Application of Lean Concepts in textile manufacturing company in Argentina

Case Study in R&A Indumentaria

Karen Nataly Krebs

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Supervisor: Professor Amílcar José Martins Arantes

Examination Committee

Chairperson: Professor Tânia Rodrigues Pereira Ramos

Adviser: Professor Amílcar José Martins Arantes

Member: Professor Francisco Afonso Severino Regateiro

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RESUMO

Na busca de novas formas de melhorar a produtividade e aumentar as margens, as empresas tem-se focado em evoluir em termos de estrutura organizacional para refletir melhorar desempenho. O principal objetivo desta dissertação é implementar processos de melhoria que permitam aumentar a eficiência produtiva da empresa R&A Indumentaria, uma empresa de manufatura têxtil localizada em Buenos Aires, Argentina. Apresenta-se a implementação de uma filosofia que busca continuamente mudanças para processos de excelência, também conhecida como Lean Manufacturing (LM). Este conceito de operação envolve a redução de desperdícios, eliminação de pontos críticos e melhoria da satisfação do cliente.

Desenvolve-se uma descrição completa das atividades da empresa e uma contextualização da indústria têxtil na Argentina para um melhor entendimento da situação e dos problemas e desafios que a empresa enfrenta. Realizou-se uma análise crítica que levou à identificação de possíveis áreas de melhoria através da aplicação do LM.

Foi levada a cabo uma revisão da literatura abrangendo a filosofia Kaizen e as ferramentas Lean – Mapeamento do Fluxo de Valor, Análise de Causa Raiz, 5S e Gestão Visual –, conjuntamente com outros processos e ferramentas de melhoria, como mudanças no processo de gestão de stocks de materiais para melhorar a eficiência produtiva e a satisfação do cliente.

Por fim, os resultados foram compilados para criar um roteiro específico de implementação Lean que consiste em uma lista de etapas, processos e ferramentas a serem aplicados na empresa têxtil R&A LM.

Palavras-chave: *Lean Manufacturing; Value Stream Mapping; Kaizen; Indústria têxtil, 5S*

ABSTRACT

Looking for new ways to improve productivity and achieve good efficiency margins in overall production, companies have focused on evolving in terms of organisational structure to reflect better performance. The main objective of this dissertation is to implement improvement processes to increase the operational efficiency of the company R&A Indumentaria, a textile manufacturing company situated in Buenos Aires, Argentina. The implementation of a philosophy that continuously seeks changes towards excellent processes is being presented, also known as Lean Manufacturing (LM). This working concept involves waste reduction, eliminating critical points, and improving customer satisfaction.

A thorough description of the company activities is developed as well as a contextualization of the textile industry in Argentina for a better understanding of the situation and problems that may be encountered in the company. A critical analysis carried out led to identifying possible areas of improvement by applying LM.

After conducting a literature review, the Kaizen philosophy, and the lean tools – Value Stream Mapping, Root Cause Analysis, 5S and Visual Management – were analysed alongside other processes and improvement tools such as changes in the material stock management process to improve customer satisfaction and inefficiencies in the production sector.

Finally, to achieve the purpose of this research the results were compiled to create a specific lean implementation roadmap which consists of a list of steps and processes to apply in the textile company R&A LM tools.

Keywords: *Lean Manufacturing; Value Stream Mapping; Kaizen; Textile industry, 5S*

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LIST OF ABBREVIATIONS AND ACRONYMS

BOM – Bill of Materials

CED – Cause-Effect Diagram

D&PD – Design & Product Development

ERP – Enterprise Resource Planning

GCQ – Growth, Quality, Cost

JIS – Just-in-Sequence

JIT – Just-in-Time

LM – Lean Manufacturing

LMP – Lean Manufacturing Project

MPS – Master Production Schedule

MRP – Material Requirement Planning

NVA – Non-Value Added

PCS – Production Control System

PDCA – Plan-Do-Check-Act

PGH – Thread Management Sheet

PO – Production Order

PUO – Purchase Order

R&A – Name Abbreviation for R&A Indumentaria

SKU – Stock Keeping Unit

SMED – Single Minute Exchange of Die

SOP – Standard Operating Procedure

TPS – Toyota Production System

T&A – Trims and Accessories

UDE – Undesirable effects

VAT – Value Added Time

VSM – Value Stream Mapping

WIP – Work-in-Process

I. INTRODUCTION

1.1. Background Overview

The textile industry contemplates many production activities from the transformation of natural raw materials into products we buy to wear every day. Different types of industries can be found in the textile department, from making leather seats for cars to creating the ultimate running shoe. Since the beginning of time China, India and Turkey are regions known as the main providers of textiles worldwide due to their raw materials and techniques to fabricate them, still, the manufacturing of clothes was to remain for each country a workspace for most ladies in rural areas and small sewing places. It was not until the industrial revolution in 1800 that due to the increasingly growing population and the basic need of society to dress with more elaborated apparel the manufacturing industry made its first big step towards innovation and defy the methods known until now.

Nowadays, the textile industry employs over 25 million people and generates $450 billion annually worldwide, but it is also important to remark that only 0.5% of that revenue is generated in the fair-trade market industry. The remaining percentage corresponds to sweatshops[1] manufacturing which leads not only to unsustainable life conditions but also makes it difficult for this sector to seek better practices from the industrial point.

However, since the internet appearance, many of the questionable working conditions were exposed and brands that were responsible for this were forced to opt for more socially conscious and humane management of their participation in this industry. This is where the second industrial revolution lies because now the industry is seeking still affordable clothing with a rising cost in production, which leads to more investment in efficient production methodologies.

Data from 2019 states that apparel production is mostly concentrated in Asia, being the largest exporter of apparel with 50% of the world's production, including countries such as China, Bangladesh, Vietnam, and Cambodia. Given the socio-economic situation of these countries, with large populations and low wages, the textile industry in the rest of the world corresponds to more local markets and small-medium scales.

Particularly in Argentina, the political restrictions for importation since 2008, which enables a lot of companies to import their goods from the previous countries where most of the textile companies have settled their factories, and the poor conditions for workers in sweatshops, responsible for two-thirds of the textile sector workforce, have created the need for companies, whose guidelines are ethical clothing, to source their products locally.

[1] factory where workers endure unhealthy and exploitative conditions, such as long hours, unventilated workspaces, low pay, or exposure to toxic materials.

Given that this political scenario favours the national industry in Argentina, it is important to emphasize that this is only a temporary issue so that if tomorrow the goal is to compete within the international market, it is crucial to obtain the best results in terms of the production process and achieve competitive prices for the market.

This thesis seeks to support R&A Indumentaria, an apparel manufacturing company in Argentina, with the use of Lean tools and methodologies to improve the productivity of the plant by eliminating waste in the processes and optimizing time.

1.2. Master's Dissertation Objectives

Through the development of the master's dissertation presented arises the opportunity to investigate and elaborate on improvements for the company R&A Indumentaria, where I have been practising my industrial engineering knowledge for the past two years. The main goal of this project is to raise productivity and lower the production costs for the company, and for this it is developed a methodology that responds to the identified problems in a real-life context, considering the risks and gains of its implementation and a projection of the results to be obtained in the company.

The operational objectives targeted in this dissertation are described continuously:

- Define the concepts necessary to support the process diagnosis and improvement using Lean Manufacturing.
- Identify the activities and processes in the manufacturing of clothes to calculate the current productivity.
- Apply Lean Manufacturing to determine the main waste and/or problems in the product manufacturing process.
- Search for improvements based on the application of Lean Manufacturing tools to reduce the identified waste.
- Propose improvements to increase productivity in production.

1.3. Methodology

The methodology to be followed in the present dissertation is structured and developed within five stages outlined in Figure 1:

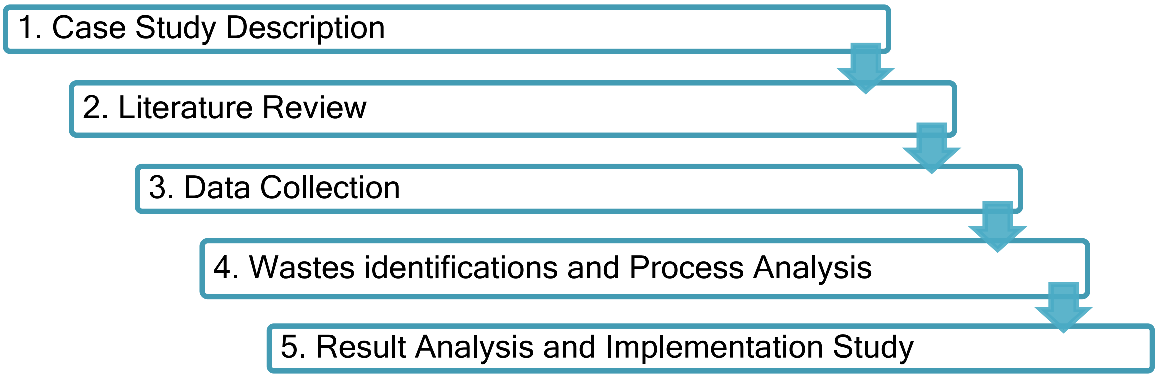

Figure 1 - Methodology followed in the master's Dissertation.

The first stage of the methodology consists in introducing the case study company situation, and its production process configuration and emphasising the problems and limitations the company faces. The following step consists of a literary review to support the case study with solid concepts and theoretical knowledge that helps focus the research on the given subject. Later, data collection regarding the process will take place, where the type of data and collection method will be determined after the integral survey of the production process. Based on the observations made, the appropriate tool will be identified to capture the data needed to continue with the next step of identifying waste, unproductive actions, and downtime. With this information we continue with the survey of the process with a more critical look at the potential areas for improvement or weak points in the production chain. Finally, a final report is developed explaining the analysis for the choice of the proposed Lean tools to be adopted in the case study. This includes the impact analysis in relation to the previously identified waste as well as the improvement projection in terms of work quality and production times in the company.

1.4. Project Outline

Considering the research objectives and methodology presented in the previous points, this dissertation is divided into four chapters, which each involve the following contents:

- Chapter 1: Introduction - Contextualization of the research project is being held out in this chapter, including the methodology carried out and general guidance for the project.
- Chapter 2: The Case Study - The aim is to provide the reader with references to the past and present situation of the production process and product development in the textile industry in Argentina, the country where the company under study is located. Then an explicit contextualization of the organizational and productional structure of the company R&A Indumentaria, with descriptions and details relevant to the development of the engineering thesis.
- Chapter 3: Lean Manufacturing – reference framework for the main objective of the thesis, which is the application of the studied methodologies. The various techniques and processes that can be used to generate an impact on the productivity and efficiency of a company. It will

also cover the description of various techniques within the Lean methodology that could potentially be used by the company understudy to achieve the forementioned goals.

- Chapter 4: Implementation Model, results, and discussion. Development of project regarding the implementation of Lean tools and the analysis regarding the choice of each tool. Application of Lean methodologies for the R&A Indumentaria case study and predict the positive impact that this would generate in terms of production.
- Chapter 5: Conclusions. Exposure of main topics developed in the dissertation, key results, implications, recommendations and limitations, and future work.

II. THE CASE STUDY

The second chapter is an introduction and contextualization of the company R&A Indumentaria, where the curricular internship developed by the candidate for a master's degree in Industrial Engineering and Management has been held. It is organized into three sections, firstly the industry market and business sector where R&A is involved; secondly it is introduced the background and history of the company and thirdly framing the improvement targets expected by the company. The closing section will present conclusions about how to direct the investigation in lean manufacturing methodology by analysing the information in the chapter.

2.1. The Textile Manufacturing Industry in Argentina

Argentina is in the modern world known as a developing country, that's why it's relatable to say that the industrial development is relatively delayed from other leading countries in this matter, mainly because its economic stronghold is agriculture. Analysing the evolution of this industry it is possible to remark on the six different time socio-economic stages that shaped the textile business known today. As represented in Figure 2.

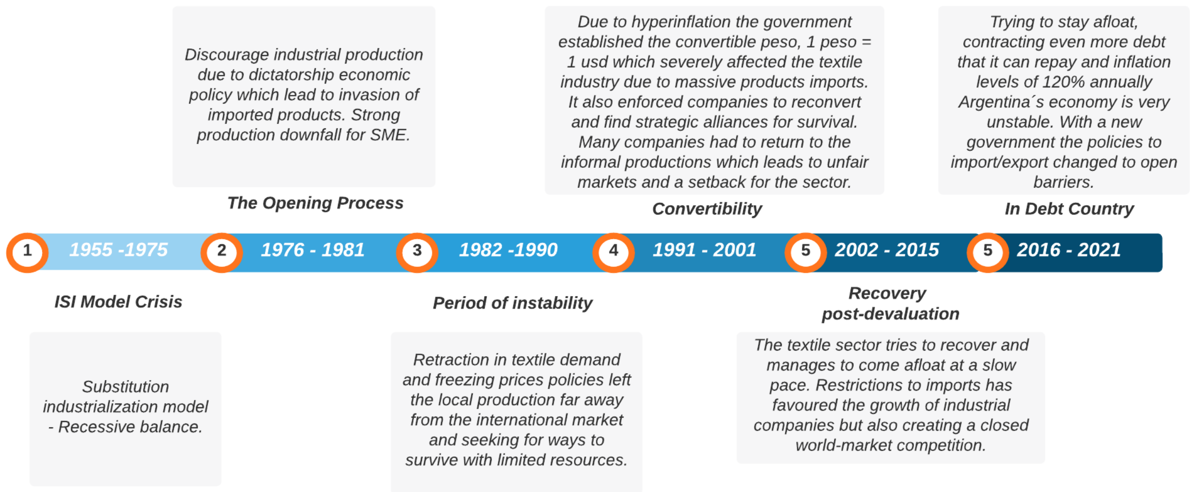

Figure 2 – The Evolution of the Textile Industry in Argentina

The first stage took place between 1955 and 1975 known as the ISI Model Crisis there was a substitution industrialization model which led to a recessive balance.

