	**PFx5**	41x35
	17x39		43x32
PL3	26x41	**PFx6**	43x29
	29x43		50x28

The route that these pieces take, since when they arrive from the foundry supplier until they reach the assembly line is condensed in the Figure 11.

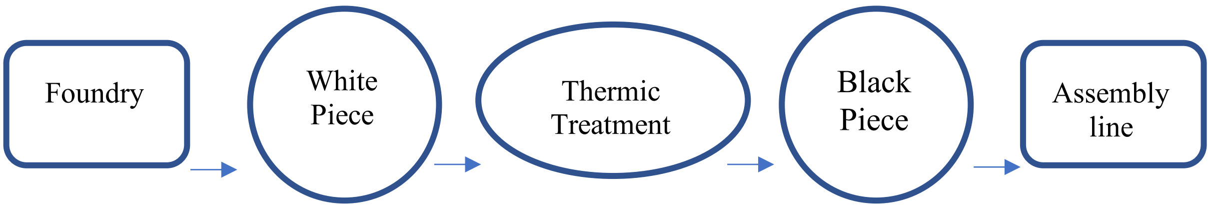

Figure 11: Production flow

The pieces of rough metal, received at the factory from the foundry partner, pass through the main three areas:

- White Piece Sector;
- Thermic Treatment Sector;
- Black Piece Sector.

When those pieces leave the last stage, they are ready to be provided to the final assembly line, where the gearboxes are assembled and prepared to be shipped to its customer.

3.2 Detailed explanation of the production process

The beginning of this production flow starts with the reception of the rough pieces of metal that come from the different foundries that are partnered with the group. These pieces are in an oversized shape, ready to suffer the initial milling process (as can be observed in Figure 12).

Figure 12: Aspect of a rough gear and shaft

3.2.1 White Piece Sector

This first sector is responsible for the initial machining of the pieces that come from the foundry. In this process, the pieces go through a series of milling processes, that give the initial shape of each piece. After this, the pieces take different routes, since several gears go through a welding process, where a specific part is welded to the gears, and then go to the washing area, whereas the shafts go straight to the washing area. In the end of this step, there is a stock area, responsible for the housing of the finished pieces, waiting to be sent to the next phase (as can be observed in Figure 13).

These differences in this first production process, can be observed in Appendix A, where a VSM (Value Stream Map) was created to specify the route of each product in the factory.

Figure 13: Pieces ready to receive thermic treatment

3.2.2 Thermic Treatment Sector

This next step is responsible for providing the pieces with a thermic treatment that will allow them to resist to the use and impact of the gearbox in the different vehicles. Here, the pieces go through an oven that functions at temperatures of 800ºC, allowing for a molecular redistribution, strengthening its structures and preparing them for the extreme usage. After leaving the oven, they pass again through a washing area and achieve the look that can be seen in the Figure 14.

Figure 14: Pieces after leaving the oven

After the oven, and still in the Thermic Treatment Sector, the pieces go through a step of dust blasting, where they are pulverized with black dust, helping to improve, even further, the durability of the parts that will make the internals of the gearboxes. Both in the end of the oven and dust blasting, the finished pieces are stored in a stock area, waiting to go through the next step (as can be observed in Figure 15).

Figure 15: Pieces after the dust blasting process

3.2.3 Black Piece Sector

The final step in the production of the pieces that will be mounted in the gearboxes, is responsible for their end shape. This step, also called rectification, sends the pieces through a series of grinding stones, removing the excess material, and finishing them with the designed dimensions. These, again, go through a washing process and are finally ready to be sent to the assembly line. These finished pieces are, then, stored in a specific area, destined to hold the products until the assembly line needs to use them (as can be observed in the Figure 16).

Figure 16: Pieces ready to be sent to the assembly line

The manufacturing stages end with this step, being the following actions a responsibility of the logistics department, where they have to prepare and assemble the boxes with all the components necessary to build the gearboxes.

3.3 Electronic Kanban associated with the production flow

The electronic kanban (whose main interface can be seen in the Figure 17) applied at the factory works the same way as the traditional system with cards, but with technology associated with it, allowing for an interconnectivity that enables a good communication throughout the factory.

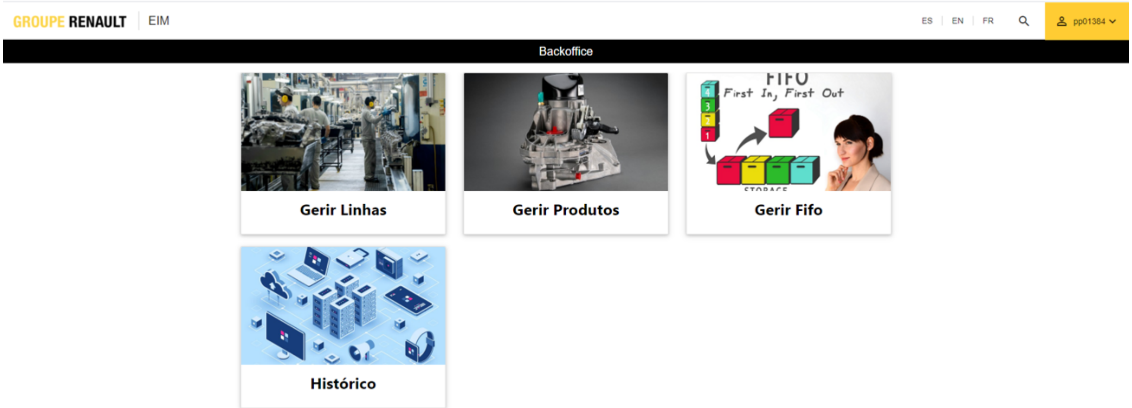

Figure 17: Main page of the kanban system

The working principle of this system is the rotation of labels through the different stages of the production flow. These labels contain a certain amount of a specific part, which is used to identify the different products. Every time a production phase is completed, a worker is responsible to introduce that information into the system, passing the label to the next phase, keeping track of the position of the different pieces.

In order for the system to operate in the correct order, the kanban needs to be introduced with different calculations and parameters, which allow for the correct transcription of the reality of the production flow to the system. These parameters are introduced in a software called EKS (Easy Kanban System), where they are used to determine the number of labels per product in each FIFO, as well as the number of pieces per label that will be circulating.

The characteristics necessary to provide to the kanban system are:

- Cycle time;
- OEE (Overall Equipment Efficiency);
- Manufacturing rate;
- Batch sizes;
- Set-up times;
- Safe amount of stock size.

With these details, the EKS system (whose layout can be observed in Figure 18) is capable of providing the specific number of labels for each piece, as well as the accumulation amount, in order to guarantee an efficient production order, as will be explained in the following paragraphs.

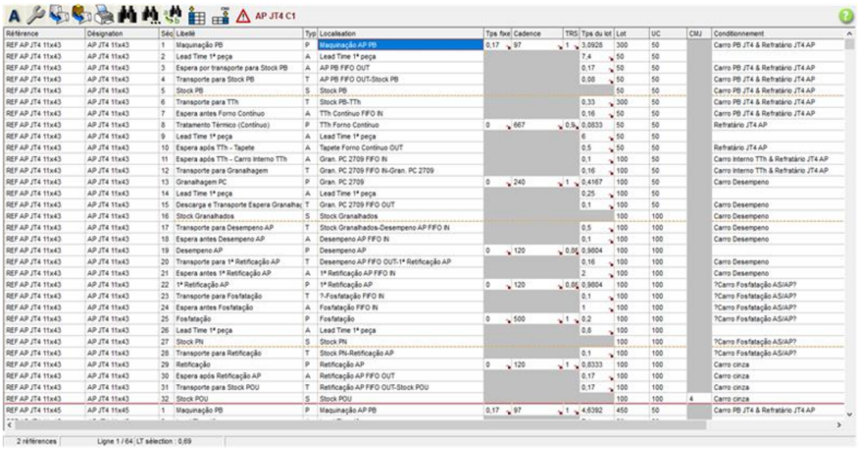

Figure 18: EKS system with all the information to dimension the kanban

Each production phase, which in this case are four steps, is represented in a FIFO (First In, First Out), following the mentality that the first pieces ready, are the first ones to go through the next step. The different labels circulate between the different FIFOs, beginning in the White Piece Sector, passing to the oven, then dust blasting and ending in the Black Piece Sector. Each FIFO is characterized with four states (Prod, WIP, Stock and Accumulation), and inside each FIFO, the labels circulate through the order represented in Figure 19. Each label starts in the Prod stage, passing to the WIP step, then going to the Stock phase and finally go to the Accumulative one.

- Prod

This state represents the beginning of each FIFO. It has, in the correct sequence, all the correct orders of production that the system is “pulling”.

- WIP (Work in Progress)

This phase indicates that the pieces are under work, which in this specific case means that they are under fabrication in the manufacturing lines.

- Stock

This step concludes the production phase, indicating that the pieces are ready for the next client of the value chain.

- Accumulation

This is a waiting stage, where the pieces are stopped until they reach a specific amount in the labels, which then can go back to the Prod phase (the specific number of pieces that is necessary is related to the production order in the Prod stage).

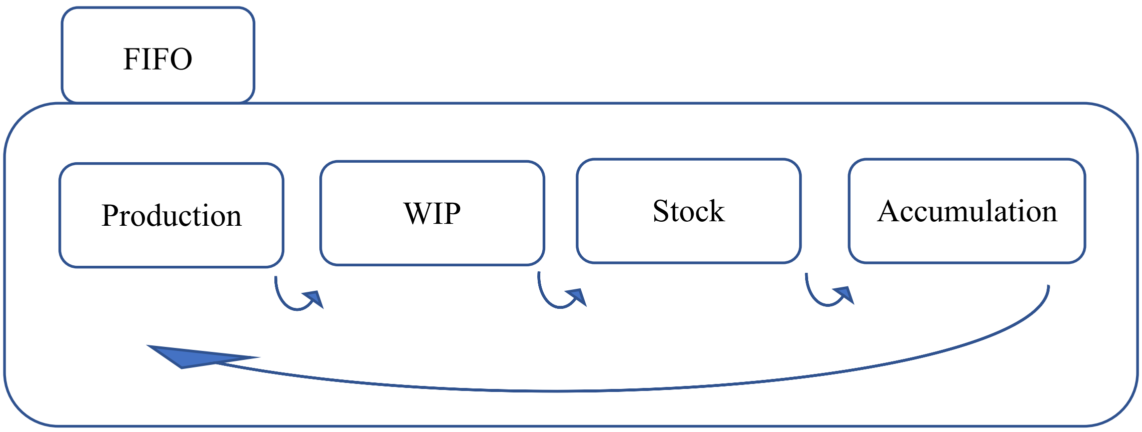

Figure 19: FIFO´s functionality

Since there are four FIFOs, the necessities that make the pull system function are generated by the following “clients”. This means that the prod state of each FIFO is defined by the succeeding FIFO. For example: if there is an oversized stock of a specific piece in the third FIFO, in the second one will not be a production order, until those stock levels reduce to a certain amount. On the other hand, if there is a shortage of stock of that same piece in the fourth FIFO, the production order in the third one will be pulling that piece to the highest priority of production.

There are several types of labels that can be implemented in the kanban system. These labels vary between their objective, and can be describes as:

- MTS (Make to Stock)

The most used labels in the system, which have a specific number defined, and automatically circulate through the different FIFOs.

- MTO (Make to Order)

As the name represents, these labels are only used in specific moments when the client asks for special pieces, which have low production numbers. These are labels that are introduced in the system manually, and after they circulate through the entire Kanban system, they are automatically deleted.

- AVP (Advance in Production)

These labels are also temporary in the system and are used when the production quantities are higher than the limits that were defined by the EKS system for the kanban.

An important aspect of the kanban system, besides respecting the FIFO rule, is to have a well-defined and calculated order of production. These orders are very important because they will be the information that each factory worker will see when they start the manufacturing process in each production line. These orders take in consideration the information that the EKS provides, calculating a good balance for the production of each product type having in consideration the time spent to change the manufacturing line type and to reach the highest OEE. Here is where the accumulation steps in, allowing for the correct number of pieces to go to the Prod phase. For example, in the production line of the ASH (High Secondary Shaft), the order of production should be well balanced, in order to optimize the OEE of the line (as can be observed in Figure 20).

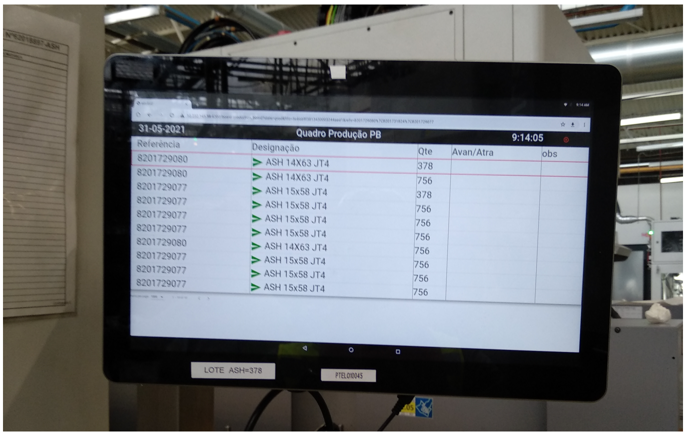

Figure 20: Order of production in the ASH production line

3.4 Description of the original Kanban system

In order to better understand the functionality of this system, a complete description of the process is explained. The basics of this system can be understood in the Figure 21.