From the year 1976 to 1981 a huge discouragement to industrial production hit the country, due to dictatorship economic policies which lead to the invasion of imported products and a strong production downfall for small and medium enterprises. This stage is called The Opening Process.

The following eight years were even harder for the industry, retraction in the demand and freezing prices policies left the local production far away from the international market and seeking ways to survive with limited resources.

In 1991 due to hyperinflation, the government established the convertible peso, setting the nominal value of the Argentine peso equal to the United States dollar. This severely affected the textile industry due to massive product imports. It also enforced companies to reconvert and find strategic alliances to survive. Many companies had to return to the informal productions which led to unfair markets and a setback for the sector. The stage of convertibility took place for ten years ending in 2001.

After a great crisis in 2001, every aspect of the country suffered a stunning devaluation which left the local currency with a lot of fluctuation leading to a value close to 0.30 USD. To encourage the local production industries, some governmental policies such as the restrictions on imports helped the textile sector to recover and came afloat, however, these policies created a closed world-market competition, which ended up being the political and economic scene for the following fifteen years with some opportunities to get back on foot with hard work.

Things didn't get much better from that moment to nowadays trying to stay afloat, contracting even more debt than it can repay and inflation levels of 120% annually Argentina's economy is very unstable making it almost impossible to forecast business over long periods (+5 years). With a new government, the policies to import/export changed to open barriers.

2.1.1. The sportswear market in Argentina

Sport in Argentina, as in many countries in the world, is not only the main entertainment that people have, but it has also become the element of consumption par excellence and an immense business. Also, it is known that sports, in general, have become a route of escape from daily routines where people turn to professional leagues to follow a preferred team and develop a certain dependence on that, known as fanaticism. This leads to many different growing markets that rely on the sports industry being one of them the sports clothing market, not only for people that practice it and need to wear appropriate and comfortable clothing but also for the fans world. The clothing not only brings identity to a person or a team, but also to the community and supporters that share the same passion for that sport.

In a survey carried out by the Social Observatory of Sports reliant on the Ministry of Tourism and Sport of Argentina, 3 out of 4 (74,6%) people said they were interested in sports in general and seven out of ten respondents (69.5%) said they were interested in doing sports and physical activity. This can be translated as potentially high demand for products that revolve around the sports world, bringing more to the subject of study, to the sports clothing market.

It is relevant to the investigation developed in this thesis to remark that in the same survey mentioned before around 40% of the population practice football, which makes this sport the most practised in the country. Although it is the most popular sport to be practised, it is also the sport of cultural preference it has the largest social support.

According to the INDEC[2], the total amount of sales for sports clothing and accessories in 2019 was $ 2.538.364.000 Argentine pesos which represents 10,4% of the total sales at current prices (December 2019) by jurisdiction and item, percentage composition for the total amount of purchasing centres.

Finally, the analysis that can be observed is that culturally the society in Argentina has a high consumption within the markets that arise from the sports world which leads to the development of this type of local market enough to establish the related manufacturing industry.

2.2. R&A Indumentaria S.R.L

2.2.1. Introduction to the Company

R&A is a company founded in the year 2002 with the union of two business leaders, Guillermo Krebs and Roxana Pillas, who with the need to resurface because of the 2001 Argentinian crisis looked for their place in the sector they knew best, the textile industry. In the early years, the company was mainly focused on making clothing for sports brands and casual brands, where the quantities did not exceed 6000 units per month. This first factory was in the city of Buenos Aires, where they remodelled an old house for the needs of the time. However, they were limited not only physically to grow but also by the residential area in which they were located.

The company works towards creating quality products and having a high level of compliance with customers, which caught the attention of well-known companies such as Nike. This is how in 2008 they were faced with the possibility of closing a contract with the previous brand and launching the company to another level. For this, they not only needed to relocate, and expand the workforce and machinery but also to rethink certain processes to make it work. So, in 2009 they started the construction of the nowadays main plant in the industrial district of San Martin – Province of Buenos Aires[3], where they carry out the core activities of the company since 2010.

Working with brands on the level of Nike is not an easy task, since they not only measure the quality and costs of their products but also place a lot of emphasis on the work environments, the work ethic of the companies that supply them with products and the reliability of the company to maintain the same values as the brand.

By obtaining outstanding marks in audits carried out by international representatives, R&A became the second company in the country to obtain the privilege of being a clothing manufacturer for Nike. This achievement led other international brands to focus on the company since the need to produce in the country grew as imports became more and more complicated. As a clear consequence in 2012, R&A

[2] INDEC – National Institute of Statistics and Census (Argentina)
[3] RSM – is the reference used for the plant located in Rosales, San Martin.

became the first company in the world to produce items for The North Face without being a VF Group factory. Since then, the company's client portfolio has targeted a market sector that seeks not only good quality and production times but also social compliance and good practices for production.

In 2019 R&A was looking for the expansion of its plant, after having been renting a plant in the vicinity of RSM, and it was able to specify the expansion of it with land adjacent to RSM, raising the plant from 1100mts^2 to 2100mts^2.

The year 2020 stands out for being a very complicated one for many industries due to the events caused by COVID, the heavy drops in demand for products and falling economies also affected the apparel sector. Although for a period R&A reconverted to produce medical supplies such as masks and overalls for medical staff, these products do not leave a good margin profit nor is it a market in which they want to dive. Therefore, when the local economy began to reactivate and like the Asian market was saturated, the demand for domestic production drove the expansion of the company even more. This time a new production plant was established in the province of La Rioja where textile hand-labour is abundant and industrial developments in the area are growing.

R&A Mission and Vision Statements

- Mission: *To offer our customers top quality products in strict compliance with the stipulated delivery dates, providing a working environment by international standards.*
- Vision: *To become the number one supplier of sportswear in Argentina.*

Company Organization

As mentioned in the previous section, the company is owner-managed and categorized as a medium-sized enterprise within the SME sector with a task force of 120 employees (October 2021). However, the hierarchical structure of the company is still governed by the classic organizational structure of a family business. The owners, besides being part of the board of directors in charge of taking the most important decisions at a business level and defining the mission, vision, and strategy of the company, also have a defined executive role for tasks related to the day to day running of the company. This leads to a greater impact and involvement of top management in the day-to-day operations and therefore more contact when it comes to transmitting the corresponding decisions. That said, the organization chart is presented in Figure 3 below, where the structure by R&A areas can be appreciated without referring to the people involved in each one.

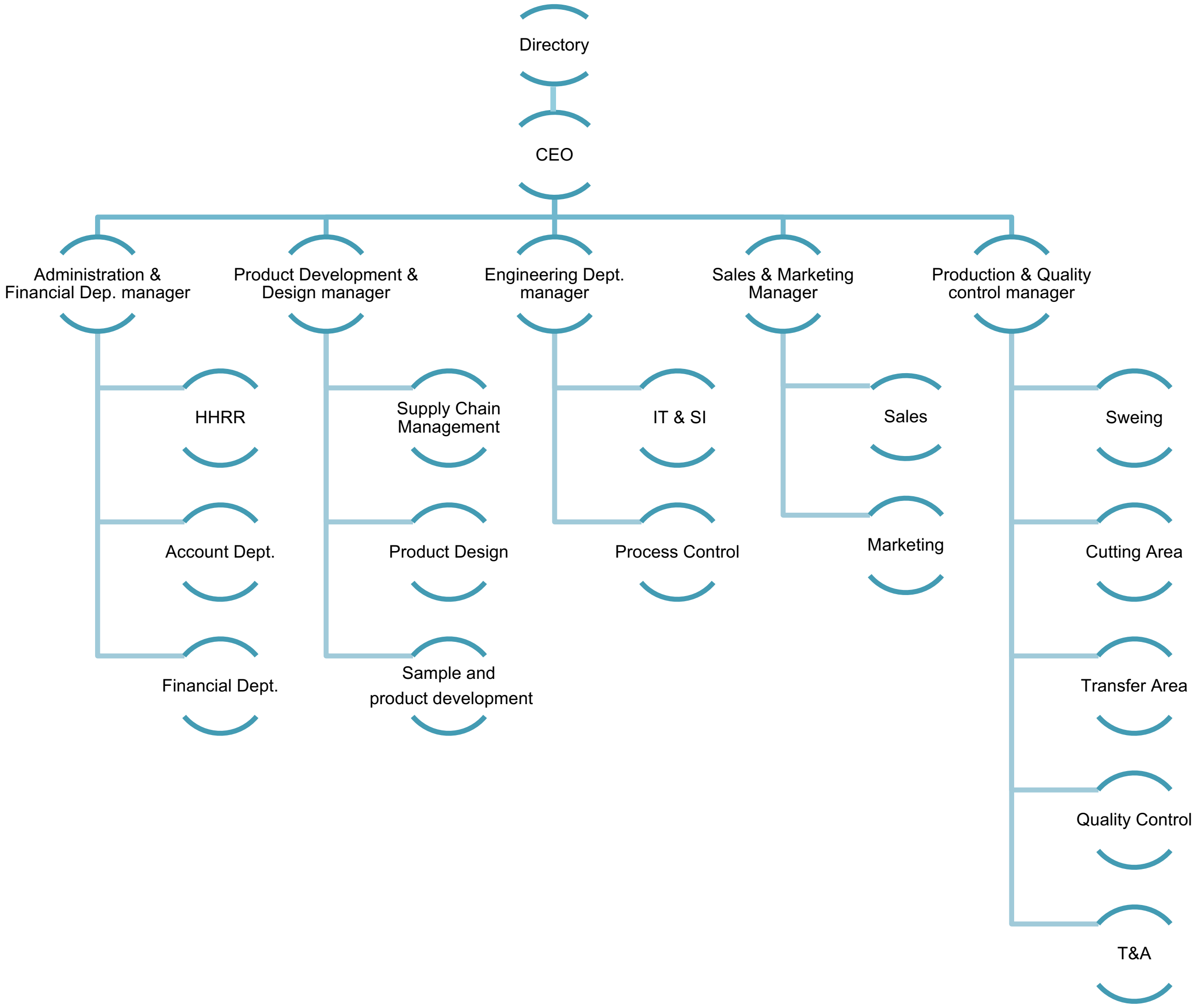

Figure 3 – R&A Organizational structure

In the following section 2.2.3, the areas observed in Figure 3 are detailed together with the explanation of each area of industrial activity carried out in R&A. By the end of this chapter all the production processes that are carried out will be conceptualized accordingly to the company's operations. This will help the lector have a better understanding of the company case and the problems and actions for productive improvement set out in the following chapter.

Service & Products Description

The company focuses on manufacturing mainly goods for sports brands, which include a big portfolio of products, that change constantly due to the core of the apparel business. Although R&A might seem like a product end facility, it is primarily seen as a service company. Clients are known to bring the tech pack[4] for each product they want to develop and with the area of product design reach a proper definition having in consideration technical details and costs.

The products that the company can produce can be identified in three groups of clothing, which are described in Figure 4. For each type of sub-section, there are many products depending on the season and the brand, where the differences lie in the techniques used and materials.

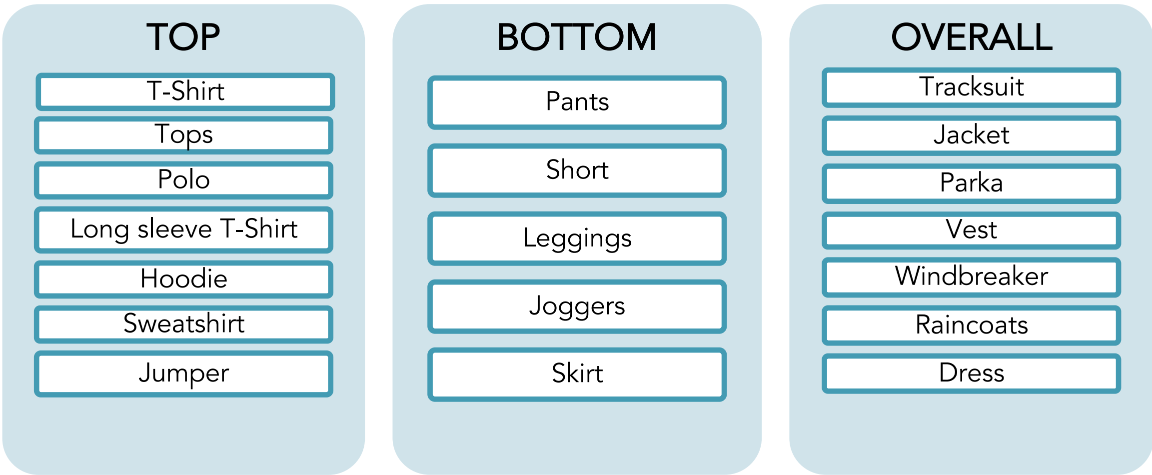

Figure 4 – Categorized product list

It is important to remark that the clothing industry has two different distinguished seasons, Spring/Summer & Fall/Winter, and for each year's collection the developing process starts one year in advance and the productions of goods tend to start between 1 to 6 months prior the delivery due date.

The materials needed to produce the goods can be divided into 3 groups: fabric[5]; trims & accessories[6] and threads.

Current Demand

R&A's current average monthly demand for the more representative products is presented in Table 1 is divided by product category and season. Nevertheless, there can be a variation in demand depending on the seasonal trend between 10% and 15% of items per category.

Annual demand has been growing since 2008 with a stable of approximately 535.000 garments annually in the last 3 years, not considering 2020. Before that, for 4 years the annual production was 400.000 which leads to an incrementation in productivity of 130% mainly due to the incorporation of new technology and workforce enlargement. It is appropriate to mention that 11.5 months are considered

[4] Tech Pack is a term used in the textile industry to describe a product sheet with images and references to its composition and processes needed to manufacture the given product.
[5] Fabric: cloth or woven material.
[6] Trims & Accessories: group of different materials used to complement the garment, for example zippers, heat transfers, elastic, cord, hand tags, stickers, and packaging.

for the annual production calculations because the company closes for 2 weeks during the festive season.

Table 1 – Average monthly demand of the more representative products each season.

CATEGORY PRODUCT	TOP			BOTTOM			TOTAL MONTHLY AVERAGE
SEASON / PRODUCT	Cotton T-Shirt	Sport T-Shirt	Sweatshirt /Jumper	Pant	Short	Legging / Short Legging	
SPRING/SUMMER	18.000	12.000	5.000	4.000	2.500	5.000	46.500
FALL/WINTER	18.000	12.000	5.000	4.000	2.500	5.000	46.500
TOTAL	**40.000**	**10.000**	**10.000**	**8.000**	**5.000**	**10.000**	

R&A's core activities are held in the RSM plant, which is divided into seven main productive areas:

1. Fabric Store
2. Trim Store
3. Cutting sector
4. Semifinished distribution sector
5. Transfer sector.
6. Sewing sector.
7. Packaging and Shipping sector.

To support the correct functioning of these areas and have an efficient workflow there are support areas that also have an important role such as the design and product development area, production and quality area, engineering and IT department and administration and human resources department. For a better understanding of R&A's necessities and conditions, an overview of the plant is provided in the following section.

2.2.2. Plant Overview

Throughout this section, the previously mention production areas will be shown and described as well as the operational functions in the RSM plant which is divided into two buildings that will be identified as RSM-R (Right) and RSM-L (left) due to the expansion of the plant that took place over 2021 on the adjacent land. The layout of the plant is shown in the following figures, Figure 5, 6 & 7, to provide a better vision of each area and how the workflow in the factory functions. Each figure represents a working floor and is divided into the different areas previously mentioned by colour, which are referenced in the legend. In the following sub-section, the different areas are explained as the manufacturing process is described.

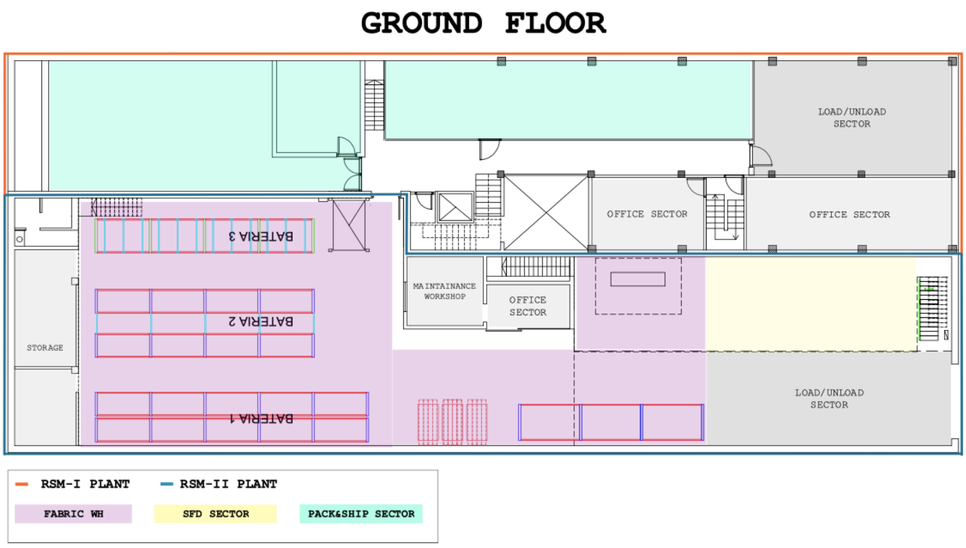

Figure 5 – Layout of the ground floor level of the RSM plant.

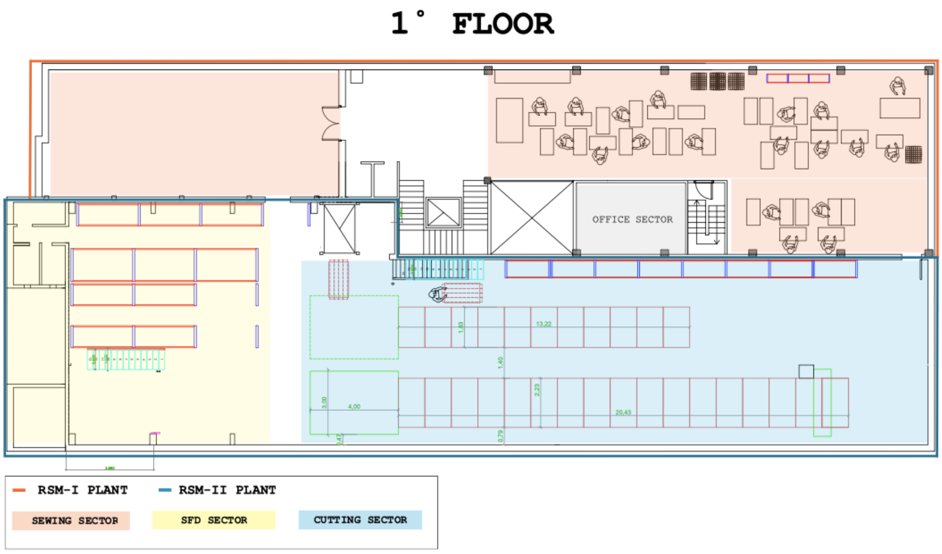

Figure 6 – Layout of the first-floor level of the RSM plant.

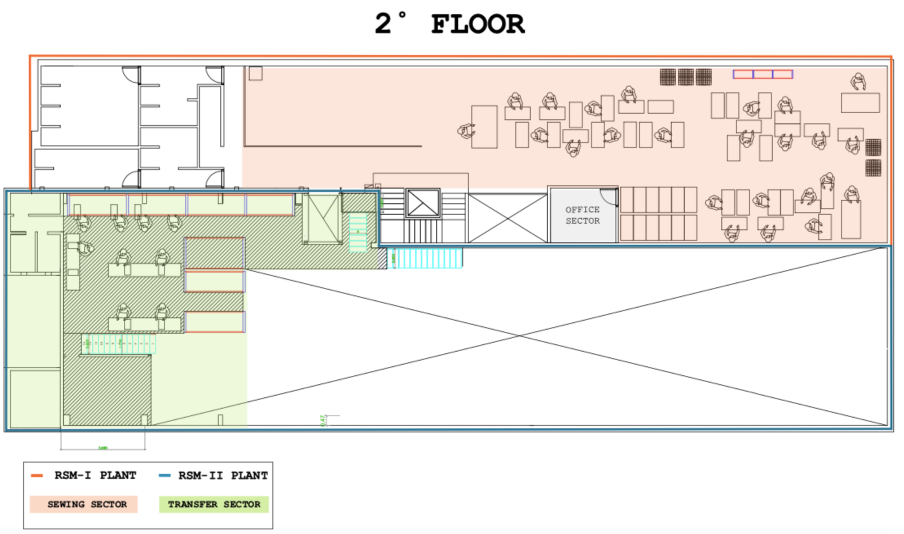

Figure 7 – Layout of the second-floor level of the RSM plant.

2.2.3. Description of the manufacturing process

To describe the manufacturing process, it is important to have into account the information needed to get started as well as the production process, for that Figure 8 shows the pre-manufacturing processes while Figure 9 shows the flow of information files required to start with the workflow. Following, Figure 10 shows how is the manufacturing process once the tech pack has passed through all the previous shown stages and is approved for production.

R&A is characterised by having an average of seven clients, which is fixed since the production levels they require are high and this type of production is in line with the structure that the company has built up over the years as mentioned above. Although each customer has its products and customised developments for each item, the process of generating a garment is almost similar for all customers. Firstly, the client brings a sample like what they want to develop to start with the costing procedure which will determine which articles meet the client's pricing expectations and continue to the production phase. For each styling collection, the list of articles can be quite extensive and varied, so each costing sheet is based on a preliminary tech pack that will be adjusted with the clients until the final list of garments is reached, a sort of feedback process between phases 1 and 2 in Figure 8.

As the companies they work for are mostly international brands with cost disclosure policies, the most used form of costing is open costing. This implies that all the elements that make up the cost of a garment must have a corresponding price. For example, in the costing of a basic plain cotton T-shirt, it is presented for the client a sheet where it is detailed:

- The price of fabric and any other inputs required (tags and packaging) and the suppliers involved.
- The number of minutes required for the building up the garment (from cutting to packaging) detailing the time required for every operation.
- Administrative costs and fixed costs
- R&A profit percentage
- Taxes

The costing procedure involves the D&PD area manager working in accordance with the general manager, who is responsible for analysing the purchasing needs of all customers and the company's sales opportunities.

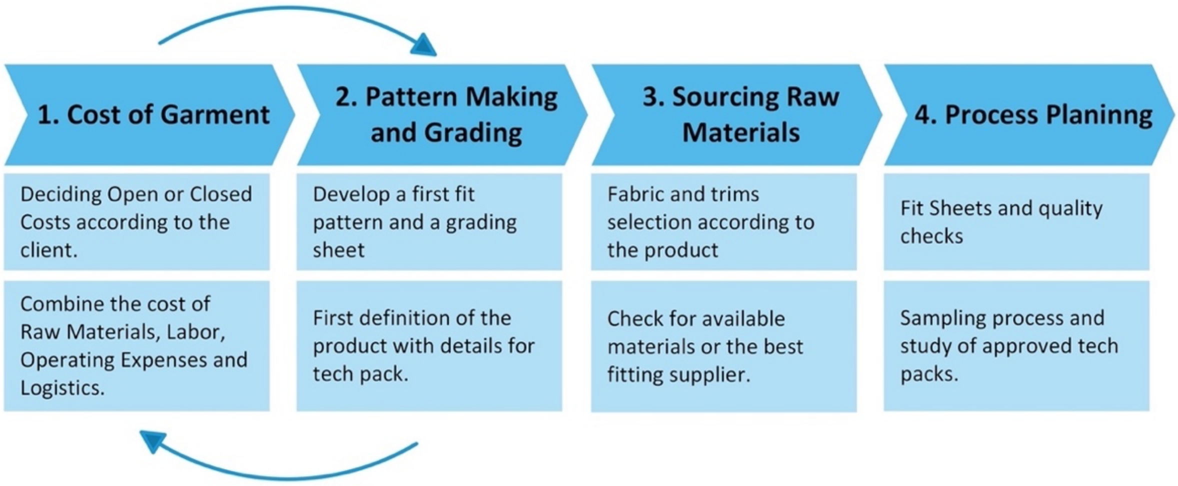

Figure 8 – Pre-production processes in garment manufacturing

To complement the process done to start the production of each article Figure 9 it is detailed the different informational stages and how the future described productive areas will receive the information needed. The tech pack is printed and distributed to all the manufacturing areas shown in Figure 10 by the production manager. As it might have as long as 14 pages in total and not all the pages are of use to all the areas, only the concerning informational sheets are attached with the main descriptive sheet in the paper distributed tech pack. Although the full tech pack is available virtually not all the sectors may have a computer to access it.

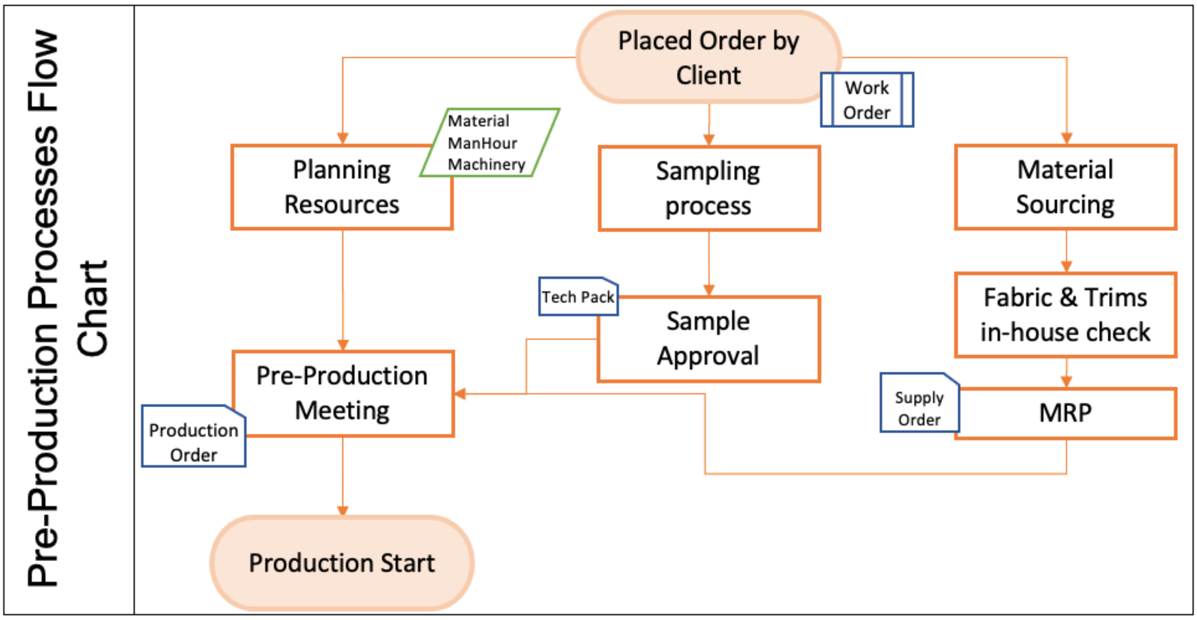

Figure 9 – Pre-Production Process Information Chart

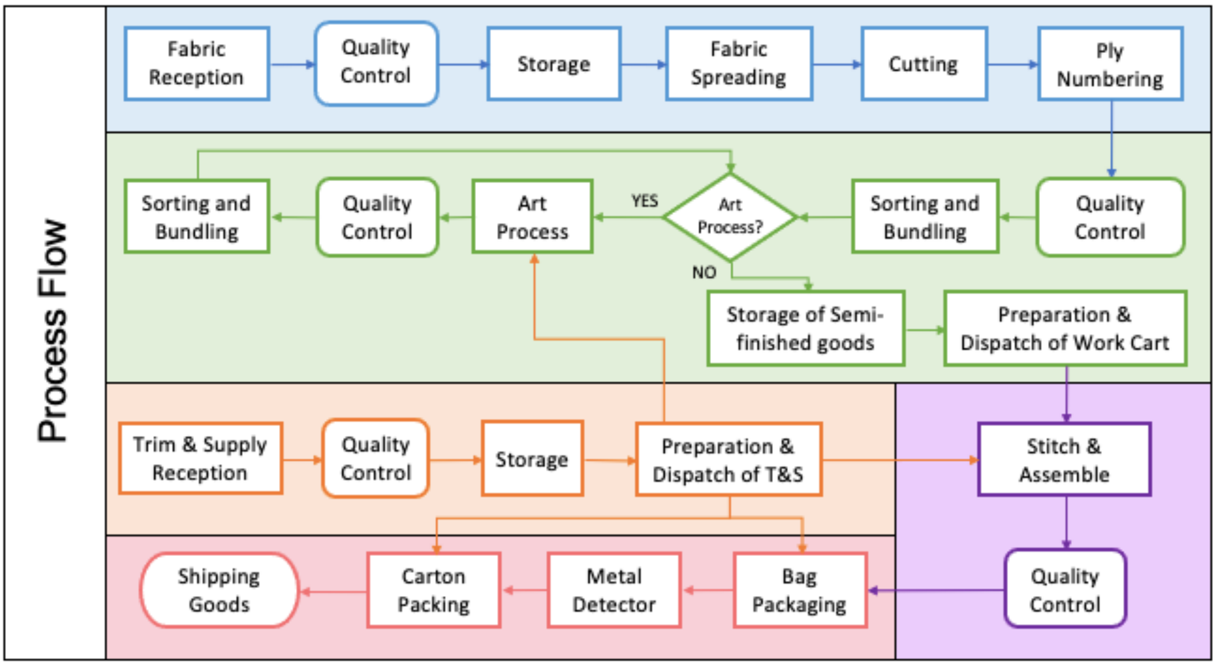

Figure 10 – Major process flow chart.