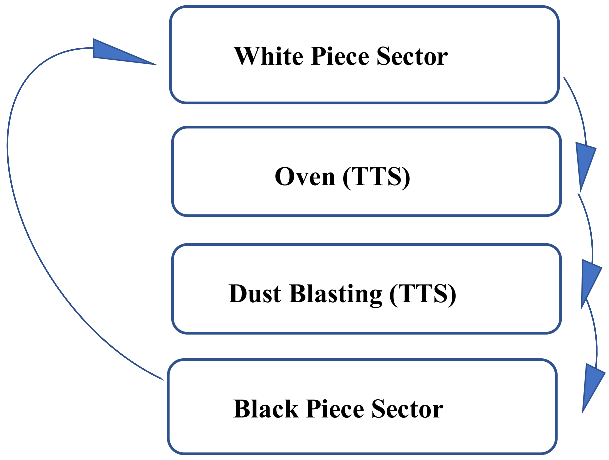

Figure 21: The 4 FIFOs that compose the factory´s kanban

The journey of the kanban in the factory starts in the beginning of the milling machines, in the White Piece Sector. Here the production workers have displayed the different quantities of the different pieces that they have to manufacture. The visualization tools used are tablets, which are specially certified by the Group Renault for this specific applicability. The correspondent FIFO is the one related to the White Piece Sector, and the labels are in the Prod state.

Figure 22: Kanban tablets in the production lines

The first moment of introducing information into the kanban puts the rough pieces of metal that came from the foundry in the state of WIP (Figure 22), which indicate that they are under work. When those pieces are ready, they are sent to the Stock area of the White Piece Sector, and there, a designated person is responsible for giving the second introduction in the system, which put the pieces in the state of Stock of that first FIFO (Figure 23). The third action to the system is done when the pieces are sent to the Thermic Treatment Sector, which is done by the same person who does the second action (Figure 23). Here, the first FIFO is completed, and the labels travel to the second FIFO, which is related to the Thermic Treatments, specifically the oven.

Figure 23: Stock area of the WPS

This step puts the pieces in the state of WIP, meaning that they are inside the oven. After leaving the oven, the fourth action to the system happens, passing the labels to the state of stock of the second FIFO. In the same place, but in a different table, the fifth moment of feeding the system happens when the labels leave the stock state of the second FIFO and travel to the WIP stage of the third FIFO (Figure 24).

Figure 24: Tablets placed in between the oven and dust blasting

This WIP stage of the dust blasting process, which has a short period of time, then leads to the sixth interaction with the system, putting the pieces in the state of stock of the third FIFO (Figure 25). Here the processes in the Thermic Treatment Sector stop, and only the final sector is missing.

Figure 25: Dust blasting tablet

In this final sector, the three last actions to the kanban system are condensed. The seventh action removes the labels from the state of stock of the previous FIFO and puts them in the state of WIP of the fourth FIFO. The following one, the eighth, passes the labels to the stock phase of the fourth FIFO (Figure 26).

Figure 26: BPS stock area

The nineth and last interaction with the system is done by the logistics workers, who pick the finished pieces in the stock area of the Black Piece Sector and take them to their stock area (Figure 27), where they prepare everything to provide the necessary items to the assembly line. These two last interventions to the kanban system are done by an operator in the stock zone, who is responsible for receiving the labels that identify the pieces and register them in the system.

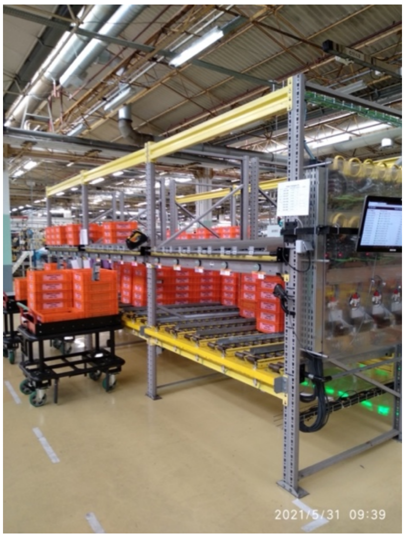

Figure 27: Logistics' stock to provide the assembly line

3.5 Improvement opportunities

The analysis of the operational side of the kanban system suggests the existence of opportunities both to improve the reliability of the system, as well as to maximize its functionalities, in order to become a fundamental tool for the production management activity.

3.5.1 Change the structure of the FIFO´s system

The visualization of the process demonstrates that there is a large accumulation of pieces in the White Piece Sector (Figure 28), causing the wrong functionality of the kanban, as well as providing the best condition to create scrap pieces, since the finished goods are stored without any thermic treatment, being exposed to the air, allowing for corrosion and parts waste.

Figure 28: Initial state of the WPS stock

Reducing the amount of stock that is placed in this area will help to decrease the scrap pieces, as will improve the flow of those pieces to the Thermic Treatment Sector. Here, working with a smaller number of products, will allow the workers to fulfil the "First In, First Out" procedure, something that was not happening previously.

3.5.2 Improve the human interaction with the electronic system by the factory workers

The initial analysis shows that there is a big difference between the number of pieces in the real production flow, and the information presented in the kanban system, in each day of production (Figure 29).

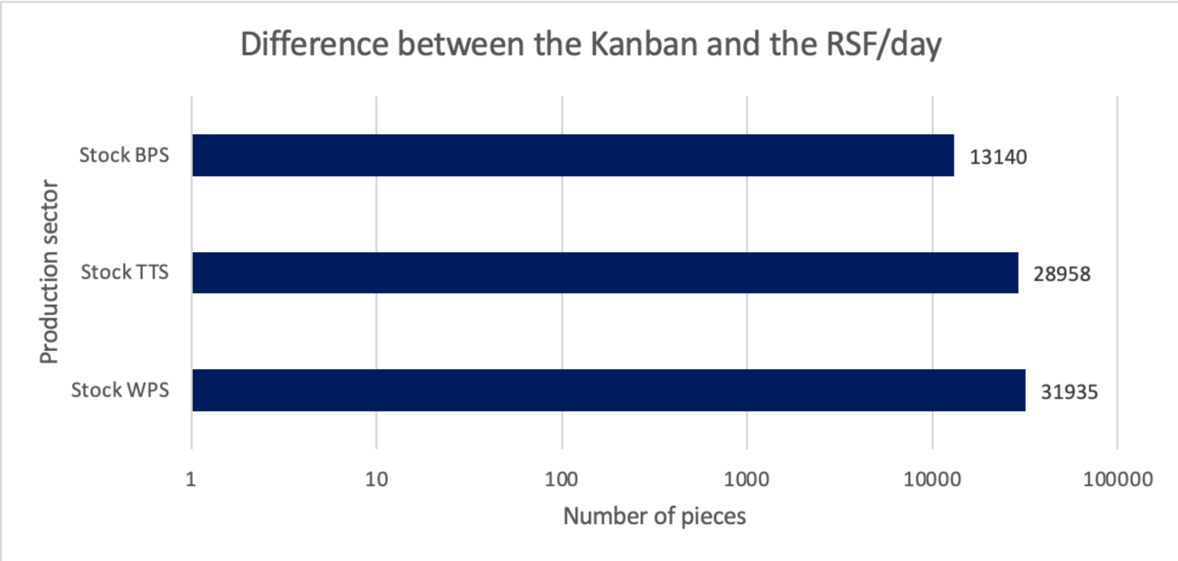

Figure 29: Initial evaluation of the kanban efficiency

This discrepancy is mainly because of the lack of human interaction with the system, whose origin is related to the following problems:

- Bad positioning of some tablets alongside with a flawed organization of who feeds the system, which lead to mistakes and forgetfulness by the workers;
- Big number of operations, which causes confusion for the workers that are using the system.

Creating a simpler system, which only needs the fundamental interactions allied with an intuitive usability action has the potential to gather the interest of the workers, who we know are the fundamental part of the production flow.

3.5.3 Improve the usability of the system by the production engineers

Use the systems capabilities to create several tools to describe the production quantities throughout the flow. Knowing the quantities of each product, in each step, is crucial to the production management team to react to what is happening to the factory in real time.

Another improvement aspect is related to the priorities in each sector, that are calculated by the kanban. By implementing some sort of alerts in the system, when the kanban detects a shortage of pieces in the production flow, it has the possibility to send messages to the production managers, in order to prioritize that specific part in the specific production line where is needed.

3.5.4 Improve the reliability of the tool

One of the most important methodologies when implementing changes in a process is to track its evolution. In this case, a parametrization tool that compares the declarations of production and the historic of interaction to the system, would help to analyse the evolution of the system, in order to understand the points where failure is being created and proceed to correct them.

In situations of discrepancy between the reality and the electronic system, due to the lack of human interaction, a tool that could help with the quick correction of the system, would improve with the truthfulness of the information that is presented in the system.

4 Proposed actions

The actions proposed compromise four lines of motion (Figure 30). First, the modification of some of the systems points of interaction, being the second the modification of the FIFO´s organization. Then, the creation of an interface within the system, that helps to manage the production. Last, the creation of tools to measure the progress and facilitate the correction of the system.

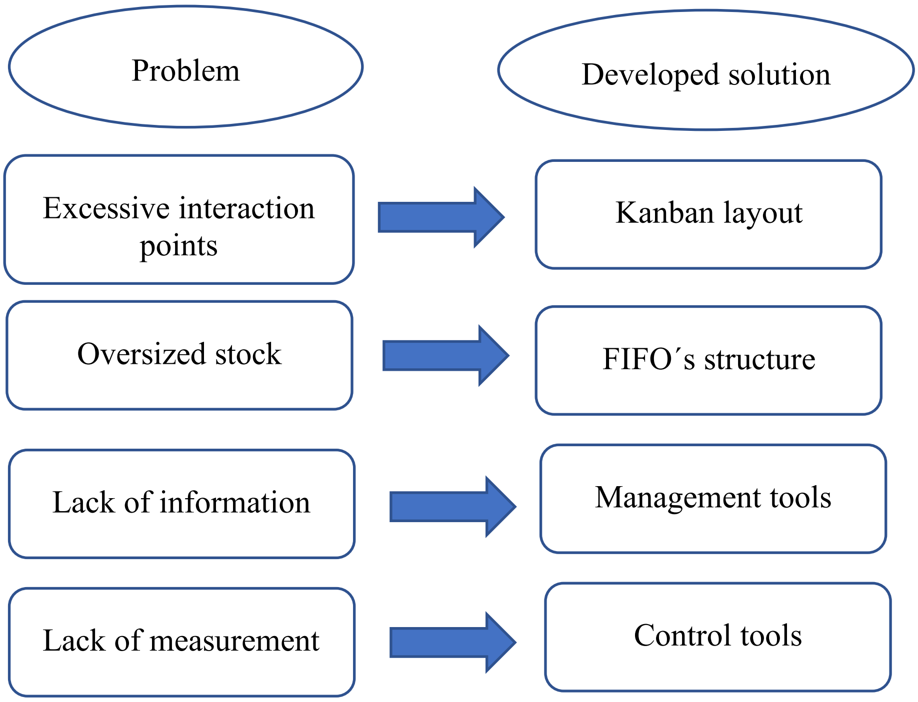

Figure 30: Improvement programme for the kanban

4.1 New Kanban layout

Since the kanban system is fuelled by the introduction of information by the factory workers, and we know that when a human being is related to some sort of action, there is always a possibility of existing an error, one of the possibilities is to improve and facilitate the conditions, as well as reducing the number of human interactions with the system. This must be a sensible choice, because if we reduce this parameter in some sort, the level of detail that the kanban provides reduces, reducing its usefulness.

The analysis of the kanban production flow shows that there are two main aspects that can be improved:

4.1.1 Location of some interaction points with the system

The actions of passing the kanban labels from WIP to Stock in the first FIFO and from the Stock of the first FIFO to WIP in the second FIFO were done by a single person, outside the production lines. This allowed for a bigger margin of error since when it was done, the batch of pieces had already left the production lines and the person responsible was not fully aware of that piece's path. In order to solve this problem, the place where the second and third interaction with the system changed to the respective production lines (end of machining and the beginning of the oven, respectively), becoming the production workers responsible for the interaction with the system, and being capable of fixing any errors, if anything occurred (Figure 31). With this implementation, the objective was to have a bigger control of the pieces that were leaving the first FIFO and entering the second one, by putting the responsibility on the workers that are destined to their specific production lines. This is a more natural flow, which helps to improve with the fulfilment of the system.

Figure 31: Tablets positioned in the end of the production lines in the WPS

The same way of thinking can be applied to the last two interactions of the system. Previously the step of passing the labels from WIP to Stock and from Stock to Accumulation was also done by a single person, outside the production lines. Here, the responsibility was passed to the workers in the production lines for the eighth interaction, and the last interaction became the responsibility of the logistics' workers, transforming this process in a more natural and intuitive as possible (Figure 32).

Figure 32: Tablets in the end of the production line in the BPS

Also, a modification that was implemented was the application of a bar code reader (Figure 33), which allows for a quicker interaction with the system. This specific improvement was applicated in the last interaction with the system, where the logistic workers, who are already used to using this type of reading devices, use the tool to read the parts code, and automatically deduct the pieces from the Stock phase.

Figure 33: Bar code reader

4.1.2 Reduce a stage in the FIFO

Another improvement resulted from the analysis of the production process in the factory floor, which allowed to conclude that the process of dust blasting implicated a small period of time, when compared with the other processes, and it only allowed small quantities of pieces to be worked on each cycle time. This presented a chance to eliminate the phase of WIP in the third FIFO (Figure 34), converting the passage of the labels, which now would pass directly from the Stock of the second FIFO to the Stock of the third one. This action allowed for a reduction of one interaction with the system, in a place that, in the beginning of the project, was showing one of the highest rates of errors in the system. This change, in terms of parts location will unite the stock of the second FIFO and the WIP of the third FIFO, but since it is a quick and low capacity in terms of parts, there are no worrying problems associated with it.

Figure 34: Removal of the WIP stage

4.2 New FIFO´s structure

One of the biggest problems observed on the production lines was the oversized number of pieces that were stocked at the end of the first FIFO, the White Piece Sector. This happened because the factory was continuously producing pieces, even when the kanban was not asking for and that, combined with a smaller number of cars available to send those different pieces, originated an oversized number of products in that sector.

In order to reduce this factor, it was proposed to unify the first two FIFOs (Figure 35), transforming the Stock area of the White Piece Sector into a waiting area. This limits the number of pieces in that area, because since it is a WIP phase, it will only have what the Stock phase is asking for. With this change, that FIFOs stage will only have what is necessary, and will not be producing to stock. This will force to eliminate the higher quantities in the waiting area, strengthening the FIFO rule in that sector.

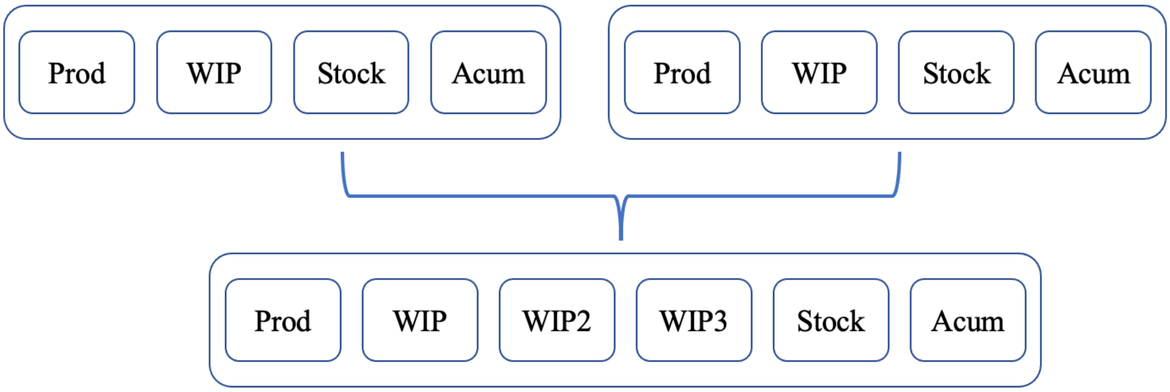

Figure 35: Changes in the FIFO structure

4.3 New management tools

These changes were created to improve the production management team capabilities. The main change is to create a global table that shows the specific number of pieces, from each reference of the pieces, that are placed in the different sections of production.

Table 2: Global stocks distributed throughout the production flow

Peça	PB	ENT. FORNO	FORNO	STOCK TTH	STOCK GRAN	WIP PN	STOCK PN	INDICE	TOTAL
AP 11X45-17X41 JT4	1700	4000	400	0	200	646	1890	002/004/008/011/013/016/017	**8836**
AP 11X43-17X39 JT4 006	0	0	0	0	0	2	0	006/012/015/018	**2**
AS 14X63 JT4	50	2000	400	550	0	848	2248	002/006/008/012	**6096**
AS 14X69 JT4	0	0	0	0	0	0	0	013/018	**0**
AS 14X59 JT4	0	0	0	0	0	0	0	17	**0**
AS 15X58 JT4	450	3650	1400	550	350	444	184 ! 2	004/016	**7028**
ASH 14x63 JT4	0	0	0	0	0	252	1716	002/006/008/012	**1968**
ASH 14X69 JT4	0	0	0	0	0	0	0	013/018	**0**
ASH 14X59 JT4	0	0	0	0	0	0	0	17	**0**
ASH 15x58 JT4	756	756	378	0 ! 3	378	0	480	004/016	**2748**
PL1 11X45 JT4	180	3420	1170	180	1170	180	240	002/004/008/011/013/016/017	**6540**
PL1 11X43 JT4 006	0	0	0	0	540	0	0	006/012/015/018	**540**
PL2 17X41 JT4	1296	4752	648	0	1620	180	300	002/004/008/011/013/016/017	**8796**
PL2 17X39 JT4 006	0	648	432	432	1620	0	0	006/012/015/018	**3132**
PL3 26X41 JT4	0	4256	0	448	224	1824	1200	002/004/008/011/013/016/017	**7952**
PL3 29X43 JT4 006	0	0	224	0	0	0	0	006/012/015/018	**224**
PFX3 26X41 JT4	4320	0	900	360	0	0	2232	002/004/008/011/013/016/017	**7812**
PFX3 29X43 JT4 006	0	0	0	0	0	0	0	006/012/015/018	**0**
PL4 35X39 JT4	0	7056	288	1008	0	0	2076	002/004/008/011/013/016/017	**10428**
PL4 38X39 JT4 006	0	576	0	0	2592	0	0	006/012/015/018	**3168**
PFX4 35X39 JT4	4896	0	576	0 ! 1	0	0	480	002/004/008/011/013/016/017	**5952**
PFX4 38X39 JT4 006	0	0	0	0	0	0	0	006/012/015/018	**0**
PL5 41X35 JT4	4752	0	576	576	432	0	564	002/004/008/011/013/016/017	**6900**
PL5 43X32 JT4 006	0	864	0	0	1152	0	0	006/012/015/018	**2016**
PFX5 41X35 JT4	8640	0	640	0 ! 1	0	1304	0 ! 1	002/004/008/011/013/016/017	**10584**
PFX5 43X32 JT4 006	0	0	0	0	0	0	0	006/012/015/018	**0**
PL6 43X29 JT4	1296	144	1584	0	432	420	1200	002/004/008/011/013/016/017	**5076**
PL6 50X28 JT4 006	0	1728	0	0	432	384	480	006/012/015/018	**3024**

Table 2, besides providing the detailed information of the stocks in each sector, will also provide alerts, whose function is to prioritize the pieces that are more important to produce, in order to prevent failures when supplying pieces to the following "customers". These alerts were programmed to be sent by email to the specific engineers, responsible for that failing production line (An example of an email can be analysed in the Appendix B).

Another important improvement is related to the timing of each production label. This functionality, developed at the end of this project, helps the production engineers to know if the production rates are at a good speed, or if they can face a problem of failing to feed the next phase of the FIFO on time (Figure 36). It functions by comparing the stock quantities of each FIFO with the labels in the WIP stages, and according to the productions rates, calculates the timing of each label. The green areas represent a production situation on time and the red areas represent a production situation of delay.

Quadro Produção AS PB

Referência	Designação	Qte	Avan/Atra	Obs
7701717833	AS 14X69 C200	504	225h 12m	.
7701717833	AS 14X69 C200	504	225h 12m	.
7701717799	AS 14x63	504	225h 12m	.

Produção Linha 1/2

Referência	Designação	Qte	Avan/Atra
8201729202	PL1 PB 11X45 JT4	180	2301h 52m
8201729202	PL1 PB 11X45 JT4	180	2301h 52m

DIRECTION/ LOGISTIC | DATE | RENAULT INTERNAL | GROUPE RENAULT

Figure 36: Timing of the production labels

4.4 New parametrization tools

When implementing changes to a process, it is important to measure the progress of those changes and if they are having a good impact on the main process. In this specific case, there were created two methodologies to measure the reliability of the kanban, as well as correcting it, when there were errors in the quantities that were displayed in the system.

4.4.1 Evolution control method

Regarding the evolution of the system, this analysis was created having in consideration the actual declarations of production, based on the RSF data base, from the different sectors and comparing it with the record of all the interactions that the kanban system had registered. For this analysis, it was necessary to create a history backup of the several information that were provided to the system by the factory workers, as can be observed in the figures 37 and 38.

data	dia_industrial	turno	fifo	referencia	designacao	estado	estado_seguinte	quantidade	segue_ordem	comentario
1-6-2021 1:3:38	31-5-2021	3º Equipa	THContinuo	8201729085	AS 15X58 JT4	wip	wip2	1		passar etiqueta para o estado seguinte
1-6-2021 1:5:52	31-5-2021	3º Equipa	THContinuo	8201729085	AS 15X58 JT4	prod	wip	1	Não	passar etiqueta para o estado seguinte- não segue a ordem, a ref correta seria 8201731
1-6-2021 1:6:5	31-5-2021	3º Equipa	THContinuo	8201729226	PL MAR 45X44 JT4	wip	wip2	1		passar etiqueta para o estado seguinte
1-6-2021 1:6:9	31-5-2021	3º Equipa	THContinuo	8201729226	PL MAR 45X44 JT4	wip	wip2	1		passar etiqueta para o estado seguinte
1-6-2021 1:6:13	31-5-2021	3º Equipa	THContinuo	8201729226	PL MAR 45X44 JT4	wip	wip2	1		passar etiqueta para o estado seguinte
1-6-2021 1:17:56	31-5-2021	3º Equipa	THContinuo	8201729224	AP 11X45-17X41 JT4	wip	wip2	1		passar etiqueta para o estado seguinte
1-6-2021 1:17:56	31-5-2021	3º Equipa	THContinuo	8201729224	AP 11X45-17X41 JT4	wip	wip2	1		passar etiqueta para o estado seguinte
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		
1-6-2021 1:20:17	31-5-2021	3º Equipa	PL5/6_PN	323713969R	PL5 41X35 JT4	stock	acumulação	1		

Figure 37: History backup document downloaded

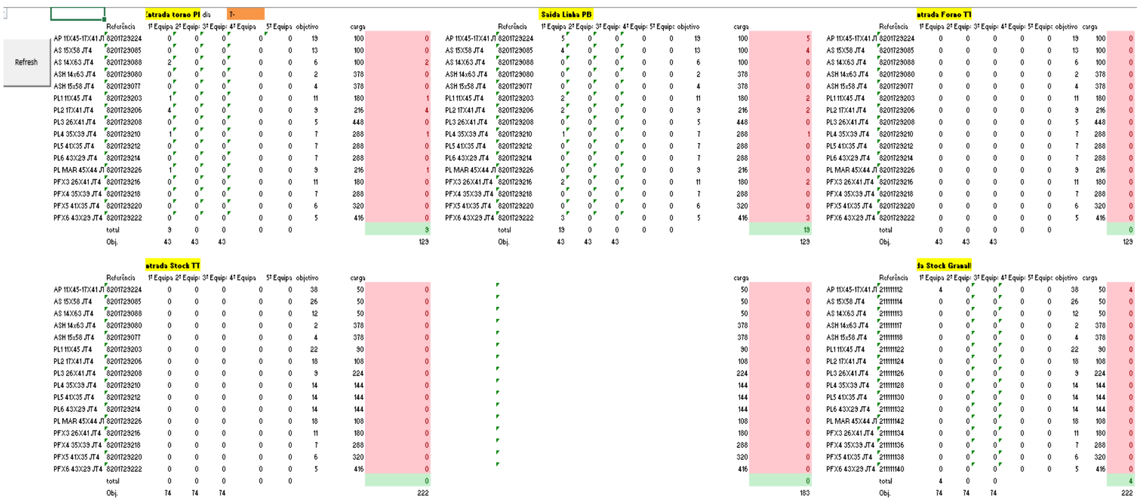

Figure 38: Filter applied to the history backup file

By having a history backup, it has been possible to detect if the failures in the system were caused by a lack of interaction to the system, or, on the other side, an excessive amount of information provided.

This analysis was done for each manufacturing sector, distinguishing each production line and through the different working shifts (Table 3). It also allowed the quantification of the difference between the RSF and the kanban, specifying the number of interactions that were missing or were in excess (Table 4). This tool allows both to determine who is failing to interact with the system, as well as helping to find errors and bugs in the system.