Once the styling collection from a client has been approved and reviewed, the D&DP department receives a Purchase Order (PUO) with all the items approved with a defined delivery plan and other informational details such as EAN codes. This is the starting point for manufacturing an item, although it may suffer some modifications afterwards the standard procedure requires almost closed tech packs so the flow throughout the plant can be identified as a pull system of production, where each PUO transforms into a different PO's that will be drivers for the production needs. In the appendix section B, it is shown in representative figures, Figure 28, 29 & 30, the layout of the factory overlapped with material movement arrows that indicate the production flow along the manufacturing process. It can be appreciated the colour differences to distinguish the changes of sectors as well as the material transformation from raw material to semi elaborated goods to finally the finished product.

To have a smooth flow, every morning a general meeting is held with the department managers and the general manager of the company. This is a key factor for establishing the priorities and needs that the company is facing and having a clear overview of how the short-term objectives are progressing. As it was mentioned before the production is driven by placed orders so if any unforeseen matter occurs it is highly important that quick action takes place and review the issue carefully until is solved, as the production is leaning toward a JIS and JIT flow system. In the following section, these terms will be discussed in more detail.

<u>Design & Product Development Department</u>

The Design and Product Development area are responsible to deal with the client for developing the product requested and adjust the needs of them to what the suppliers offer as well as technical aspects that might be related. The process of sampling and sample approval is another task of this sector, which usually takes two months long for new products and is recognized as a critical phase to start the production process in the right place.

Moreover, to carry out the necessary tasks, constant communication with customers and suppliers is important as well as knowing the new developments and innovations that may be in the market. It is important to stay competitive and that the company provides and enhances these aspects. Although the product is not developed from scratch and customers provide their tech-packs as guidance, the internal tech-pack used is also developed here as the information needed is far more extensive and detailed. It has all the information needed to pass it on to every productive area and have all the information of that product.

Internally the D&PD department oversees resupplying the raw materials (fabrics, T&A, heat transfer), as well as coordinating with suppliers of necessary art processes (embroidery, printing, transfer). In conjunction with the general manager and the production manager, this area diagrams the production program monthly and over weekly meetings checks the progress and possible modifications that may arise. Although the delivery priorities are defined by the general manager, this area also acts as support since it has a broad vision of the process in terms of external factors, such as suppliers and customers. To fulfil the necessary tasks, this area has 4 people working in shifts of 8.5 hours, 5 days a week.

Fabric Store and fabric sourcing department

The fabric store (Appendix C – Figure 32) is handled by the fabric in-charge and the in-charge is assisted by a team of helpers for loading and unloading fabrics from trucks and rack storage and issuing fabric to the cutting department. The fabric department receives and stores all kinds of fabrics, all of them delivered in rolls that are entered into the information system by the in-charge person and are kept in the rack or on wooden pallets.

Following are the major activities of the fabric store:

- Receive Fabrics: control of incoming goods with the purchase order and location of it in the corresponding warehouse zone to be entered into the system.
- Quality Control with 4 Point System[7]: Whether the fabrics are purchased from the buyer nominated fabric suppliers or from the open market, every fabric has to pass the quality control point which consists of analysing a portion of the incoming rolls by putting them in a fabric inspection machine (Appendix C – Figure 31) and by the previously mentioned system decide whereas the lot it is approved or not and enter any pertinent comments for the batch.
- Sourcing of Fabrics: once the products are approved for the seasons, the calculation of the consumption of the necessary fabrics must be carried out, the head the fabric sourcing together with the head of product development carry out this task and contrast with what is in stock to

[7] 4 Point system for fabric inspection is widely used in apparel industry for fabric quality inspection, which consist of upon inspection of the element the user has criteria of giving penalty points based on defects and defect length, where it uses a different scale for acknowledge of different types of defects (how a defect looks and its appearance). Later it is used a calculation method of total penalty points for total defects found in a fabric roll with a check sheet or format for recording data.

carry out a new purchase order. The calculation of needed fabric per product is almost standard which makes this process more agile. When it is time to start production, the store in charge must deliver the fabric to the cutting sector and is responsible for resting the fabric if required before the cutting process.

- Basic Testing of Physical properties of fabrics: stretching or breaking elongation of the fabric is measured as well as the elasticity and resistance to friction. In some cases, the fabric is submitted for waterproof tests, moisture, and air permeability.
- Maintain inventory record for fabrics: the approved fabrics are entered digitally into a stock database and physically placed in the designated rack area according to their composition and time until production. This stock record allows for other processes such as materials requirement planning and production planning, therefore it is very important to have a valid and efficient control of the product, and above all reliability.
- Fabric Issue: According to the production plan the fabric warehouse must prepare and send to the cutting sector the right amount of fabric needed for each production order. This procedure also requires the fabric relaxation time to be considered, which depends on the composition of the fabric and the method used to perform it.
- Fabric Reconciliation: fabric usage analysis, for example out of the total amount purchased how much was wasted, used, and how much remains as deadstock. Fabric usage analysis is important because it cost 50-85% of the total garment cost. You can plan for saving fabric in future orders based on the current fabric usage analysis.
- Communication with Fabric supplier: to know when new fabrics are going to be delivered to prepare space for storage and organise the time and resources to enter that new stock with all the procedures needed it is important to maintain communication with suppliers. Also, for quality claims, if there is any type of flaw in the fabric or quality problem it can be solved directly with the supplier or even the supplier can inform it in advance to alert the production sector as well as customers about this and solve possible future problems.

Cutting Sector

Here is the starting point for the PO, where the transformation from fabric rolls to create the first pieces of a clothing item (Appendix C – Figures 33 to 39). This sector counts with two highly important robotic machines; the fabric spreading robot and the cutting robot; with this mentioned it is important to separate the different main activities that the sector does. For a better understanding of the following procedures, it is important to remark that a single garment is constructed from different body parts (e.g., chest, back, sleeves, neck) displayed on the same ply. After receiving the fabric issue from the fabric store the next steps are:

- Fabric Spreading: It is the action of rolling the fabric from one point to the other end of a big table spreading it manually or automatic with a robot. The length of the layer is decided based on the marker size and marker length. Multiple numbers of fabric layers are spread on the table and all the fabric layers are cut together. Depending on the fabric thickness the number of plies in a lay is decided and depending on the cutting process that will be done. Normally the height of the lay is kept according to the cutting machine blade height. In Appendix C Figure 33 are showing both types of spreading used in the company that mainly depends on the fabric amount needed to be piled up, type of fabric, availability of the table and machinery as well as personnel to perform that task.

From the observation of the process and the interaction in the plant over the years, it is highlighted that this activity is a critical point since this is where it is highlighted the fabric defects that would later generate deficient garments. So, when spreading takes place, the operator in charge must observe in detail and if there is any unacceptable finding part a *splice*[8] is made. It is important to remark that if the fabric roll finishes in the middle of a ply, then the part that was spread is removed and it starts again with a new roll from the beginning of the ply. This procedure enables any problem regarding the tone of the fabric that later may appear.

- Cutting: The bulk cutting is done employing cutting machines, manual or automatic (Appendix C – Figure 36). For both types of procedures, it is necessary first to do a maker guide to have a reference of the many parts needed for each kind of garment (Appendix C – Figure 38 & 39). This marker is as wide as the fabric roll to be used and long enough to fit all the pieces of each size.

  Is important to note that fabric is the costliest item in garment manufacturing. About 60-70% cost of the garment is incurred in fabrics, for this reason, garment makers wisely utilize fabrics, trying to leave as less unused fabric on each maker as possible. For some years now, the company has been using software to create intelligent markers, which are then reviewed and corrected, if necessary, by the cutting manager. These markers are printed in a plotter in the actual size to be displayed on top of the total bulk fabric to be cut. If the process is manual then the cutters use the marker as a reference to know where to cut, instead with the cutting robot the marker is loaded into the computer and the robot already knows where to cut, reducing the margin of error. In any case, the marker is laid out on top so that when the cut parts come out of the robot they can be identified with their corresponding article, size, and sequence.

- Sequencing: Once the parts go through the cutting process, the outcome needs to be identified with a sequence number. For example, on one marker there is four size medium and two sizes large of the same garment, this means there is going to be six chest parts indicated on top of the bulk order in the marker with the article, size, and the number of repetitions for that combination on the marker. According to the three factors mentioned before an operator carries out the sequencing process of each part to maintain the order in which it was piled up. The fact that these parts are numbered serves to maintain order throughout the different processes that may occur until reaching the sewing line where it is of utmost importance to respect the order of sequence

[8] Splice – overlapping of two parts of the same fabric because a cut of the full width of the fabric in question was made in the middle of the spreading.

established to avoid incomplete garments and changes of fabric tone in the same garment or size errors.

Semi-Elaborated Store

This sector oversees semi-elaborated products which are the different parts cut piled up according to the PO (Appendix C – Figure 41). For every article, there are different parts and processes needed according to the tech pack as explained before, so here each part is sent to the destination expected.

For example, for a t-shirt that has four parts (chest, back, two sleeves) the *sleeves* don't have any art process so they will be stored in the warehouse, the *chest* needs to be printed[9] so only this part is taken to the area of where this art process takes place, and for the *back,* a transfer application is indicated in the tech pack. Once all the parts are finished with the art processes, it is stored as pending to be sewn. The responsible for the sector receives the production plan weekly with the sewing sector requirements for the POs stored to set up production trolleys (Appendix C – Figure 40) that are sent to the sewing line upon request.

Trim and Accessory Store

Like the fabric store, this store receives all kinds of T&A and stores them in racks. The main activities carried out in this sector are the following:

- Sourcing trims like sewing thread and packing accessories
- Checking of Trims and accessories in terms of quality and quantity
- Storing trims and inventory maintenance
- Trim and accessory issue
- Dying of trims like twill tape
- Arranging trims in racks or bins to get trims easily when the request is received from someone.

to meet the production demand promptly by performing all the tasks previously mentioned, this sector has 3 people working a full shift.

Transfer Sector

In the transfer sector, a process is carried out in which some parts of a garment are subjected to the application of a plastic design on the fabric through heat, only if required by the customer's specifications. This sector oversees receiving and storing the parts of the fabric to be used once they are already cut and the necessary supplies such as prints.

To carry out this process, the company has 5 automatic transfer application machines and 3 manual machines, with a total of 6 operators working full time.

[9] Printing – external process that prints a pattern into a plain fabric.

Sewing Department

Stitching or sewing is done after the cut pieces are bundled according to size, colour and quantities determined in the PO by the semi-elaborated sector in carts ready to be entered into the sewing line. Garments are sewn in an assembly line, with the garment becoming complete as it progresses down the sewing line. Sewing machine operators receive a bundle of cut fabric and repeatedly sew the same portion of the garment, passing that completed portion to the next operator. For example, the first operator may sew the collar to the body of the garment and the next operator may sew a sleeve to the body.

Quality assurance is performed at the end of the sewing line to ensure that the garment has been properly assembled and that no manufacturing defects exist. When needed, the garment will be reworked or mended at designated sewing stations. This labour-intensive process progressively transforms pieces of fabric into complete garments.

Different operations can be done according to the sewing machines that the factory possesses. Also, according to the tech pack and the PO, the layout of the sewing line is planned as well as how many operators will be designated to that line, as one person can perform more than one operation in some cases.

The company owns a total of 140 sewing machines. These machines are of different types, as previously mentioned, they can achieve different finishes on the garment. Also, other kinds of machines are used in the line for fusing collar components, buttons, and buttonholes.

Finishing and Packaging Sector

Major activities of a finishing department include thread trimming, checking of garments and ironing. The packing department in a factory works side by side with the finishing department.