Table 3: Comparison between the RSF and the kanban

	Saida Linha PB									
	1º Turno		2º Turno		3º Turno		4º Turno		5º Turno	
	RSF	Kanban	RSF	Kanban	RSF	Kanban	RSF	Kanban	RSF	Kanban
AP 11X45-17X41 JT4	640	13	648	18	712	2				
AS 15X58 JT4	0	0	309	4	710	14				
AS 14X63 JT4	116	2	235	5	0	0				
ASH 14x63 JT4	0	0	0	0	0	0				
ASH 15x58 JT4	164	1	644	0	645	2				
PL1 11X45 JT4	392	9	500	3	762	2				
PL2 17X41 JT4	800	0	580	1	750	3				
PL3 26X41 JT4	770	2	800	4	712	3				
PL4 35X39 JT4	450	2	286	1	600	2				
PL5 41X35 JT4	760	0	660	0	800	8				
PL6 43X29 JT4	760	0	738	9	680	2				
PL MAR 45X44 JT4	220	0	797	5	620	4				
PFX3 26X41 JT4	642	8	360	0	0	0				
PFX4 35X39 JT4	631	0	831	2	910	4				
PFX5 41X35 JT4	375	0	1120	0	1700	0				
PFX6 43X29 JT4	326	3	0	0	0	0				

Table 4: Detailed information about who failed when interacting with the system

	1º turno	QTD	2º turno	QTD	3º turno	QTD
AP 11X45-17X41 JT4	Falha p/ excesso	1	Falha p/ excesso	6	Falha p/ defeito	13
AS 15X58 JT4	OK		Falha p/ defeito	3	Falha p/ defeito	1
AS 14X63 JT4	Falha p/ defeito	1	Falha p/ excesso	1	OK	
ASH 14x63 JT4	OK		OK		OK	
ASH 15x58 JT4	Falha p/ excesso	1	Falha p/ defeito	2	Falha p/ excesso	1
PL1 11X45 JT4	Falha p/ excesso	5	Falha p/ defeito	3	Falha p/ defeito	7
PL2 17X41 JT4	Falha p/ defeito	8	Falha p/ defeito	5	Falha p/ defeito	4
PL3 26X41 JT4	Falha p/ defeito	2	Falha p/ excesso	1	Falha p/ defeito	1
PL4 35X39 JT4	Falha p/ defeito	2	Falha p/ defeito	1	Falha p/ defeito	3
PL5 41X35 JT4	Falha p/ defeito	6	Falha p/ defeito	5	Falha p/ excesso	3
PL6 43X29 JT4	Falha p/ defeito	6	Falha p/ excesso	4	Falha p/ defeito	3
PL MAR 45X44 JT4	Falha p/ defeito	3	Falha p/ defeito	3	Falha p/ defeito	2
PFX3 26X41 JT4	Falha p/ excesso	5	Falha p/ defeito	2	OK	
PFX4 35X39 JT4	Falha p/ defeito	3	Falha p/ defeito	1	Falha p/ excesso	1
PFX5 41X35 JT4	Falha p/ defeito	2	Falha p/ defeito	4	Falha p/ defeito	6
PFX6 43X29 JT4	Falha p/ excesso	3	OK		OK	

These tools had a double impact, since they allowed us to check the specific areas that were failing when it came to feed the system, but also allowed to check if the changes that were made were working correctly.

The strategy that was implemented was to daily send a report, that can be viewed in the Appendix C, for the several manufacture CUETs, who then were responsible to talk to the production workers to understand the origin of the error and if necessary, teach them the right way to do.

One other problem that was encountered was the lack of information that was provided to the night and weekend working shifts. This is a problem related to the high number of shifts that the factory has, since during the week there are three shifts and two more in the weekend. In order to solve this issue, were created several documents, called FOS (Folha de Operações Standard), which contained detailed information about the several processes of interacting with the kanban system. The objective with these documents was to make any doubts that may occurred with the system easy to solve autonomously. The procedure that was followed was to teach the workers on how to interact with the system, and in case of any doubt, the FOS would be available to clarify everything. An example of a FOS that was developed can be consulted in the Appendix D.

During the implementation of these changes, several meetings were held to analyse the problems that were occurring with the system, and in order to solve those problems, a document (LUP - Lista Única de Problemas), was created to detail each problem and monitor it, until it was solved. An example of this document can be analysed in the Appendix E.

During the last two weeks of the project, this parametrization was done, and the results are displayed in the Table 5. The different colours represent the three types of situations that could happened. The red areas represent a percentage of compliance of below 80%, while the orange ones represent a compliance of over 100%. Here, a value of over 100% of compliance means that the system was updated with a higher quantity of pieces produced when comparing with the reality, which is a very complicated mistake for the kanban. The green area, between 80% and 100% represents the "safe zone" where the workers were complying with the system. The objective was to every two weeks shorten this gap, in order to increase the evaluation parameters and improve the reliability of the kanban.

Table 5: Results from the parametrization tool

Taxa de realização de Picagens - Kanban

		Sab - 22 Maio		Dom - 23 Maio		Seg - 24 Maio			Ter - 25 Maio			Sex - 28 Maio			Sab - 29 Maio		Dom - 30 Maio	
Setor	Artigo	4º turno	5º turno	4º turno	5º turno	1º turno	2º turno	3º turno	1º turno	2º turno	3º turno	1º turno	2º turno	3º turno	4º turno	5º turno	4º turno	5º turno
PB	AP 11X45-17X41 JT4	7000%	7000%	78%	60%	98%	51%	119%	293%	131%	129%	78%	85%	162%	335%	0%	83%	41%
	AS 15X58 JT4	77%	200%	200%	87%	95%	106%	100%	72%	112%	95%	109%	102%	89%	68%	300%	0%	0%
	AS 14X63 JT4	45%	106%	45%	200%	100%	0%	91%	286%	0%	100%	100%	100%	100%	200%	13%	200%	200%
	ASH 14x63 JT4	50%	145%	0%	0%	200%	144%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	ASH 15x58 JT4	0%	100%	100%	100%	0%	0%	73%	118%	118%	60%	61%	132%	115%	79%	155%	89%	126%
	PL1 11X45 JT4	18%	0%	0%	0%	183%	180%	115%	100%	140%	118%	0%	0%	0%	0%	100%	0%	100%
	PL2 17X41 JT4	0%	100%	0%	100%	86%	101%	108%	54%	122%	62%	0%	0%	100%	0%	100%	21%	100%
	PL3 26X41 JT4	0%	92%	0%	74%	200%	93%	138%	100%	50%	32%	100%	0%	0%	0%	0%	0%	0%
	PL4 35X39 JT4	0%	107%	0%	0%	123%	32%	77%	71%	89%	108%	113%	351%	0%	0%	0%	0%	0%
	PL5 41X35 JT4	0%	100%	0%	0%	0%	200%	173%	72%	0%	144%	77%	96%	0%	0%	43%	0%	28%
	PL6 43X29 JT4	0%	40%	0%	0%	0%	200%	200%	200%	100%	100%	0%	79%	117%	0%	122%	100%	83%
	PL MAR 45X44 JT4	103%	94%	200%	103%	36%	100%	154%	38%	100%	42%	0%	0%	68%	59%	167%	91%	96%
	PFX3 26X41 JT4	0%	200%	0%	200%	93%	77%	0%	0%	92%	0%	0%	0%	0%	0%	100%	0%	100%
	PFX4 35X39 JT4	0%	200%	0%	200%	0%	204%	0%	0%	97%	0%	0%	0%	0%	0%	200%	0%	100%
	PFX5 41X35 JT4	100%	200%	100%	200%	100%	100%	0%	200%	100%	100%	100%	0%	0%	0%	100%	0%	100%
	PFX6 43X29 JT4	0%	100%	0%	100%	0%	146%	100%	0%	0%	0%	0%	100%	200%	100%	200%	100%	100%
TTh	AP 11X45-17X41 JT4	0%	56%	0%	13%	60%	100%	15%	27%	60%	0%	100%	100%	0%	53%	0%	11%	0%
	AS 15X58 JT4	0%	94%	0%	50%	100%	80%	88%	122%	116%	79%	100%	100%	0%	35%	0%	135%	0%
	AS 14X63 JT4	100%	100%	100%	100%	0%	0%	0%										
	ASH 14x63 JT4	0%	0%	0%	0%	50%	50%	50%	0%	0%	300%	100%	200%	0%	67%	200%	0%	0%
	ASH 15x58 JT4	100%	100%	100%	100%	0%	0%	0%										
	PL1 11X45 JT4	18%	50%	17%	23%	117%	33%	50%	100%	100%	0%	200%	200%	0%	0%	0%	0%	0%
	PL2 17X41 JT4	44%	44%	0%	0%	300%	100%	0%	33%	100%	0%	100%	100%	0%	0%	0%	145%	0%
	PL3 26X41 JT4	100%	17%	40%	25%	50%	0%	100%	100%	100%	0%	100%	100%	100%	75%	100%	0%	0%
	PL4 35X39 JT4	0%	0%	0%	8%	33%	60%	100%	0%	50%	0%	100%	100%	0%	129%	0%	50%	0%
	PL5 41X35 JT4	0%	67%	200%	0%	100%	50%	0%	0%	100%	0%	100%	200%	0%	300%	0%	150%	0%
	PL6 43X29 JT4	100%	100%	100%	56%	0%	22%	0%	100%	100%	0%	100%	100%	100%	200%	100%	0%	0%
	PL MAR 45X44 JT4	0%	0%	0%	22%	100%	67%	250%	100%	83%	100%	100%	200%	0%	0%	0%	1100%	0%
	PFX3 26X41 JT4	0%	0%	0%	33%	100%	100%	0%	0%	129%	0%	100%	100%	0%	100%	0%	450%	0%
	PFX4 35X39 JT4	0%	33%	50%	0%	50%	100%	0%	0%	100%	100%	100%	200%	100%	100%	0%	20%	100%
	PFX5 41X35 JT4	0%	100%	100%	0%	100%	0%	100%	100%	100%	0%	100%	100%	100%	0%	0%	0%	100%
	PFX6 43X29 JT4	100%	100%	100%	100%	100%	100%	133%	100%	0%	100%	100%	100%	100%	0%	100%	0%	0%
PN	AP 11X45-17X41 JT4	190%	0%	0%	100%	84%	114%	39%	86%	85%	43%	84%	100%	100%	171%	0%	155%	27%
	AS 15X58 JT4	100%	107%	76%	51%	80%	108%	101%	29%	109%	107%	49%	15%	0%	46%	0%	135%	0%
	AS 14X63 JT4	95%	0%	0%	71%	109%	100%	100%	0%	150%	100%	0%	100%	0%	0%	100%	200%	100%
	ASH 14x63 JT4	0%	0%	0%	0%	36%	0%	75%	38%	116%	100%	100%	100%	100%	100%	100%	100%	100%
	ASH 15x58 JT4	100%	100%	100%	0%	200%	100%	100%	100%	67%	101%	79%	137%	0%	0%	100%	0%	0%
	PL1 11X45 JT4	0%	0%	100%	100%	0%	71%	70%	0%	100%	95%	143%	90%	96%	61%	80%	25%	0%
	PL2 17X41 JT4	0%	0%	0%	100%	98%	86%	0%	102%	103%	123%	198%	100%	98%	102%	55%	91%	184%
	PL3 26X41 JT4	100%	100%	0%	0%	92%	76%	91%	98%	117%	114%	100%	100%	100%	100%	38%	191%	0%
	PL4 35X39 JT4	0%	100%	0%	0%	222%	100%	59%	95%	30%	60%	0%	121%	100%	100%	0%	91%	114%
	PL5 41X35 JT4	0%	0%	0%	100%	200%	98%	88%	88%	100%	94%	130%	100%	99%	88%	100%	75%	100%
	PL6 43X29 JT4	0%	100%	0%	0%	81%	231%	0%	178%	170%	84%	0%	100%	100%	100%	100%	100%	0%
	PL MAR 45X44 JT4	0%	0%	0%	0%	105%	200%	100%	78%	97%	127%	99%	55%	200%	120%	100%	69%	100%
	PFX3 26X41 JT4	0%	0%	0%	0%	0%	100%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	PFX4 35X39 JT4	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%	0%	0%
	PFX5 41X35 JT4	100%	100%	100%	0%	77%	198%	38%	421%	100%	100%	109%	100%	64%	119%	0%	100%	0%
	PFX6 43X29 JT4	100%	0%	100%	100%	100%	0%	37%	111%	151%	96%	0%	51%	182%	100%	0%	100%	0%