Folding, tagging, and packing of garments are done in the finishing department. Based on product categories finishing room activities may vary. Activities of the finishing department are listed below:

- Thread trimming
- Attach button and buttonholing in case these jobs are not done in the stitching section.
- Checking of garments: finished garments are inspected for quality assurance of the outgoing products. This process is followed for internal quality audit and to ensure that no defective garments are packed into the cartons.
- Garment Pressing / Ironing: some fabrics may need to be ironed, but for most of the fabrics used in R&A it is not necessary. Still, they count with an industrial steam pressing machine to correctly fulfil this procedure.
- Folding and Tagging: The finished garments are then folded in a specific dimension by using a template. The price tags, hang hags and any other kind of tags are attached to the garment.

- Packing: The folded garment is packed into a polybag to keep it fresh till it reached the retail showroom. Different types of packing accessories are used to keep the garment in the desired shape.
- Carton packing: To transport the finished garments, they are packed into bigger cartons, where the size of them depends on the client. It also must be identified on the outside by a sticker with information about what is inside that box.
- Prepare for dispatch: Finally, the garments are ready for shipment in carton boxes labelled, then they are stored in the finished goods warehouse till the truck for delivery arrives. Also, information between sectors needs to be smooth as the cargo has to be carefully documented.

Quality Control Department

As an international standard company with clients that require and value high-quality products, this process is a key sector of the company. Activities of the Quality control department are as follows:

- Setting up Quality Standards
- Establishing Quality SOP[10]
- Quality Assurance
- Quality Control activities at the Pre-production stage:
    - Auditing inward fabric and T&A and ensuring only quality goods are accepted.
    - Involvement in product development and sampling stage and take care of quality aspects of samples.
    - Conducting pre-production meeting before production start.
    - Ensure that no faulty fabric is sent for cutting. If a minor fault is present in the fabric, defects should be marked on the fabric and the same thing must be communicated to the cutting department.
- Preparing the audit report of the fabric and T&A quality.

Other necessary sectors for the company that ensure a correct workflow and effectiveness of processes are the following, but as they are not directly related to the manufacturing process they will not be thoroughly described as previous sectors:

- Maintenance Department
- Industrial Engineering Department
- Accounting and Administration Department
- Human Resources Department
- IT Department

[10] SOP – Standard Operating Procedure

2.3. Contextualization of main problems

Any procedure change in the clothing manufacturing can potentially affect the production performance, quality of garments, and timely delivery. Whereas there's no such thing as a seamless procedure for clothing fabrication, knowing how, when and where the issues may occur and dealing with them in the right way is the key. Among those issues, some areas are more likely to be affected in this kind of industry, such as communication issues, failure to share Tech Pack changes, and loss of critical information in the conversation thread between the different sectors of the company. Another highly common issue is the loss of control of inventories causing overstocks or even a lack of inventory for raw materials which leads to very inefficient material handling and requesting, additionally creating unproductive spaces and time wastes.

Picking up on the objective of this thesis, which is to elaborate on an improvement proposal based on the use of Lean Manufacturing tools that will increase the productivity of a textile SME, in this section different issues regarding the need to optimize R&A's operations and processes are presented to maintain their competitiveness and reduce costs. To mitigate time loss and create efficient processes by the end of 2022, it is important to analyse and understand the production time of a single product as well as to know those idle times that will generate productive waste and inefficiencies.

The structure of this section is subdivided into 3 sub-sections which aim to cover the different problems that are characterised as barriers to achieve not only the expected time reduction but also a reduction of costs and an improvement in the quality of work. The first section describes R&A's production planning and operations with emphasis on the information flow, followed by section two which describes the problem of inventory management of threads, T&A, which generates incompetence in the physical space of each storage place respectively and the third section explains the need for flexibility towards customer changes that must be accommodated in the manufacturing process on relatively short periods of time.

2.3.1. Production Planning and Operations

Production planning and control are two of the most important aspects of the clothing manufacturing process and involve a complex process and requirements to be planned out way in advance, very often months ahead.

Planning procedures requires information from the various sector as was explained before, whilst the production manager facilitates information on the available time for new products or updates on the productive timeline, the sales manager provides data on which products each client requires and delivery times for PUO, and finally, product development manager contributes with the available materials or analyses procurement of new if needed. The key to a well organised and in sync company is the correct flow of data and communication between the key sectors of the company.

The previously stated flow between sectors is highly informal, leading to also some degree of informal productive processes. Having no established method to pass information from one sector to another apart from emails calls or daily meetings, in which not all the involved sectors are present, numerous defects in production happen that may not be specifically blamed on a productive error but instead from disorganization or lack of information. It is common that under these ways of workflow some routes depend solely on each individual and to be completely done this person needs to control the process entirely. Some of the setbacks that occur due to this is the lack of raw materials when they are required for manufacturing.

In working toward an efficient production planning method several aspects must be considered. From R&A's point of view, the two most important ones are the delivery dates agreed with the client as well as the dates agreed with the fabric suppliers to receive the raw materials. Crossing information from these two variables is what aligns monthly and weekly planning of all the production areas mentioned above in point 2.2.3.

As seen in Figure 8 there is an established pre-production process where all the relevant information is reviewed and established, but it is very important to note that clients require R&A to have great flexibility towards changes. For example, R&A is the manufacturer of the clothing equipment for a well-known club in Argentina, which happens to be having a good season this year in the tournament and R&A's client is expecting a rise in the sales, so they request more football t-shirts for next month. The production for the next six months is already closed, but as the client is quite important it is necessary to fulfil that demand so if the production manager can rearrange some of the clients PO, the general manager accepts the new quantity. This leads to a downflow change of information that not always happens correctly or reaches everyone involved. As this case is not an exception but a normal condition being that R&A is the manufacturer for 8 football clubs it is indispensable to review the information flow and how and where those changes need to be communicated.

2.3.2. Inventory management of T&A and threads

Effective management of the supply chain plays a key role in the strategy of all organizations. From the beginning with the supply of raw materials until finishing with the delivery of goods to the client on time. So, for the development of this master thesis regarding the chosen theme, a focused look on the productive flow was made by analysing the material flow in each sector from start point to endpoint.

During the time that the critical production survey was carried out in R&A looking for causes of improvement, it was found that on recurrent occasions there were stopped materials in process stored in trolleys waiting for necessary components that were not yet in the factory. In addition to this, the warehouses of these materials were physically overflowing, which made it very difficult to search and check for possible raw materials to replace them. Although a digital stock search is possible for T&A, this does not happen in the case of yarns where there is no digital or paper record of the availability of these materials.

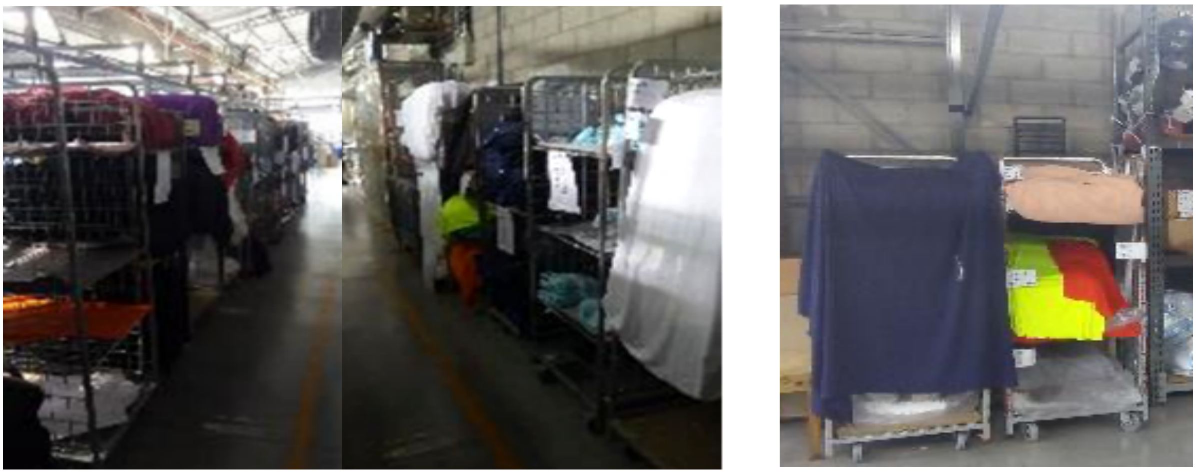

Figure 11 – Example of trolleys parked on production floors.

Figure 11 shows trolleys parked on production floors with started PO's that lack some component, in this case the security and composition fabric tags that are sewed on the inside of the garment, so it cannot enter the production sewing line although it was programmed, and the trolleys are already filled with the cut parts separated by sizes. This not only causes a delay in the programmed production causing delays on delivery dates but also generates inefficient spaces for work.

Figure 12 – Threads Deposit with no clear identification or control documentation.

Figure 12 shows no organization in the thread deposit and no clear identification towards the material. The racks are uneven and in not good conditions making it difficult to have categorized standard method of organization. Colour differentiation is a clear distinction seen on Figure 12 but different materials such as cotton and polyester threads are mixed all over the rack not following a rule making it difficult to find either of them quickly.

Figure 13 – T&A deposit disorganised and difficult to access.

Figure 13 is a clear portrait of the previously stated fact of disorganization in the deposit. Here it is seen the surplus of material for a given space and the lack of identification in the spaces designated for each material as well as the correct way of distributing the elements in it. This situation causes extra amount of time for the operator to find and collect the required material and the try to accommodate everything in a random way so that is easier to retrieve it. The whole operation has a lot of dead time regarding productive activities causing NVA operations to the final product.

To conclude a summary of this section, the following problematic situation is presented, which is part of the current production process described and represented in the previous figures, Figure 11, 12 & 13. The procurement of threads is carried out by the production sector as it is easier to access the information since a manual stock check is required, whereas for all other raw materials the procurement is carried out by the purchasing sector of the product development area. Since they oversee approving with the customer if the selected raw material is approved for each article.

In order to carry out the stock check process before purchasing, it is necessary to write down the need on paper and go to check its availability in a warehouse where there is no defined order for the materials, which makes it very cumbersome to search for them. Then, once found, check that the quantity is sufficient and if not, write down the difference to make the purchase. Normally, a quality check is also carried out, as the yarns dry out over time and can become inefficient to use. This could be related to an expiry date for these products. Once this information is available, the purchase order is placed with the suppliers.

The second part is when the production area starts a PO where the different raw material storage sectors must start to prepare the necessary material to send to the other sectors. Here it can be highlight two important issues, the first is the time it takes to find the threads for the operators and in some cases also some T&A. As can be seen in Figure 13 the order of the warehouse is very sloppy and in some cases without any control. And secondly, the thread requirements come as separate information to the rest of the needs, often incomplete or informal (a phone call), which causes a loss not only of time but inefficiencies in terms of the work of the operators for all the delays that this can cause.

The main problems that can be listed due to this finding are:

- Uncertainty of the real available stock of raw.
- Difficulty in physically locating the required material.
- No standard rack positions for the raw materials.
- Waste of time in controlling the necessary stock of yarns and their availability.
- Disused yarns and large quantities of remnants of this material.

2.3.3. Meeting Client's needs on time

Both the problem described in section 2.3.1 and section 2.3.2 inevitably led us to encounter the problem of almost non-compliance with customer delivery dates. As mentioned previously, for R&A, this factor is very important because in several product lines (e.g., football shirts) critical customer demand leads to a quick response without neglecting the other product lines of that or other customers.

In the first two-quarters of 2021 R&A received from its clients 240 orders which consist of any of the products mentioned in Figure 4, each order having its own delivery date. Once it is received the PUO follows the steps mentioned in section 2.3. Description of the manufacturing process and ends up being delivered to the customer. The time this whole process takes is crucial to fulfil the client's requirements to be able to place their products in the market at the correct moment.

Figure 14 presents the data about the orders received by month and how many of them were fulfilled and delivered on time.

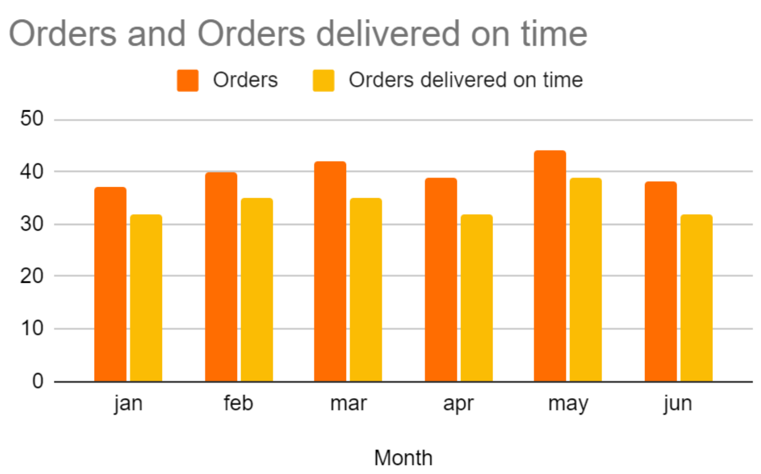

Figure 14 - Orders and Orders delivered on time in the first two quarters of 2021 by month.

Having a critical and informed look over the monthly difference of delivery orders on time and total order, it can be precepted that there is a problem. During the six months that sampling data were collected, the client's requests were completely satisfied but at least 5 orders were not delivered on time every month. This could cause less fidelity by the clients and sometimes economic losses.

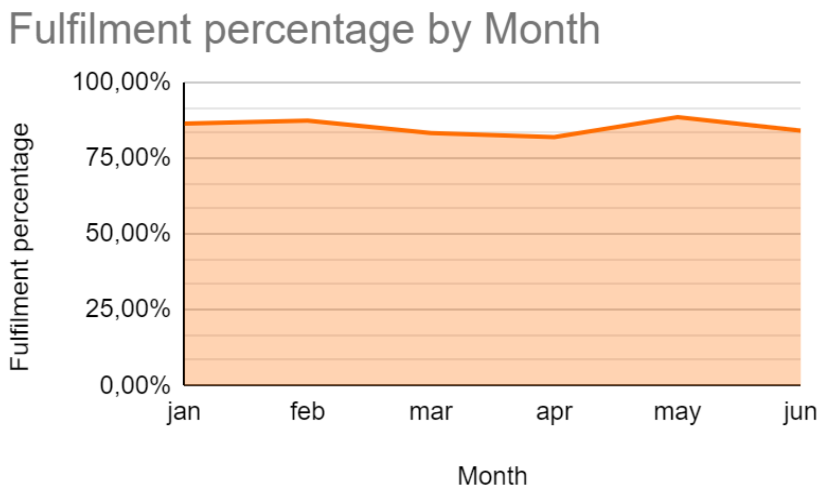

Figure 15 - Percentage of orders fulfilled on time by month in the first two quarters of 2021.