		Seg - 31 Maio			Ter - 1 Junho			Quar - 2 Junho			Quint - 3 Junho			Sex - 4 Junho			Sab - 5 Junho		Dom - 6 Junho		Seg - 7 Junho		
Setor	Artigo	1º turno	2º turno	3º turno	1º turno	2º turno	3º turno	1º turno	2º turno	3º turno	1º turno	2º turno	3º turno	1º turno	2º turno	3º turno	4º turno	5º turno	4º turno	5º turno	1º turno	2º turno	3º turno
PB	AP 11X45-17X41 JT4	74%	80%	150%	91%	54%	108%	108%	150%	14%	100%	100%	100%	260%	62%	125%	105%	61%	67%	50%	83%	186%	127%
	AS 15X58 JT4	100%	0%	93%	29%	100%	100%	100%	67%	100%	91%	86%	92%	125%	86%	100%	105%	105%	95%	89%	0%	0%	0%
	AS 14X63 JT4	32%	0%	100%	200%	92%	15%	100%	125%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	200%	175%	200%	200%
	ASH 14x63 JT4	100%	102%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	ASH 15x58 JT4	100%	100%	62%	200%	200%	100%	200%	0%	200%	100%	100%	100%	200%	200%	100%	150%	100%	100%	100%	100%	200%	100%
	PL1 11X45 JT4	75%	75%	26%	0%	0%	133%	225%	60%	25%	100%	100%	100%	100%	29%	100%	75%	100%	50%	100%	71%	0%	113%
	PL2 17X41 JT4	54%	84%	31%	200%	100%	100%	0%	20%	50%	100%	100%	100%	100%	0%	133%	67%	100%	33%	100%	117%	29%	17%
	PL3 26X41 JT4	97%	105%	47%	150%	200%	200%	67%	133%	100%	0%	33%	100%	100%	150%	150%	100%	200%	0%	75%	100%	100%	100%
	PL4 35X39 JT4	0%	186%	67%	300%	0%	0%	67%	100%	50%	0%	100%	100%	140%	0%	100%	80%	80%	0%	100%	100%	100%	250%
	PL5 41X35 JT4	100%	41%	82%	75%	50%	133%	0%	0%	160%	0%	100%	100%	125%	40%	200%	0%	200%	0%	200%	0%	0%	60%
	PL6 43X29 JT4	75%	0%	100%	50%	80%	75%	0%	180%	50%	0%	100%	100%	125%	50%	125%	0%	183%	0%	33%	0%	120%	150%
	PL MAR 45X44 JT4	50%	67%	46%	71%	33%	71%	0%	71%	80%	100%	100%	100%	80%	100%	100%	63%	111%	89%	110%	57%	29%	114%
	PFX3 26X41 JT4	118%	73%	90%	0%	75%	0%	267%	0%	100%	100%	100%	100%	0%	367%	0%	0%	0%	0%	200%	0%	0%	0%
	PFX4 35X39 JT4	148%	68%	32%	0%	67%	0%	0%	100%	133%	0%	100%	0%	100%	200%	100%	100%	0%	100%	100%	100%	100%	100%
	PFX5 41X35 JT4	100%	100%	145%	100%	100%	200%	0%	0%	0%	267%	0%	0%	0%	0%	0%	0%	100%	0%	100%	100%	0%	0%
	PFX6 43X29 JT4	100%	152%	100%	0%	0%	100%	200%	100%	100%	100%	0%	100%	100%	0%	0%	0%	0%	0%	0%	100%	0%	100%
TTh	AP 11X45-17X41 JT4	0%	94%	0%	113%	100%	100%	100%	100%	57%	100%	100%	78%	0%	100%	81%	0%	0%	100%	0%	125%	43%	75%
	AS 15X58 JT4	100%	114%	0%	300%	100%	86%	83%	86%	109%	67%	38%	100%	90%	107%	114%	0%	0%	0%	17%	0%	108%	36%
	AS 14X63 JT4																						
	ASH 14x63 JT4	0%	0%	0%	0%	0%	0%	0%	100%	100%	0%	100%	0%	100%	100%	200%	0%	0%	0%	100%	100%	50%	200%
	ASH 15x58 JT4																						
	PL1 11X45 JT4	100%	175%	0%	100%	88%	88%	88%	100%	67%	60%	100%	0%	100%	80%	163%	0%	0%	150%	0%	100%	100%	67%
	PL2 17X41 JT4	0%	60%	0%	0%	100%	86%	100%	50%	67%	100%	100%	113%	100%	90%	75%	0%	0%	160%	0%	133%	0%	40%
	PL3 26X41 JT4	100%	100%	0%	100%	100%	100%	200%	50%	50%	250%	100%	0%	67%	100%	100%	0%	0%	50%	0%	100%	100%	100%
	PL4 35X39 JT4	0%	0%	0%	200%	100%	100%	50%	100%	100%	200%	100%	86%	0%	100%	150%	0%	0%	75%	50%	200%	100%	0%
	PL5 41X35 JT4	50%	100%	0%	100%	25%	83%	100%	100%	100%	0%	100%	100%	120%	111%	88%	0%	0%	50%	0%	100%	100%	0%
	PL6 43X29 JT4	0%	9%	0%	50%	17%	125%	100%	100%	0%	100%	71%	100%	100%	78%	100%	0%	0%	100%	0%	100%	0%	0%
	PL MAR 45X44 JT4	100%	87%	0%	125%	60%	100%	50%	93%	75%	100%	100%	100%	100%	100%	40%	0%	0%	0%	0%	100%	100%	50%
	PFX3 26X41 JT4	100%	100%	0%	100%	50%	100%	300%	100%	133%	200%	100%	0%	0%	100%	0%	0%	0%	100%	100%	75%	100%	100%
	PFX4 35X39 JT4	100%	100%	100%	100%	100%	100%	33%	50%	100%	100%	100%	100%	100%	100%	100%	0%	0%	100%	0%	200%	100%	0%
	PFX5 41X35 JT4	100%	0%	100%	100%	0%	100%	100%	100%	100%	125%	100%	0%	0%	100%	100%	0%	0%	50%	0%	50%	100%	100%
	PFX6 43X29 JT4	100%	100%	0%	100%	100%	100%	0%	0%	0%	150%	100%	100%	100%	100%	0%	0%	0%	100%	0%	0%	0%	0%
PN	AP 11X45-17X41 JT4	97%	120%	64%	81%	91%	106%	0%	74%	109%	113%	101%	27%	105%	85%	117%	97%	121%	95%	103%	90%	128%	107%
	AS 15X58 JT4	14%	78%	0%	81%	114%	0%	100%	98%	0%	0%	195%	100%	80%	99%	97%	70%	100%	47%	82%	55%	95%	78%
	AS 14X63 JT4	100%	100%	93%	200%	103%	18%	81%	42%	100%	200%	71%	0%	0%	133%	60%	100%	100%	100%	100%	100%	100%	100%
	ASH 14x63 JT4	100%	100%	100%	100%	44%	80%	80%	100%	200%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	ASH 15x58 JT4	0%	85%	39%	0%	0%	100%	100%	0%	48%	100%	0%	91%	69%	103%	78%	95%	100%	0%	55%	41%	78%	91%
	PL1 11X45 JT4	83%	0%	100%	85%	115%	56%	100%	66%	114%	90%	98%	63%	133%	100%	0%	100%	0%	41%	108%	113%	100%	100%
	PL2 17X41 JT4	100%	200%	67%	76%	44%	108%	58%	95%	93%	123%	200%	100%	94%	80%	545%	169%	61%	100%	100%	102%	97%	101%
	PL3 26X41 JT4	93%	83%	79%	92%	91%	0%	95%	105%	89%	92%	0%	100%	80%	109%	109%	100%	100%	38%	100%	83%	98%	96%
	PL4 35X39 JT4	97%	110%	0%	117%	100%	100%	29%	46%	110%	100%	0%	169%	0%	0%	87%	22%	200%	133%	71%	0%	118%	100%
	PL5 41X35 JT4	91%	500%	77%	137%	102%	105%	65%	48%	73%	100%	100%	72%	100%	92%	98%	119%	93%	61%	110%	114%	100%	100%
	PL6 43X29 JT4	100%	50%	121%	88%	50%	116%	103%	144%	97%	101%	75%	87%	100%	100%	0%	96%	103%	156%	100%	93%	114%	91%
	PL MAR 45X44 JT4	114%	113%	66%	45%	100%	141%	91%	167%	100%	200%	100%	80%	68%	82%	77%	99%	100%	100%	100%	118%	76%	80%
	PFX3 26X41 JT4	0%	0%	0%	0%	0%	100%	23%	0%	94%	200%	141%	100%	0%	0%	0%	0%	0%	100%	100%	0%	0%	0%
	PFX4 35X39 JT4	0%	0%	0%	0%	100%	0%	0%	150%	41%	100%	100%	0%	34%	0%	100%	0%	0%	0%	0%	38%	0%	0%
	PFX5 41X35 JT4	98%	100%	42%	0%	100%	100%	100%	100%	0%	100%	63%	91%	280%	91%	93%	233%	0%	80%	24%	100%	0%	0%
	PFX6 43X29 JT4	29%	100%	0%	800%	119%	0%	119%	89%	160%	100%	125%	100%	0%	0%	108%	100%	0%	117%	71%	100%	0%	56%

4.4.2 Correction tool

Due to the lack of interaction with the Kanban, there was a necessity to create an easy and effective way to correct the system (Figure 39), when there were discrepancies between what existed in the real production flow and in the software. This tool works by balancing the different labels between the different states, passing them to the right position.

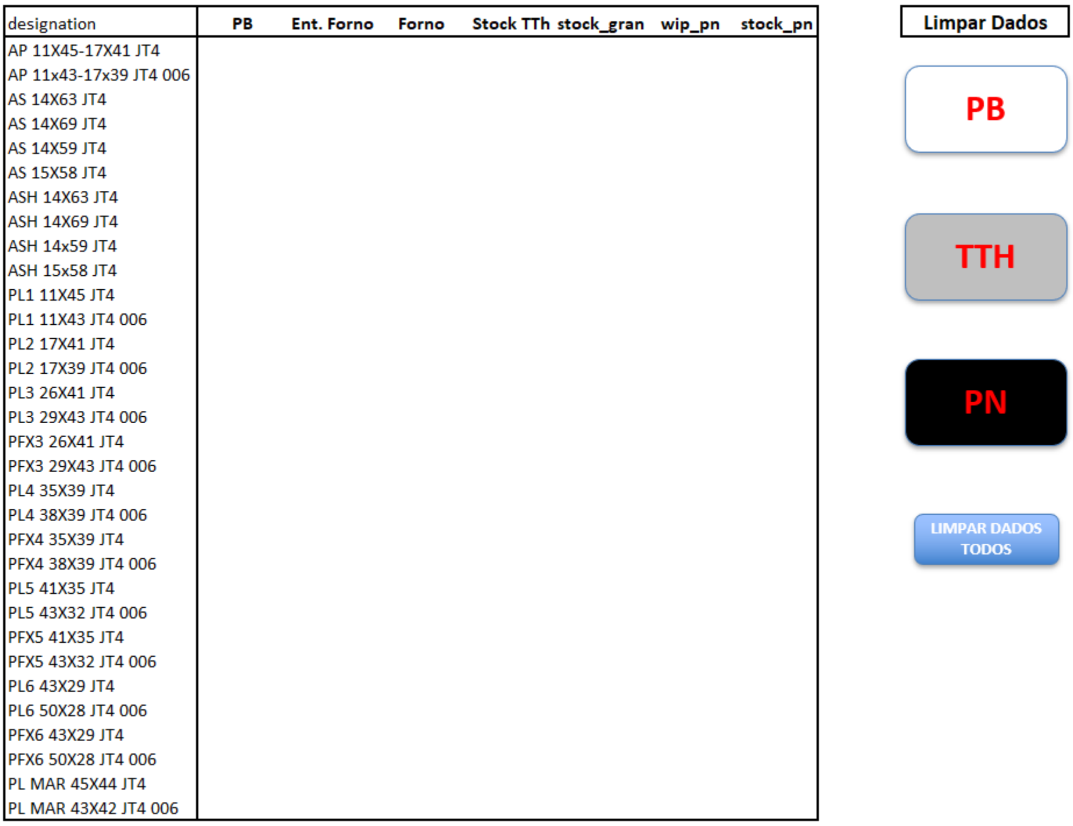

Figure 39: Tool created to correct the kanban system

The correction process is based on the natural movement of the labels. The principle works by comparing the current state that is defined by the kanban system and depending on what the correction tells (done by a person responsible for that action) it can take two different routes:

- If there is a smaller quantity of pieces in the kanban system, comparing with the reality, the program searches for the missing labels in the previous state, which in this case will be always the Prod state.
- If there is a higher quantity of pieces in the kanban system, comparing with the reality, it sends the extra pieces to the following step.

It is important to refer that these corrections were done to each FIFO at the time, allowing for a correct and immediate actualization of the different FIFOs. This is the more suitable process of correction, since it uses the same principles as the kanban system, which in most of the times, by correcting one stage of the FIFO, it automatically corrected the following one.

Despite the importance of this tool, when the system becomes reliable, it should be discontinued, because the kanban must flow naturally and without any manual correction.

4.5 Analysis of the improvement program implemented

An important step after applying changes to any process is to evaluate them. For this phase, the specific tool created to measure the impacts will play an important role in this project.

The initial stage of the project showed a big non-compliance of the system. This analysis also displayed that the WPS (White Piece Sector) and the TTS (Thermic Treatment Sector) were the focus of the main differences between the system and the reality.

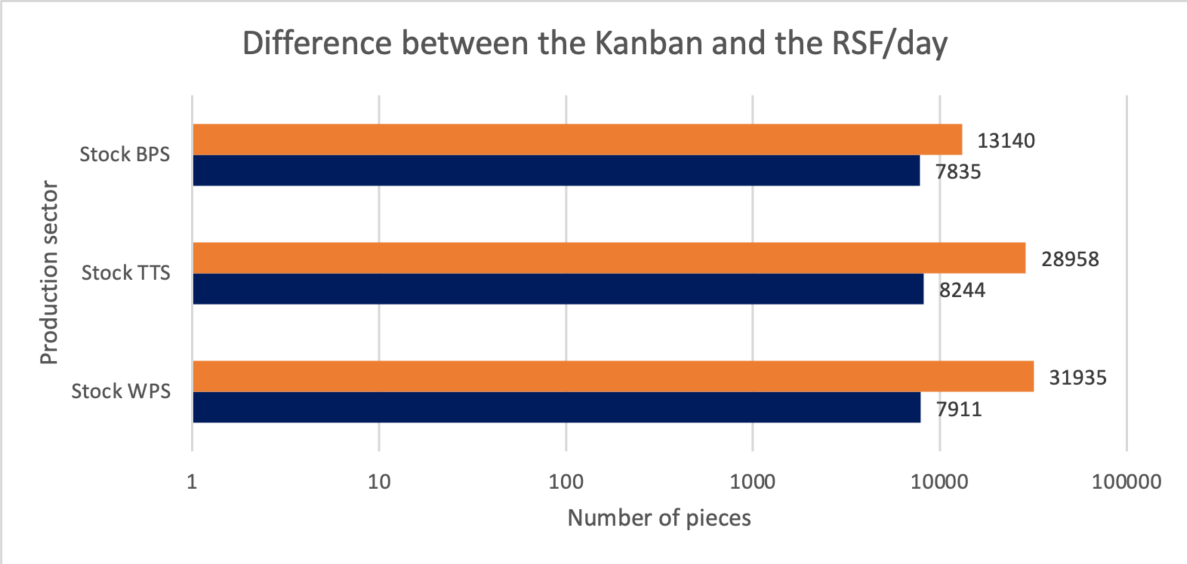

Figure 40: Difference in reliability of the system before and after the changes implemented

After the implementation of the measurements mentioned before, followed a period of parametrization, where the evolution of the compliance of the system was measured in order to understand if it had any impact in the system.

The results show an improvement of compliance (Figure 40), but still with a big failure rate. Despite having improved results, there are still impactful differences in the system. The analysis show that a big percentage of that failure comes from the third, fourth and fifth shifts, which are the ones that operate during the night and during the weekend. Also, the sector which has the worst results is the Thermic Treatment Sector, while the White Piece Sector experienced a large improvement when compared with the initial state.

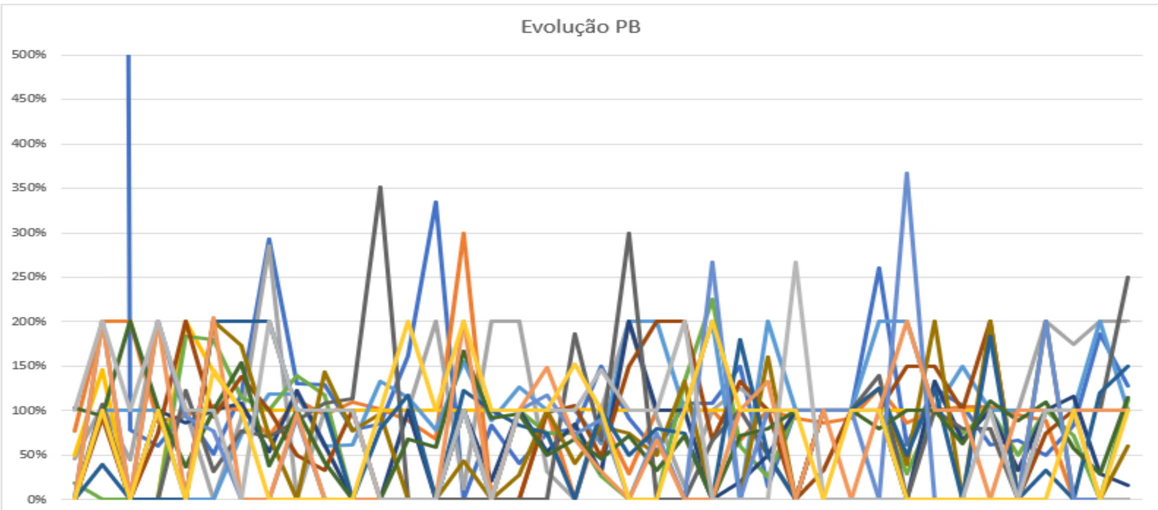

Figure 41: Evolution in the WPS

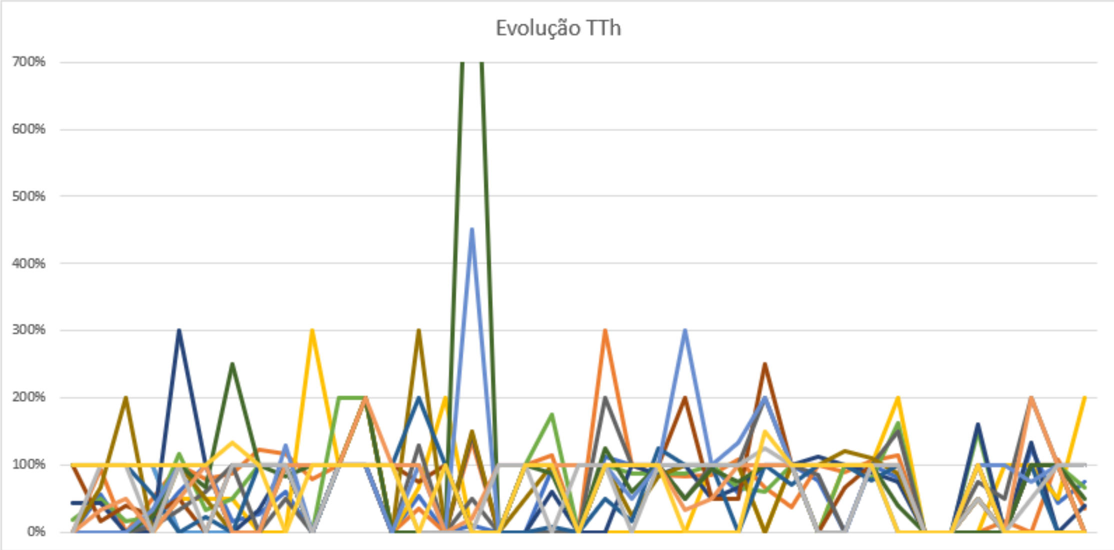

Figure 42: Evolution in the TTS

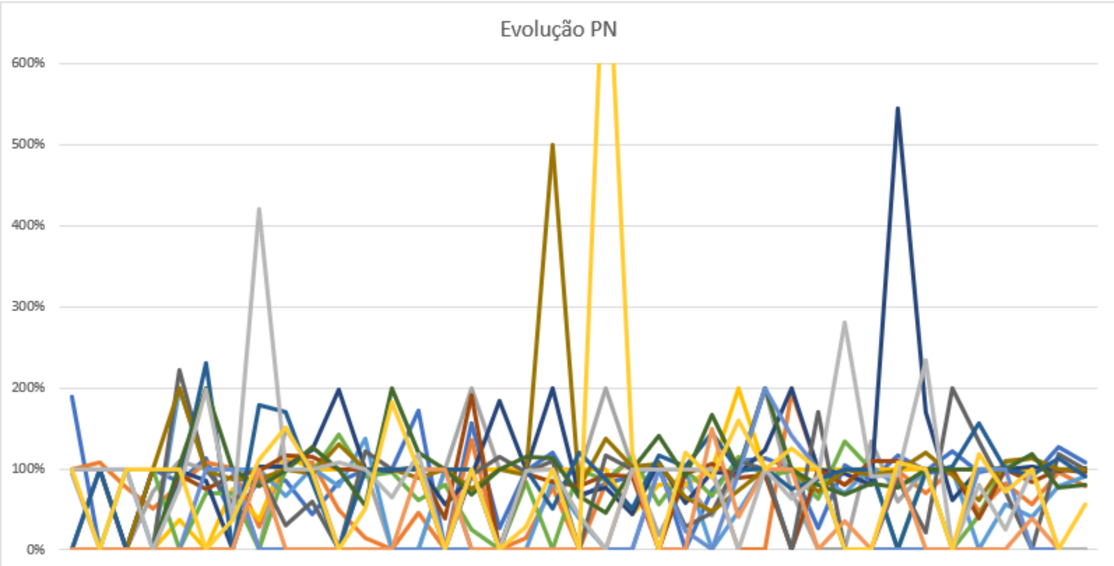

Figure 43: Evolution in the BPS

The analysis of each individual production sector (figures 41, 42 and 43) shows that there are still a few moments of noncompliance with the system, but analysing the global situation, the workers are starting to become more familiar and comfortable with the system.

These results are a consequence of several actions that were put to work. The small changes in the kanban system, alongside with the parametrization and correction tools that were developed, which allowed a direct communication with the production supervisors, allowing for a direct and effective approach to the problems.

Regarding the problem related with the oversized stock in the White Piece Sector, it was possible to reduce this amount (as can be observed in the figure 44), due to the modification that happened to the FIFO, which limited the production in the beginning of the FIFO, and due to the arrival of transportation cars. These transportation cars allowed for the freely circulation of the pieces through the production flow.

Figure 44: WPS stock after the changes implemented

5 Conclusion and future work

The present project aims at improving the implementation of a kanban system in the production flow of the factory. The importance of this project increases with the competitiveness of the automotive industry, where each cost has to be analysed and reduced. In this specific case, this lean tool has the possibility to reduce stocks and improve the factory´s communication, helping with the production flow of the gearboxes that are manufactured in the plant.

The kanban has been having problems with its implementation in the factory due to its difficulty in being integrated within the factory workers, transforming it into a nonreliable tool. The focus of this project is to make this tool as reliable as possible, in order to take advantage of its characteristics and improve the production flow of the gearboxes in the factory.

5.1 Main results

The changes that were applied to the system helped to reach an increase of reliability (Figure 45) of the lean tool by 62%. This result is a consequence of several actions that were put to work. Firstly, the reduction of human interactions with the system, that together with an improved set of operating conditions, allowed to reach a more natural and user-friendly system. The changes in the FIFOs structure helped with the circulation of the labels, reducing potential errors that occurred to the system. Finally, the management tools developed to facilitate the production management tasks, alongside with the correction and parametrization tools, allowed for a daily follow-up and report of the system, helping to keep in track the main goal of this project.

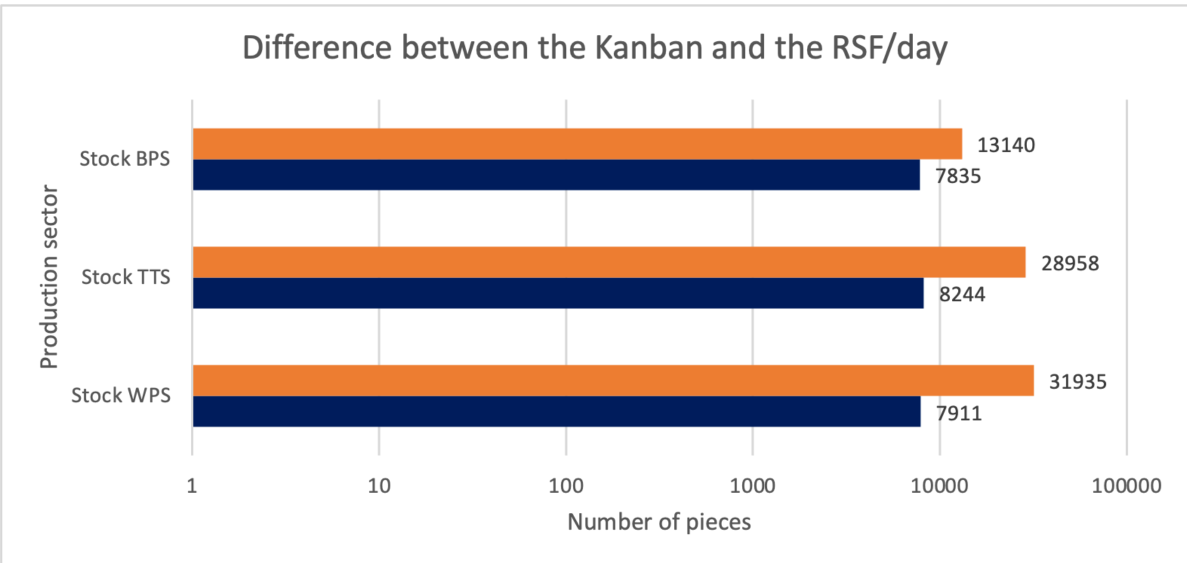

Figure 45: Final analysis of the kanban system

5.2 Further developments

The work developed through this project shows that the implemented changes actually helped with the reliability of the kanban system, which was the main objective of this project. Despite these positive results, there are still many upgrades that can be done to the system.