Figure 15 shows that each month more than 10% of the orders were not delivered on time. It is very important for R&A to be reliable to its clients on delivery dates due to quick fluctuations in demand depending on the results of some teams in the season. As it was mentioned before working with high-standard companies requires not only quality satisfaction but high levels of delivery performance as well.

Having an overall fulfilment of 85% of orders delivered *on-time in-full* is below the expected level to meet the client's requirements for this purpose it should be reduced by at least 10% the indicator, attacking the possible main causes that will allow R&A to achieve this.

2.3.4. Conclusion of R&A points of improvement

R&A's production planning is subjected to great variability due to product changes from the client as well as the shortage of supplies from the providers. The lack of decisions from the clients regarding the definition of the tech pack from a single item delays the whole process of production from requesting the raw materials to the programming of production. As these situations are not an exception but the rules of the market in which this industry operates, it is important to look for the right tools to transform these situations that are nowadays perceived as problems in the company, as they are not adjusting the productive changes to the speed of the customer or to the new ways of working, to a smooth production process where key factors such as delivery timelines are met or inventories have both data and physically clear access.

Considering all the drawbacks mentioned in the previous sections, through the right tools of analysis it can be supported the fact that the problems encountered are not isolated, but all have a certain degree of incidence in the other problems. In the end, this dissertation will seek to propose improvements through lean manufacturing tools to increase the company's performance, by reducing costs and improving the efficiency of the processes.

III. LEAN MANUFACTURING

The concept of Lean Manufacturing is studied and used in a wide-ranging variety of industries, being one of the most influential manufacturing paradigms of recent times (Holweg, M., 2007). This paradigm says Holweg is built up from a sequence of dynamic learning events mainly in the textile and automotive industries. Properly speaking, according to Gonzalez (2007) Lean Manufacturing is a concept that arises in the Toyota Production System (TPS), which refers to the Lean concept as tools that serve in the identification and elimination of waste called Muda, by performing this process efficiently, the process will generate not only quality improvement but also reduction of time and cost of production. To recap the fundamental principles of Lean Manufacturing are principally identifying added value, eliminating waste, and creating a flow of value for the customer (Melton, T., 2005). Furthermore, the definition of the concept is constantly evolving, and as such, trying to define it definitively is like trying to take a photograph of a moving object (Hines et al., 2004).

3.1. The 5 Lean Principles

According to Womack and Jones (2003) and the Lean Enterprise Institute (LEI, 2013), there are five lean principles for guiding the implementation of lean techniques, presented in Figure 16:

Figure 16 - The 5 Lean Principles Cycle (Lean Enterprise Institute, 2013).

I. **<u>Specify value</u>** – Value can be defined only by the ultimate customer. Any features or attributes of the product or service that does not meet the customer's perceptions of value enlighten the path towards reorganization and structure of value input in a product. Figure 17 is a value impact matrix where it shows how can we identify and discern between activities that do generate a valuable product and which do not, as areas of opportunities or as we mentioned before activities that need to be removed.

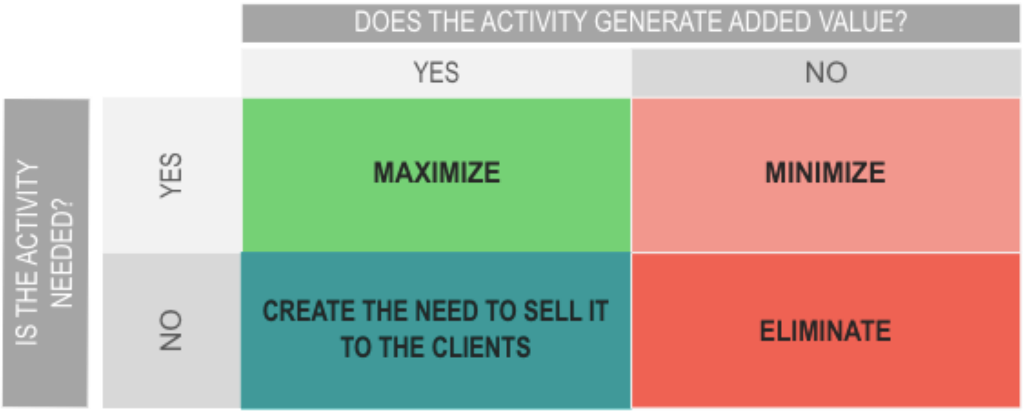

Figure 17 – Product value matrix

II. Identify the **value stream** – The Value Stream is all the actions needed to bring a product to the customer. Identify all the phases in the value stream across the organisation to achieve delivering the product or service to the customer at the right time and with the expected quality product or service. Identifying unnecessary steps in the supply chain will be exposed as waste in the value stream.

III. Make the value-creating stream **Flow** – Eliminating waste ensures the product or service flows to the customer without any interruption or waiting.

IV. **Pull** between steps – Produce only what the customer wants when the customer wants it. Demand-driven production needs quick responses from manufacturing sectors. Creating a pull system that starts with the client's needs.

V. **Pursue perfection** – There is no end to the process of reducing time, space, cost, and mistakes. If all the previous steps are followed accordingly the process of identification and removal of unnecessary flows should deliver a zero-waste process keeping in mind that these principles do not have an end, rather than a continuous start from an improved situation if all the steps are done correctly through the organization.

3.2. Lean Production

The author Shah and Ward (2007) describes Lean Manufacturing as a multidimensional approach that encompasses a range of management activities, stating that there are ten factors that constitute the operational complement to Lean production:

1. JIT delivery from suppliers.
2. Supplier feedback.
3. Supplier development.
4. Customer involvement.
5. Employee involvement
6. Pull system.
7. Continuous flow.

8. Reduced setup time.
9. Fully preventive maintenance.
10. Statistical process control.

Different points such as the statement from Chen, Li and Shady (2010) where it is found that any activity for which the customer is not willing to pay should be eliminated; or that from Hines et al. (2004) where is stated that value is created whenever internal company waste is reduced and whenever new features valued by consumers are offered to them, conclude on the idea that Lean Production focus to succeed is to work around the wastes before adjusting any production process and have a very clear picture towards this matter.

The main benefits of Lean production are the reduction of clients waiting time, achieved through the reduction of lead-time, and production inventories, and accomplishing robustness of processes by analysing methods to reduce wastes and reprocessing of products (Melton, T., 2005). Hofer (2013) also relate the performance of companies with Lean manufacturing practices, concluding that these have a positive impact on the financial performance of companies, much due to the decrease in operating costs.

Focusing on one of the five principles mentioned before, *Pull between step*s, it can be transferred into the productive core by implementing a pull production system, where the creation of a product occurs only when the customer places an order (Melton, T., 2005). Pulling from the beginning of the productive chain rather than pushing allows to significantly reduce inventory at all stages of the process which leads to a decrease in the lead-time to the customer. An example of a pull production system can be seen in Figure 18 complemented by a Lean tool, *Kanban*, which emphasizes the fact that Lean methodology needs to be seen as a global cultural organizational change towards productivity improvement using all the tools when possible.

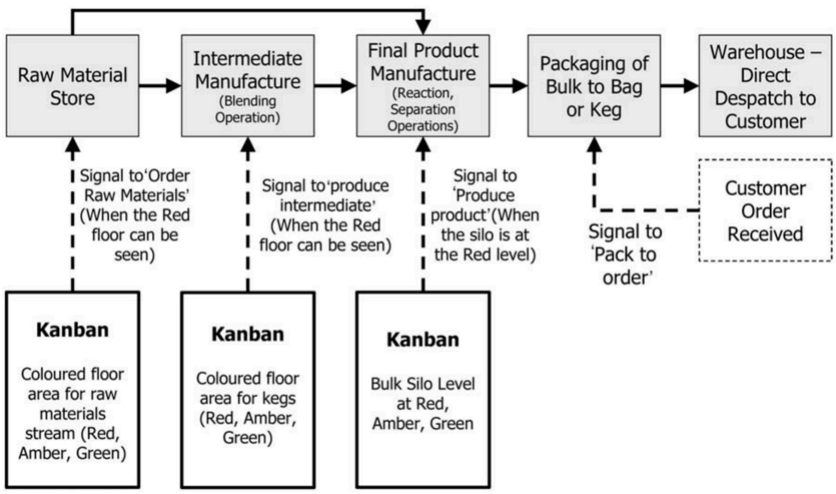

Figure 18 - 'Pull' production example—using Kanban (Melton, T., 2005)

The last important concept to take on a lean manufacturing focus in an organization is the term *continuous improvement.* Melton. (2005) states that aiming for perfection is equal to a never-ending cycle of applying the concepts described before. Cultural changes can be the hardest part to overcome when new ideas are presented. Investment in time and effort to support the process of adaptation towards Lean can result in sustainable organizations that truly care for this production philosophy.

3.3. The 7 Deadly Wastes + 1

There are many definitions of waste by various authors, for example, a waste can be defined as any activity that consumes resources and the client is not willing to pay for (Chen, J. et al.,2010), another definition could be that it is any action that needs resources to be done and does not add value to the product (Herscovici, A., 2018). To improve efficiency and be more competitive, businesses should eliminate *Muda*, Japanese word for futile (Singh, B. et al., 2009), which will also help reduce costs. The savings obtained could be used to improve other processes. To summarise it is important to classify every action performed on the product, having in mind which actions should be classified as if it adds or not value to it. Afterwards, planning the elimination of those activities that do not add value and obtaining the goal of a waste-free process.

Having in mind that lean is not just for production but for the whole organization and could be implemented as a philosophy, when looking to the big picture sometimes waste is a necessary part of the process and adds value to the company but not strictly to the product. Therefore, it cannot be eliminated, e.g., financial controls. If the Muda control is done at an early-stage huge savings can be gained (Melton, T., 2005)

According to Hines and Rich (1997), there are seven types of waste seen from the perspective point of Lean Manufacturing:

1. **Overproduction** – To produce what is not necessary, when it is not necessary and in quantities not necessary. It is contrary to Just-In-Time.
2. **Transport** – Each time a product is moved it stands the risk of being damaged, lost, and delayed as well as being a cost for no added value. Transportation does not make any transformation to the product that the consumer is willing to pay for.
3. **Stock** – The excess of stock be it in the form of raw materials, work in progress, or finished goods, increases the costs, and can cause additional handling, additional workers, and additional paperwork.
4. **Motion** – It refers to all the motion that is not necessary to complete a specific task. It can refer to the motion of workers, documents, or even electronic transactions. It is due to poorly designed layouts, leading to great amounts of transportation of goods.
5. **Waiting** – The time that a worker, machine, or document is idle, waiting for a previous task to finish before commencing the next is waiting time.
6. **Over-processing** – A process that consumes more resources than is strictly needed.
7. **Defects** – This kind of Muda involves extra costs through identifying the cause of the defect and reworking the product or rescheduling production.

8. **People's time** - Underutilization of people and their ideas results in a loss of knowledge, skills and abilities which should be used to the fullest.

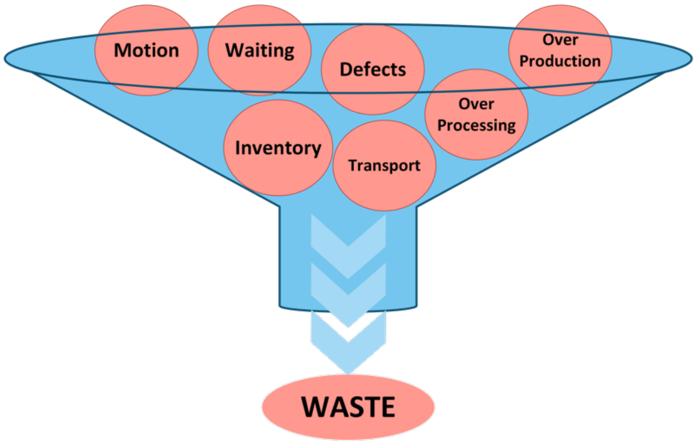

Figure 19 - The 7 types of waste

Being lean therefore implies a continuous effort to achieve a state characterized by minimal waste and maximal flow. It is essential to learn to view waste through "fresh eyes," continuously increasing awareness of what constitutes waste and working to eliminate it. (Tapping, D. et al., 2003).

3.4. Lean Methodology

Lean Methodologies impacts have been known to be difficult to measure or attribute to a specific task improvement, but throughout surveys conveyed to manufacturing companies it is found that leading a company with Lean principles breeds important benefits in the areas of operation, administration, and management, with improvements of up to 90% reduction of time in the work cycle. Also affects the final quality of the product by increasing it by 80%, allowing it to gain market share against the competition. (Green, J., 2010; Otoya, C. et al., 2017). Melton (2005) describes also the typical benefits shown in Figure 20 to show that Lean is a very real and physical concept, that can be adopted for all aspects of the supply chain and should be if the maximum benefits within the organization to be sustainably comprehended. There are many tangible benefits associated with lean business processes, e.g., the speed of response to the company's needs is reduced, generating a smoother process flow.