When a system, especially in a factory where there are lots of people working in different shifts, is dependent of the human interaction to have its information updated, there will always be an error factor associated with the human being. The solution for this problem is to automatize the system, all the way from the beginning to the end, creating specific checkpoints in the different steps of the production flow, that are responsible for feeding the kanban system.

The following propositions take in consideration the already existing tools that the factory has, and just combine them to create an automated solution that is error resistant.

5.2.1 Implement tracking technologies

In order to keep track of the pieces in the production flow there could applied two different technologies to the system: electronic counters and RFID detection.

The electronic counters work by counting the number of pieces that go through a stage in the production lines, using sensors and communicating with a server. In this case, a set of strategically positioned and directly connected sensors to the kanban system would replace the human worker. By counting the number of pieces that go through each stage, and when that counting reached a specific amount, it would send a message to the system, updating it automatically. This would be useful because it would allow for a correct and precise interaction with the kanban system.

These devices could be applied in several stages of the kanban interaction system, such as: in the beginning of the production line, both in the White Piece Sector and Black Piece Sector, as well as in the end of the production line in the Black Piece Sector. This is possible, since in those stages the pieces travel independently in the production lines, allowing the counting process of the counters.

Another possibility to strengthen the kanban system is to implement RFID technology. This technology works with radio frequency detection, where every batch of pieces would have a specific code, and throughout the production process they would be automatically detected and updated in the kanban system.

5.2.2 Interconnectivity between the factory´s several software

The factory has two applications that do the production declaration of the pieces that are manufactured in the factory, having in consideration these three aspects:

- Production sector;
- Production line;
- Production Shift,

This step of declaring the number of pieces that are manufactured is necessary and obligatory, and due to that characteristic, it could be used in favour of the kanban system. Investing in the interconnectivity of these systems, it would also help with the reliability of the kanban system. When a certain number of pieces is finished, a document is printed, using that production declaration software, that serves as an identification document of that batch of pieces. When that document is printed, a message is sent to the kanban, updating it. These measures could be applied in all stages of the kanban interaction system that were not mentioned before.

5.2.3 Addition of other relevant information of the factory

The versatility of the electronic kanban system allows it to receive other information besides the normal production flows. This adaptability could be used with a few other problems that the factory is having nowadays. Aspects like traceability of the manufactured pieces, scrap accountability and production scheduling management could be included in the system. Regarding the traceability issues, with a reliable and improved kanban system, the exact location of the manufactured pieces could be detailed, allowing for a reduction in time spent checking for unnecessary suspicious defective parts. In terms of scrap accountability, the kanban, besides allowing the indication of good pieces produced, it could also allow for the declaration of defective pieces, automatizing this process, which, in this specific industry, has a lot of value. Lastly, in terms of production scheduling management, the kanban, by having access to the different requests of the factory clients, could automatically make the production management, predicting the necessary shifts the workers would need to work, helping with the standardization of the production timetables.

All these possibilities show the huge versatility of the kanban system, allowing for the collection of different information of the factory, becoming, with that, a centralized database and operational tool to manage the different information in a manufacturing company.

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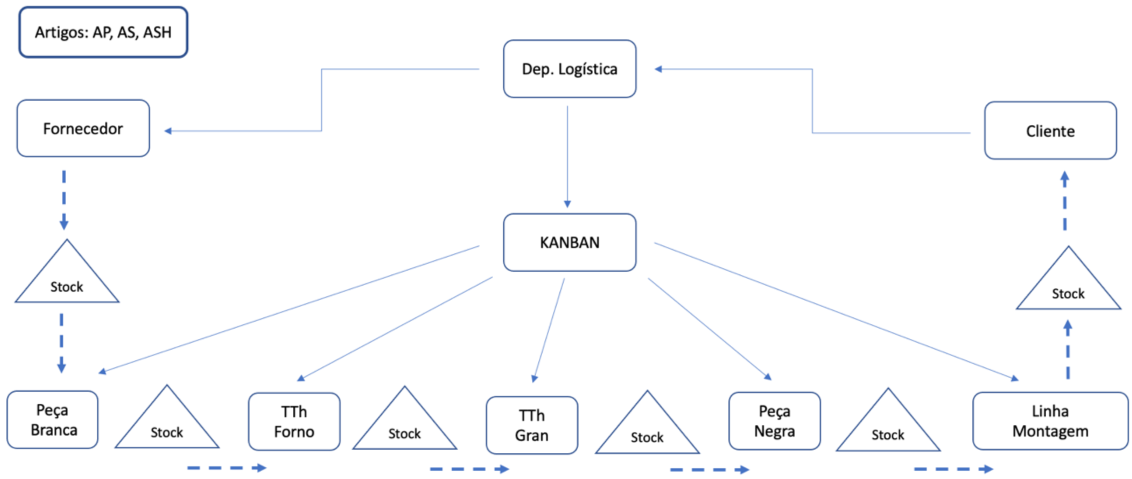
Appendix A: VSM of the pieces in the flow



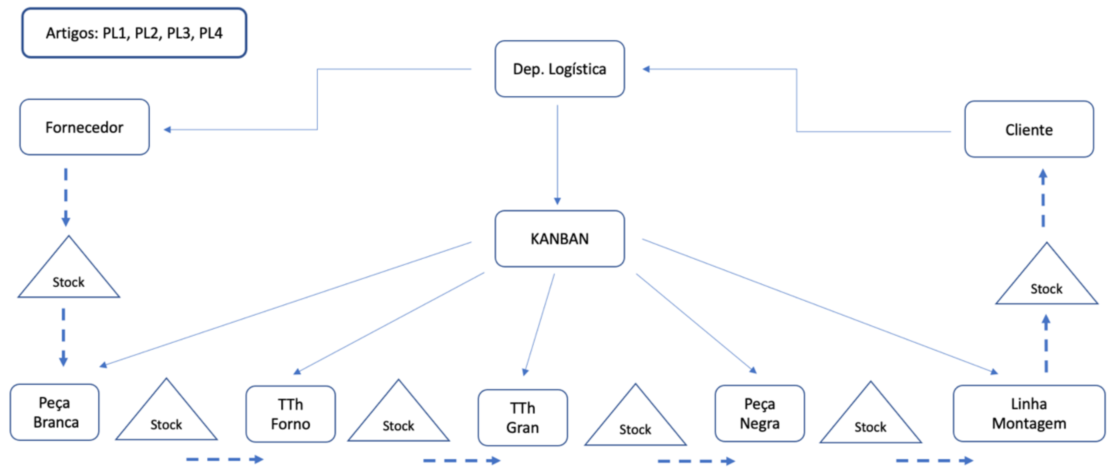
Árvores	AP	AS	ASH
Lead time (horas)	7.4	2.79	2.79
Nº operações	40	23	8
Peças/Prato	50	50	378

Árvores	AP	AS	ASH
Lead time (horas)	6	8	6.38
Nº operações	4	4	4
Peças/Prato	50	50	378

Árvores	AP	AS	ASH
Lead time (horas)	0.25	0.53	2.34
Nº operações	1	1	1
Peças/Prato	50	50	378

Árvores	AP	AS	ASH
Lead time (horas)	0.8	1	4.47
Nº operações	11	8	5
Peças/Caixa	6	4	12

Caixa de velocidades	
Cycle time (seg)	40.2
Nº operações	39



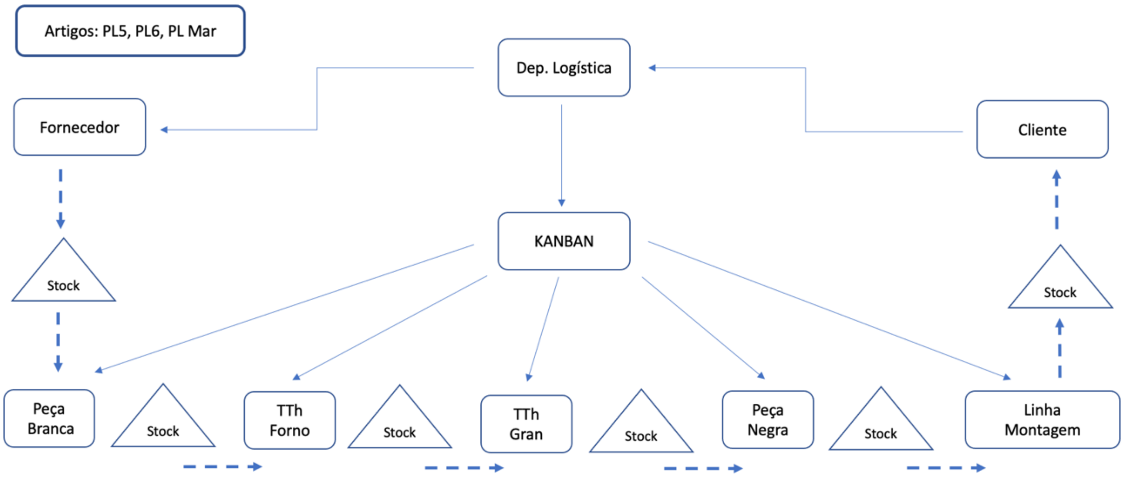
Pinhão	1ª	2ª	3ª	4ª
Lead time (horas)	2.15	2.19	2.1	1.92
Nº operações	8	8	8	8
Peças/Prato	90	108	224	144

Pinhão	1ª	2ª	3ª	4ª
Lead time (horas)	6	6	6	6
Nº operações	4	4	4	4
Peças/Prato	90	108	224	144

Pinhão	1ª	2ª	3ª	4ª
Lead time (horas)	0.5	0.81	0.17	1.2
Nº operações	1	1	1	1
Peças/Prato	90	108	224	144

Pinhão	1ª	2ª	3ª	4ª
Lead time (horas)	0.14			
Nº operações	5	5	7	7
Peças/Caixa	12	12	12	12

Caixa de velocidades	
Cycle time (seg)	40.2
Nº operações	39



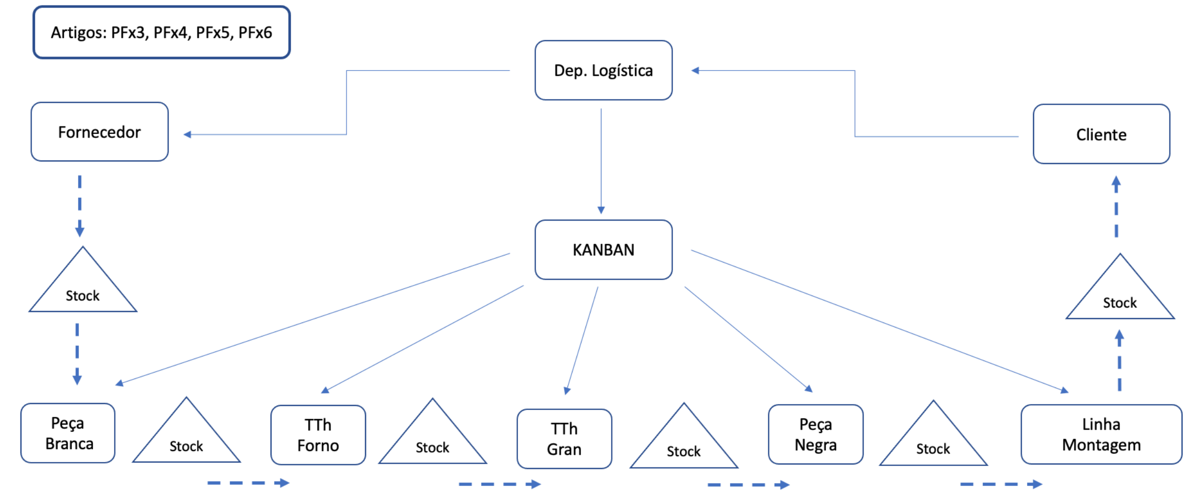
Pinhão	5ª	6ª	Mar
Lead time (horas)	2.14	2.14	1.44
Nº operações	8	8	8
Peças/Prato	144	144	108

Pinhão	5ª	6ª	Mar
Lead time (horas)	6	6	6
Nº operações	4	4	4
Peças/Prato	144	144	108

Pinhão	5ª	6ª	Mar
Lead time (horas)	0.75	1.71	0.15
Nº operações	1	1	1
Peças/Prato	144	144	108

Pinhão	5ª	6ª	Mar
Lead time (horas)	0.14		
Nº operações	7	7	5
Peças/Caixa	12	12	12

Caixa de velocidades	
Cycle time (seg)	40.2
Nº operações	39



Pinhão	3ª	4ª	5ª	6ª
Lead time (horas)	1.12			
Nº operações	8			
Peças/Prato	180	288	320	416

Pinhão	3ª	4ª	5ª	6ª
Lead time (horas)	6			
Nº operações	4			
Peças/Prato	180	288	320	416

Pinhão	3ª	4ª	5ª	6ª
Lead time (horas)	0.33			
Nº operações	1			
Peças/Prato	180	288	320	416

Pinhão	3ª	4ª	5ª	6ª
Lead time (horas)	1			
Nº operações	5			
Peças/Caixa	24	24	24	24

Caixa de velocidades	
Cycle time (seg)	40.2
Nº operações	39

Appendix B: Example of an E-mail with alerts of production stocks

ALERTA !