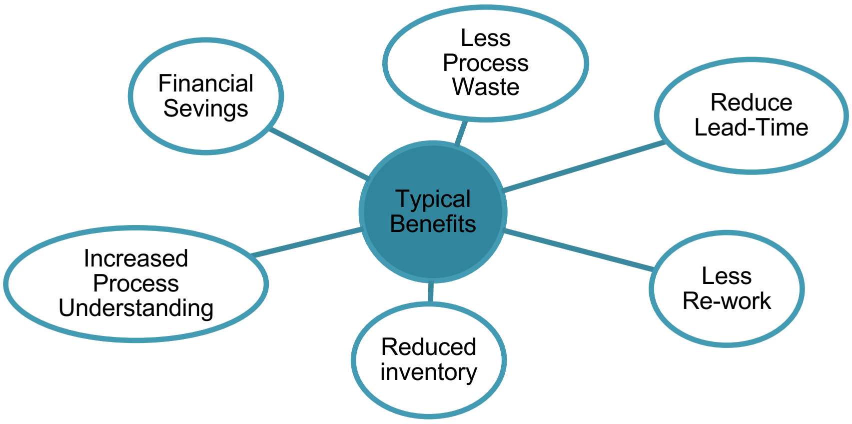

Figure 20 – The Benefits of Lean (Melton, T., 2005).

The lean methodology has proven to be an advantageous approach that ensures rapid results when it is adopted appropriately by the different actors along the supply chain. The main convenience of implementing the lean philosophy are associated with increased productivity of systems and operations, reduced costs and lead time and improved quality, providing greater value in products and services delivered to the customer (Shah, D., 2018).

3.4.1. Kaizen

Kaizen is a combination of two Japanese words, *kai* meaning change and *zen* meaning better, which together mean *change for the better* or also known as *continuous improvement*. In the early applications of this methodology, it was mainly used to pull together a cross-section of all the operational teams that were involved in the manufacturing unit (Melton, T., 2005). The aim of the Kaizen was to collect and analyse data to identify the real problem and design some solutions; as well as start to break down functional barriers and general scepticism about Lean thinking.

Herscovici (2018) states that Kaizen is one of the principles of Lean thinking that characterizes the Japanese philosophy, which focuses on continuous improvement processes through incremental changes based on constant learning. For Chen et al. (2010), once the root cause of a problem is identified it is necessary to find a solution that allows the company to reduce or eliminate waste, often achieved with the use of Kaizen events. In a Kaizen event, a multidisciplinary team is formed to find a solution to a particular problem and improve a company's production system.

To have an organizational structure that allows the ongoing improvement needed, it is important that all the employees of a company are involved and focused on process improvement, defining itself as the first part of the Lean approach. This statement is also in line with the idea of the author B. S. Kumar (2016) who supplements it by remarking that big changes are noticed after small improvements were used on a daily and continuous basis. Furthermore, S. Kumar et al. (2018) encourage the use of the two concepts, Lean and Kaizen, as a whole concept towards the same goal; continuous elimination of waste through small improvements, by installing a secure and reliable methodology to achieve efficient processes.

Chen, J et al. (2010) study the implementation of the Kaizen methodology in a small manufacturing company of switchboards and sockets located in Unites Stated of America (USA). The results of the implementation are stated as decreased processing times, improved product quality and decreased internal inventories among the company's production operations.

3.5. Lean Tools

Lean tools and techniques are good industrial engineering practices that can be applied to companies in many contexts and without a lot of difficulties (Shah, R., Ward, P.T., 2007). Lean tools are used to accomplish what lean manufacturing stands for: waste elimination, cost reduction, improved quality and decrease i.e., lead time, inventory, and equipment downtime (Chen, J. et al., 2013).

B. S. Kumar (2016) has proceeded with the implementation of Lean tools and argues that the objective of this methodology is to enable the company to be highly responsive to demand, while producing quality products as efficiently and economically as possible, by reducing different types of waste, both human factor and stock.

In the following subsection, it will be introduced the state of the art of Lean Production Tools well known in industries with this philosophy. Followed by a summary of the state of the art for a set of selected Lean tools: Value Stream Mapping, Root Cause Analysis, Visual Management, Work Standardization, Stock Management and Single Minute Exchange of Die (SMED). Concluding with a comparison between the integration of the methodologies and Lean tools to propose a comprehensive methodology to be applied in the last chapter of this master thesis. Table 2 is a representation of the *7+1 Wastes* mentioned before and which Lean tool or which group of tools would be more efficient to mitigate that problem more efficiently.

Table 2 – Lean Tools application for each waste

	Over production	Waiting	Transport	Over Processing	Inventory	Motion	Defects	People's time
SMED	X	X						X
VSM		X			X			
5S			X			X		X
Root Cause Analysis	X	X	X	X	X	X	X	X
Work Std						X		X
Stock Management	X	X		X	X			X
Visual Management	X				X		X	X

3.5.1. Value Stream Mapping

According to Hines and Rich (1997) value stream is a collection of all actions value-added as well as non-value-added that are required to bring a product or a group of products that use the same resources through the main flows, from raw material to the hands of customers. Later, Rother and Shook (1999) defined VSM as a powerful tool that not only highlights process inefficiencies, transactional and communication mismatches but also guides improvement towards cleaner processes. Jones and Womack (2003) explain VSM as the visual mapping process of the flow of information and material from the moment it is decided to implement this new tool, capturing the processes initially so that future state map can be carried out and the improvements obtained can be contrasted. A value stream consists of everything including the non-value-added activities and provides a clear view of what elements of the process are working towards generating value and which are not (Tapping, D. et al., 2003).

Value stream management is just that: a process for planning and linking lean initiatives through systematic data capture and analysis (Tapping, D. et al., 2003). For this is important to have critical knowledge of the factory and be able to walk through the company studied to have a real perspective of what is being mapped and not just theorical knowledge.

Starting from the customer delivery endpoint and working back through the entire process documenting the process graphically and collecting data along the way until reaching the suppliers. It results in a single page map containing data, such as cycle time, work-in-process (WIP) levels and the flow of information within the system (Singh, B., 2009). The steps taken in Value Stream Mapping are described as follows (Lasa, I.S. et al., 2008):

1. Select the product or product family you want to map.
2. Draw the current state value stream map, so that waste can be identified.
3. Draw the future state value stream map, using demand, flow and levelling concepts and other lean tools.
4. Create a work action plan.
5. Implement the action plan.
6. Achieve the action plan.

Having in mind the previously explained concepts it is important to remark that VSM is a proven process for planning the improvements that will allow the company to operate under Lean methodologies in the best way possible. The key ingredient in this recipe is the involvement of people throughout the process, from production plant operators to office employees including the high management. Otherwise, chances for success are severely limited. This process, along with a collection of practical worksheets, forms, templates, and checklists, will ensure a successful implementation of Lean manufacturing. (Tapping, D. et al., 2003).

B. S. Kumar (2016) carried out the VSM of the current state of a company in the textile industry in India and observed high stocks and substantial differences between production lead time and value-added lead time. Through the design of the future situation, the author concluded that it was necessary to use other tools to minimize the work in process. He also argues that this mapping tool is an ideal tool to understand the process waste in a value chain and is used to identify other Lean tools suitable for process improvement. The author states that the value chain should be reviewed until the future situation becomes the current situation.

The authors Irani, S. and Zhou, J. (2016) stand out among the various benefits obtained by the implementation of this tool, that VSM links Production Control and Scheduling (PCS) functions such as Production Planning and Demand Forecasting to Production Scheduling and Shopfloor Control using operating parameters for the manufacturing system ex. takt time which determines the production rate at which each processing stage in the manufacturing system should operate.

3.5.2. Root Cause Analysis

The CED was designed to sort the potential causes of a problem while organizing the causal relationships by Professor Kaoru Ishikawa in 1943. As its use spread to other countries, it became known as the Ishikawa diagram, or more informally, the "fishbone" because of its appearance once complete.

CEDs are drawn primarily to illustrate the possible causes of a particular problem by sorting and relating them using a classification schema. The construction and study of the diagram are intended to stimulate knowledge acquisition and promote discussion, but they can also educate others about a process or problem. The CED encourages data collection by highlighting areas of expertise or by showing where knowledge is lacking. Fredendall et al. (2002) call the CED process *an exercise in structured brainstorming*. The logic of the CED is that one cannot act until the relationship between the cause and effect of a problem is known. Consequently, it attempts to show related causes so action can be taken (Doggett, A.M., 2005)

Ishikawa (1982) outlines the following 5 steps for constructing a CED to get the best out of it

- Step 1: Decide clearly on the problem to improve or control.
- Step 2: Write the problem on the right side and draw an arrow from the left to the right side.
- Step 3: Write the main factors that may be causing the problem by drawing major branch arrows to the main arrow. Primary causal factors of the problem can be grouped into items with each forming a major branch.
- Step 4: For each major branch, detailed causal factors are written as twigs on each major branch of the diagram. On the twigs still, more detailed causal factors are written to make smaller twigs.
- Step 5: Ensure all the items that may be causing the problem are included in the diagram.

Major cause category branches can be initially identified using the six M's stand for: material, methods, machine, measurement, mother nature and manpower, or more correctly, the four Ps: parts (raw materials), procedures, plant (equipment), and people. These are the most common categories on the diagram, representation in Figure 21, but more can be added depending on the problem to be solved (Doggett, A.M., 2005).

Overall, the advantage of the CED is that it is easy to use, it promotes structure while allowing some creativity, and it works best when the problem is well defined and data-driven (Mahto, D. et al., 2008).

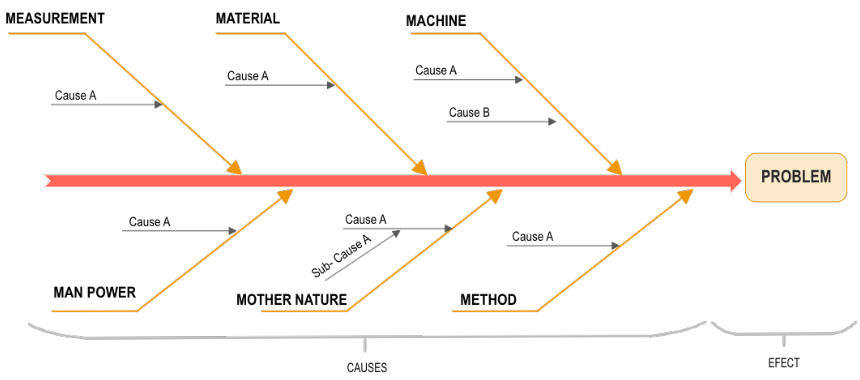

Figure 21 – Cause Effect Diagram or Ishikawa Diagram

3.5.3. Visual Management

Visual Management, also known as visual control, is one of the lean tools. This is a total view of all tools, parts, production activities, and indicators of production system performance (Womack, J.P. et al., 2003). Visual Management makes it easier to transfer information between the different areas of the company. Also, employees can display problems and important data of the day in a visible way (Tjell, J. et al., 2015).

5S

The 5S methodology is a management technique that allows controlling of the production plant by means of a visual tool for maintenance and cleanliness of the workplace (Melton, T., 2005). It is defined by 5 Japanese terms beginning with the letter S and can be translated into English as follows (Womack, J.P. et al., 2003)

i. **Seiri** (Sort) – Select and classify the items to be kept and discard those that are not used;
ii. **Seiton** (Straighten or orderliness) – Each item should go in a certain place so that it is easy to find, use and replace it;
iii. **Seiso** (Shine or cleanliness) – Identify abnormal conditions that could change production quality or lead to machinery failures;
iv. **Seiketsu** (Standardise or create rules) – Develop standardized procedures for maintaining the first 3's.
v. **Shitsuke** (Sustain or self-discipline) – Standardized methodologies are a continuous process of improvement.

In the beginning, this methodology focused on product quality. After years of development, the benefits started to change. It started to be a way of saving resources, helping to reduce storage costs and production time (Caliskan, N., 2016). All these aspects improve productivity and safety for employees (Ohno, T., 1988).

In conclusion, the 5S are a fundamental pillar in Lean implementation. It allows the reduction of waste, leaving only what is necessary to generate value. It is important to perform periodic audits to ensure the correct use of this methodology (Liker, J.K., 2004).

PDCA

The PDCA cycle is a systematic method for problem-solving to generate continuous quality improvement. This significant tool was created by Edward Deming and can be used to structure the 5s methodology mentioned above. It is composed of 4 repetitive steps that begin by facing the problem and end in its resolution. The four stages are (Deming, 1993):

1. Plan – Identify the possible causes, determine the objectives and make a comparison of the different practices.
2. Do – Several tests must be performed in order to analyze the data, understand the causes of the problem and find possible solutions.
3. Check – The results must be verified, the necessary training must be carried out and the following communication must be made.
4. Act – What was learned and executed in the previous steps should be reviewed and corrected in order to achieve continuous improvement.

3.5.4. Work Standardization

Womack and Jones (2003) define Standard Work as a listed description of each work activity in the process specifying: cycle time; TAKT time; the work sequence of specific tasks; and the minimum inventory of parts on hand needed to conduct the activity. Normally a spreadsheet it is used to register data such as: handling time; process time; TAKT time; and demand. Consequentially each process should be registered in the sequence of occurrence. This sheet also has a visual tool to analyse where time is being spent doing a necessary activity and where it is idle time that can be reduced.

Standard operation routine sheets are used to show the time relationship between the worker(s) and the manufacturing system. Adding to the information required mentioned before it can also be needed to create the routine sheet, where it is registered the time, it takes a worker to walk between processes, machine processing times, and manual operation times. Manual operations are tasks that need to be done by the worker between processing cycles, such as loading/unloading, de-burring, and inspection. The information is then turned into a graphical representation that shows what the workers and machines are doing throughout a cycle. (Chen J et al., 2010)

Standardized work pinpoints activities that are required to add value to the value stream. In the analysis of the activities in the value stream, steps can be reduced, eliminated, and/or combined to ensure that the cycle time for the process is as efficient as possible. Standardized work must provide the foundation for all your process improvement initiatives.

The following bullet points follow a guideline for implementing Standardized Work:

- Work together to determine the most efficient work methods.
- Getting consensus, or adherence is unlikely.
- Do not compromise takt time, adhere to it.
- Use the Standardized Work Combination Sheet to understand how the process cycle time compares to the takt time.
- Use the Standardized Work Chart to illustrate the operations in a process.