E eim@localhost(eim@localhost a

Para

Cc

Responder | Responder a Todos | Reencaminhar | ...

seg 07/06/2021 05:00

Política de Retenção O365 trash 5 Days Delete (5 dias) Expira 26/08/2021

O remetente real desta mensagem é diferente do remetente normal. Clique aqui para obter mais informações.

Risco de paragem da linha de montagem por falta de PFX3 26X41 JT4, PFX4 35X39 JT4, retificadas

Quadro global

Com os melhores cumprimentos,

I
CUET 1ª Equipa – AT1 Peça Negra
Telefone: 1635

GROUPE RENAULT
RENAULT CACIA

Apartado 10-Junqueira
3810-601 Aveiro

Appendix C: Example of the daily report sent to the CUETs

Bom dia,

Taxa de realização de picagens referentes ao dia 01/06/2021 Houve uma grande melhoria no dia de ontem no entanto temos de manter (TTH e PN) e melhorar bastante PB!

NOTA: O erro do Kanban tanto é por falta de picagens (<100%) bem como pelo excesso de picagens (>100%)

Legenda: Verde: Entre 80% e 100%

Vermelho: <80%

Laranja: >100%

Taxa de realização de Picagens - Kanban

		Seg - 31 Maio			Ter - 1 Junho		
Setor	Artigo	1º turno	2º turno	3º turno	1º turno	2º turno	3º turno
PB	AP 11X45-17X41 JT4	74%	80%	150%	91%	54%	108%
	AS 15X58 JT4	100%	0%	93%	29%	100%	100%
	AS 14X63 JT4	32%	0%	100%	200%	92%	15%
	ASH 14x63 JT4	100%	102%	100%	100%	100%	100%
	ASH 15x58 JT4	100%	100%	62%	200%	200%	100%
	PL1 11X45 JT4	75%	75%	26%	0%	0%	133%
	PL2 17X41 JT4	54%	84%	31%	200%	100%	100%
	PL3 26X41 JT4	97%	105%	47%	150%	200%	200%
	PL4 35X39 JT4	0%	186%	67%	300%	0%	0%
	PL5 41X35 JT4	100%	41%	82%	75%	50%	133%
	PL6 43X29 JT4	75%	0%	100%	50%	80%	75%
	PL MAR 45X44 JT4	50%	67%	46%	71%	33%	71%
	PFX3 26X41 JT4	118%	73%	90%	0%	75%	0%
	PFX4 35X39 JT4	148%	68%	32%	0%	67%	0%
	PFX5 41X35 JT4	100%	100%	145%	100%	100%	200%
	PFX6 43X29 JT4	100%	152%	100%	0%	0%	100%

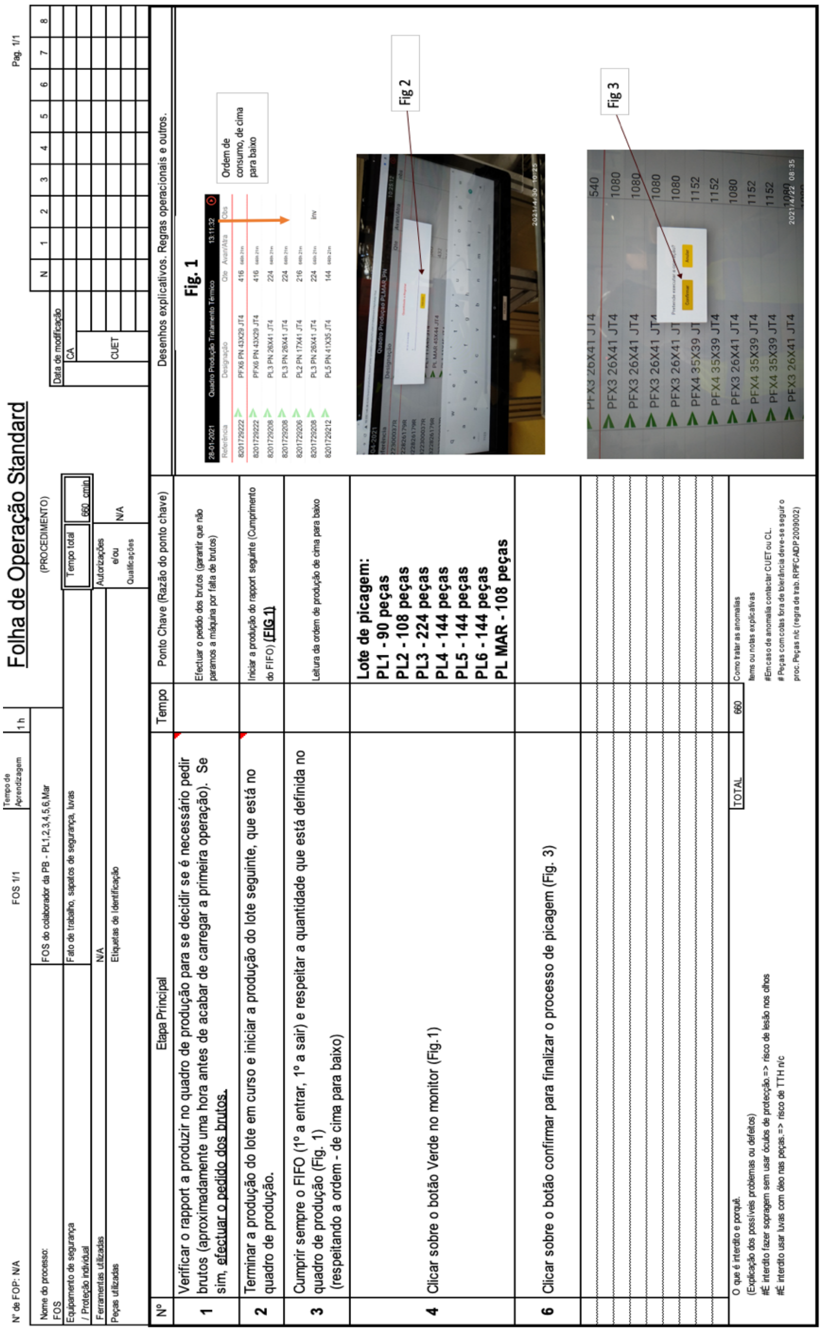
Taxa de realização de Picagens - Kanban

		Seg - 31 Maio			Ter - 1 Junho		
Setor	Artigo	1º turno	2º turno	3º turno	1º turno	2º turno	3º turno
TTh	AP 11X45-17X41 JT4	0%	94%	0%	113%	100%	100%
	AS 15X58 JT4 AS 14X63 JT4	100%	114%	0%	300%	100%	86%
	ASH 14x63 JT4 ASH 15x58 JT4	0%	0%	0%	0%	0%	0%
	PL1 11X45 JT4	100%	175%	0%	100%	88%	88%
	PL2 17X41 JT4	0%	60%	0%	0%	100%	86%
	PL3 26X41 JT4	100%	100%	0%	100%	100%	100%
	PL4 35X39 JT4	0%	0%	0%	200%	100%	100%
	PL5 41X35 JT4	50%	100%	0%	100%	25%	83%
	PL6 43X29 JT4	0%	9%	0%	50%	17%	125%
	PL MAR 45X44 JT4	100%	87%	0%	125%	60%	100%
	PFX3 26X41 JT4	100%	100%	0%	100%	50%	100%
	PFX4 35X39 JT4	100%	100%	100%	100%	100%	100%
	PFX5 41X35 JT4	100%	0%	100%	100%	0%	100%
	PFX6 43X29 JT4	100%	100%	0%	100%	100%	100%

Taxa de realização de Picagens - Kanban

		Seg - 31 Maio			Ter - 1 Junho		
Setor	Artigo	1º turno	2º turno	3º turno	1º turno	2º turno	3º turno
PN	AP 11X45-17X41 JT4	97%	120%	64%	81%	91%	106%
	AS 15X58 JT4	14%	78%	0%	81%	114%	0%
	AS 14X63 JT4	100%	100%	93%	200%	103%	18%
	ASH 14x63 JT4	100%	100%	100%	100%	44%	80%
	ASH 15x58 JT4	0%	85%	39%	0%	0%	100%
	PL1 11X45 JT4	83%	0%	100%	200%	115%	56%
	PL2 17X41 JT4	100%	200%	67%	39%	44%	108%
	PL3 26X41 JT4	93%	83%	79%	92%	91%	0%
	PL4 35X39 JT4	97%	110%	0%	117%	100%	100%
	PL5 41X35 JT4	91%	500%	77%	137%	102%	105%
	PL6 43X29 JT4	100%	50%	121%	88%	50%	116%
	PL MAR 45X44 JT4	114%	113%	66%	45%	100%	141%
	PFX3 26X41 JT4	0%	0%	0%	85%	85%	100%
	PFX4 35X39 JT4	0%	0%	0%	85%	100%	85%
	PFX5 41X35 JT4	98%	100%	42%	0%	100%	100%
	PFX6 43X29 JT4	29%	100%	0%	800%	119%	0%

Appendix D: Example of a FOS document



Folha de Operação Standard

(PROCEDIMENTO)

Nº de FOP: N/A — FOS 1/1 — Tempo de Aprendizagem: 1 h — Pag. 1/1

Nome do processo: FOS	FOS do colaborador da PB - PL1,2,3,4,5,6,Mar		
Equipamento de segurança / Proteção individual	Fato de trabalho, sapatos de segurança, luvas	Tempo total	660 cmin
Ferramentas utilizadas	N/A	Autorizações e/ou Qualificações	N/A
Peças utilizadas	Etiquetas de Identificação		

Data de modificação: N, 1, 2, 3, 4, 5, 6, 7, 8 — CA — CUET

Nº	Etapa Principal	Tempo	Ponto Chave (Razão do ponto chave)
1	Verificar o rapport a produzir no quadro de produção para se decidir se é necessário pedir brutos (aproximadamente uma hora antes de acabar de carregar a primeira operação). Se sim, efectuar o pedido dos brutos.		Efectuar o pedido dos brutos (garantir que não paramos a máquina por falta de brutos)
2	Terminar a produção do lote em curso e iniciar a produção do lote seguinte, que está no quadro de produção.		Iniciar a produção do rapport seguinte (Cumprimento do FIFO) (FIG 1)
3	Cumprir sempre o FIFO (1º a entrar, 1º a sair) e respeitar a quantidade que está definida no quadro de produção (Fig. 1) (respeitando a ordem - de cima para baixo)		Leitura da ordem de produção de cima para baixo
4	Clicar sobre o botão Verde no monitor (Fig.1)		**Lote de picagem:** **PL1 - 90 peças** **PL2 - 108 peças** **PL3 - 224 peças** **PL4 - 144 peças** **PL5 - 144 peças** **PL6 - 144 peças** **PL MAR - 108 peças**
6	Clicar sobre o botão confirmar para finalizar o processo de picagem (Fig. 3)		
	O que é interdito e porquê. (Explicação dos possíveis problemas ou defeitos) #É interdito fazer sopragem sem usar óculos de protecção.=> risco de lesão nos olhos #É interdito usar luvas com óleo nas peças.=> risco de TTH n/c	TOTAL 660	Como tratar as anomalias Items ou notas explicativas #Em caso de anomalia contactar CUET ou CL. # Peças com cotas fora de tolerância deve-se seguir o proc. Peças n/c (regra de trab. RPFCADP2009002)

Desenhos explicativos. Regras operacionais e outros.

Esquema de Funcionamento:

Appendix E: Example of a LUP document

ERROS DE PICAGEM							
Nº Ação	Área	Problema	Ação	Piloto	Data	Progresso	OBS
1	**Logística**	Falta de contadores decrescentes no início de cada linha de produção	Falar com técnico responsavel pela programação	Rui Ferreira e Leonardo Alves			Servirá como uma ferramente de auxilio nas picagens e também na passagem de informação entre equipas
2	**Logística**	Falta de formação aos CUETS	Analizar com os CUETS que faltam formar	Rui Ferreira e Leonardo Alves			
3	**Fabricação**	Definir quem faz os acertos por turno	Ao início de cada turno, garantir que o Quadro Global está acertado	CUETS Fabricação			Garantir que, se existir algum problema com as picagens, esse problema foi originado durante o turno em questão e não devido aos turnos anteriores
4	**Fabricação**	Má localizçao PC Fixos de emissao de galia	Analisar com o CUET da linha a possibilidade de troca de lugar	CUET Pfixos			Alterar local do PC Fixo do final de linha dos Pinhões Fixos
5	**Renault Cacia**	Não há rotação de cargas (etiquetas) / Falta de etiquetas nos Quadros de Produção	Evitar grandes quantidades de peças em curso (WIP)				Este problema deve-se à grande quantidade de peças que existe em contentores na Zona do Kanban da PB (que é uma Zona de espera e não uma zona de Stock)
6	**Informática**	Alteração dos Quadros de Produção após acertos		Cláudio Martins			