Standardized work provides a basis for consistently high levels of productivity, quality, and safety. Standards are established to reduce variation in any forms. As it is drawn the future-state VSM, it is not actually developed a standardized work chart in that instance, it occurs during the implementation process. However, the future-state map should always show exactly where standardized work is to be implemented (Tapping, D. et al., 2003).

3.5.5. Stock Management

To implement any kind of improvement regarding material flow it is important to have available, clear, and suitable information to work with regarding material handling. There are many systems to organize and treat supplies, in the early 1900s, Villefredo Pareto, studying the distribution of wealth of the population of Milan, observed that 20% of the population controlled 80% of the wealth. This logic, called the Pareto Principle, a stock and suppling system applied in stock management, where few items represent most of the investment.

To find the most suitable system for stock management, it is important to understand that demand can be characterized by three criteria, as dependent or independent, uniform, or non-uniform and deterministic or stochastic. Demand can not only be determined by the customer demand but for the requirements of materials that occur in between production sectors. Table 3 illustrates the relationship between the inventory management model or policy to be adopted according to the characteristics of demand.

Nowadays, there are many organizations using hybrid models that include customized Material Requirements Planning (MRP) systems, Just-in-Time (JIT) techniques such as Kanban's and Theory of Constraint techniques when classical stock management policies are still being used. JIT techniques and the use of Kanban incorporate a set of Lean tools for stock management (Guide Jr., D., 2000).

Table 3 – Methods of inventory management

Management inventory method	Demand
Inventory management policies	Continuous, independent and uniform.
MRP	Discontinuous, dependent and not uniform
JIT	Continuous and dependent.

Inventory management policies, systems or models that consider that the demand is uncertain are called stochastic models and can be classified by the frequency of their revisions as either continuous revision policies or periodic revision policies (Cavalieri et al., 2008). There are two main continuous revision policies. The first one, order quantity policy (s, Q), triggers an order of quantity Q to be ordered when the stock level reaches s, assuming that demand is also continuous. In turn, in the order-up-to-level policy (s, S), an order is placed to reach level S when the stock level reaches or falls below s. Both policies are the same when demand is discrete, that is, when it occurs per number of units (Teunter, B., et al., 2010). In contrast to the continuous revision policies, periodic revision policies only review stocks at the beginning of each revision period (e.g., daily, weekly, monthly) and orders are placed to increase the stock level to a predetermined point. These last types of policies led to a higher amount of safety stock than in continuous review policies because the lead time is also higher. Generally, in this type of policy, the day on which the order is placed with the supplier is already predefined, with a fixed periodicity between orders. Several authors mention that the order-up-to-level (T, S) is the most common periodic revision policy, in which, in each period of constant interval T, enough is ordered to increase the stock level to the level S (Chiang, C. et al., 1996). However, there are also mixed revision policies, such as the revision policy (T, s, S), which results from the combination of other policies like (T, S) and (s, S). In this model, the stock level is checked from T in T time units. If this stock level is equal to or below the order point, s, a new order is placed for enough units to bring the stock level up to S. Otherwise, no orders are placed until the next period T (Bijvank, M., 2012). As opposed to the stock management policies mentioned above, there are also situations where stock cannot be carried over from one period to the next. This happens, for example, due to the impossibility of accumulating perishable products (Kaya, O., 2017). It is very important to keep track of this information and the availability of it to specific departments. MRPs and other digital solutions are the great tools to get this information updated and available for the whole organization.

Looking at MRP's basic philosophy, we should be able to focus our scheduling only on what materials are needed, and when they are needed. MRP allows greater flexibility in product customization(Plenert 1999). To achieve this goals the MRP may succeed in this three main aspects:

- To combine information on demand for final products (independent demand) with information on the structure of these products, the required quantities of the dependent demand items do not have to be forecast (reduction of uncertainty).

- To integrate inventory management information, the net requirements for demand-dependent and demand-independent items can be obtained, and only these requirements need to be ordered.
- To enter information on lead time for purchased items and for produced items, also information of the purchase orders from clients and define production orders in periods of time that ensure delivery when the items are required.
- It is also very important to know the items needed to generate an MRP, the most revants ones are the following (Heizer 2008):
    - Master Production Schedule (MPS).
    - Stock Policies.
    - Bill Of Materials (BOM).
    - Lead Time.
    - Inventory Register.
    - Capacity Planning (Finite).
    - Factory Control.

Even though MRP was not specifically designed to have labour-based routings and a labour-based production order tracking system, it almost always does. Because of this, through its usage rather than through its design, MRP has become a workforce-production efficiency-oriented system, where production lead times are used to build buffer inventories in front of workstations so that workforce efficiencies can be maximised (Plenert, G., 1999).

3.5.6. SMED

A number of rules must be taken into account when a setup operation is performed in order to accelerate the process according to Mileham, Culley, Owen and McIntosh (1999). SMED establishes an efficient and quick way to change the product, which is manufactured in a production process accordingly to Ulutas (2011). Any changeovers that may happen should not last more than 10 minutes despite the industry and the product that is being analysed. Moreover, the operation should be divided into two parts: first the internal setup, which is formed by the setup activities that can only be carried out once the machinery is stopped; second the external setup, which is formed by the setup activities that are to be carried out when the machinery is operating. SMED's purpose is to decrease product production times, optimise machine utilisation and reduce batches' size.

The SMED methodology was created by Costa, Sousa, Bragança and Alves (2013) which is formed by nine steps, mentioned as follows: First, the initial observation; secondly, a conversation with the operator; thirdly, a video recording; fourthly, a diagram of the current operations is to be built; fifthly, the operator's movements during the change are to be represented; sixthly, the external and internal setup are to be separated; seventhly, the internal setup is converted into external setup; eighthly, the external and internal setup are to be rationalized; necessary, results are analysed. It is interesting to mention that the first five steps can be turned into one initial step, which is named the work study. Furthermore, decreasing internal setup has a greater impact on the results and therefore reduction of internal setup should go first and reduction of external setup secondly.

3.6. How to start implementing Lean Manufacturing

To be successful in the face of change, it is important to have an enabling methodology to make this happen. The following is a series of steps that are efficient for the application of Lean tools in an organization.

Both Liker (2004) in *The Toyota Way* and Spear (1999) in *Decoding the DNA of the Toyota Production System* suggest that most companies are not successful when implementing the tools of Lean manufacturing or the TPS because they fail to endorse the cultural changes required to continue finding and sustain improvements that have been made by applying the tools and methods of Lean.

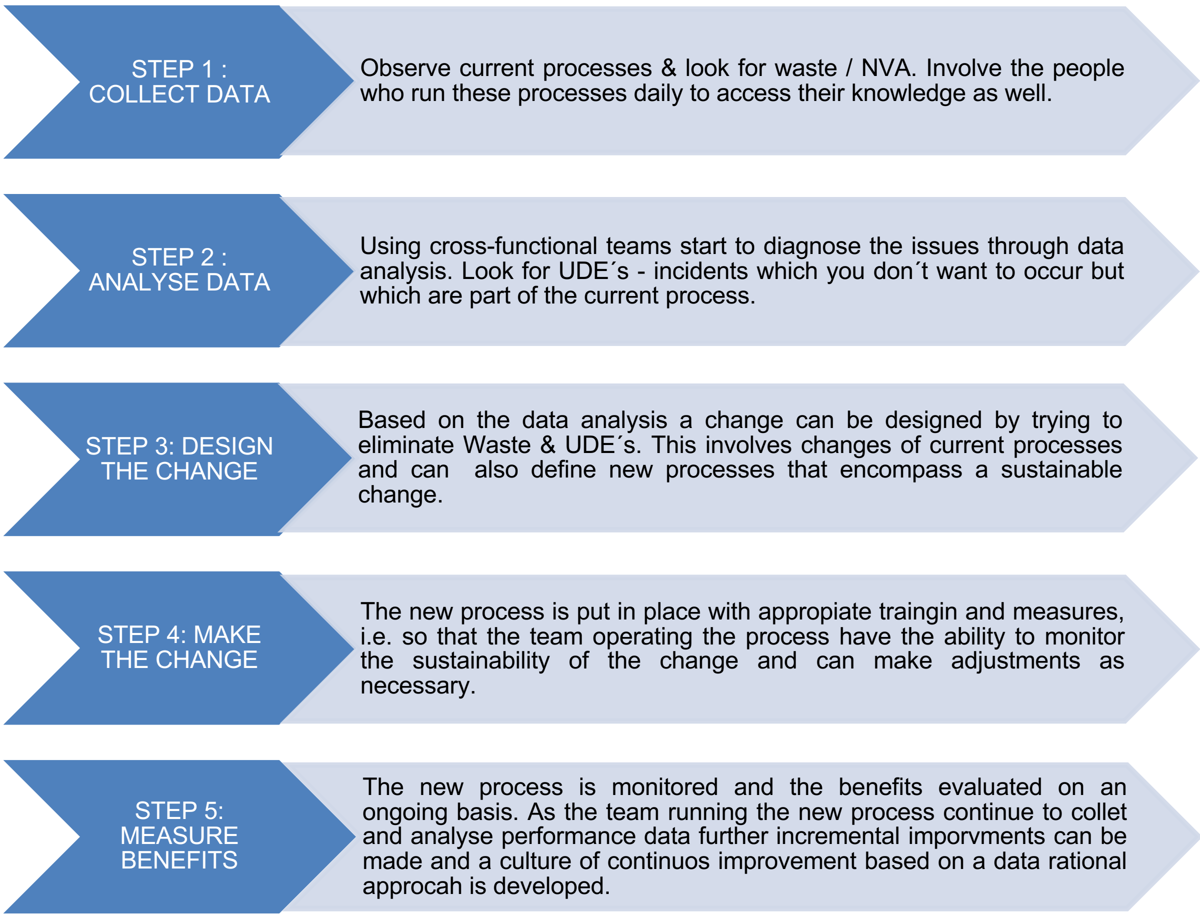

Figure 22 – How to “Lean Manufacture” – (Melton, T., 2005)

Figure 22 is a roadmap towards the correct and most beneficial way of *how to implement Lean Manufacture.* It is important to keep in mind that this step-by-step guide can be applied to the integral analysis of a company, as well as to the improvement of a part of the process or even to the improvement of a specific action. It is a clear example of the Lean methodology of being able to continuously generate substantial changes through simple steps.

3.6.1. Barriers to implementation and limitations of the Lean methodology

After reading the previous sections the Lean concept may seem easy to understand, however, the actions to put this in practice is not a simple task as it tends to change the culture and the way of working within the company, these are foundations that could be established many years ago. Such changes are considered barriers to the Lean implementation process and can be overcome through the adoption, by all elements in an organisation, of an appropriate training and communication culture. The main barriers to Lean implementation relate to a lack of commitment from the top and middle management because they are not able to see the future benefits to the organization, poor understanding of the concepts of Lean methodology and employees' attitudes and resistance to change (Gupta, S. et al., 2013).

Changes within an organization are difficult for most employees. For this reason, it is important for people to understand the context of the situation, whether it is a minor or major change. Recommendations for dealing with the concerns that arise when changes are made are written as follows (Tapping, D. et al., 2003).

1. **Communicate.** When running a lean tool in a given area, ensure that everyone understands what is happening and the root causes. Only the explanation of a leader is enough to ensure that the members of the sector do not feel excluded from the new implementation.
2. **Exposing the negative aspects at the early stage of implementation.** It is important to listen to members' concerns by talking privately with them. It is important to emphasise how the effort of implementing change can improve the future of the company. Furthermore, it is necessary to clarify that no one will lose their job during the implementation of the change.
3. **Potential problems should not stop the process.** The occurrence of one or more problems can often delay a kaizen event. In this case, the problems must be identified, analysed and solved to continue with the implementation of the event.
4. **Take into account each kaizen event as an experiment.**
5. **Recognize and reward people’s efforts.** Respect and mutual trust should be practiced. People should always be treated with integrity and honesty.
6. **Be present.** In order to encourage workers and support their improvement efforts, top managers and the value stream champion should go regularly to the work area.
7. **Be flexible.** It may happen that some things that were planned won’t turn out as expected and some things that weren’t planned might appear. However, all these opportunities will be useful for learning more about the work that people do and the department’s processes.

3.7. Conclusions

The origin of lean manufacturing began with a set of techniques on the shop floor and expanded to other areas of a company with the goal of reaching the entire organization. The Lean methodology can also be applied to services to improve cost and quality issues. However, it is a recent practice that requires a higher level of study to understand its respective benefits (Bonaccorsi et al., 2011; Dos et al., 2015). Lean applied to services consists of a standardized system of operations composed of activities that generate value for customers. In this sense, it isn't only focused on the people involved in the transformation process but also on satisfying customer needs while finding a balance point between price and quality. Lean methodology associated with services is directly related to human factors and doesn’t present tangible results. After a thorough research, there isn’t a specific model for this kind of tool (Dos et al, 2015). Lean service areas include public administration, logistics, office, teaching, and retail jobs. The use of IT is important for the application of the lean approach in the service sector (Lee, S.M. et al, 2008). On the other hand, the implementation of Lean Manufacturing achieves real change associated with growing Supply Chain speed, reducing production costs, and improving performance in all areas of a company (Melton, T., 2005).

IV. IMPLEMENTATION MODEL, RESULTS AND DISCUSSION.

Over the different sections of this chapter, the aim is to seek for an impact and feasibility analysis of Lean methodologies for the R&A Indumentaria case study. How it would be the best way to embrace them properly in the company and predict the positive impact that this would generate in terms of production. Also, aim to explain in detail how to mitigate the problems developed in section 2.3, these being: 1) Production Planning and Operations information flow; 2) Inventory Management of T&A and threads; 3) Meeting Clients needs on time.

As conceptualization of the Lean manufacturing tools and methodologies has been reviewed on the previous chapter, now it is chosen some of them to be develop in detail and applied for the case study company to generate productivity improvement regarding the problems stated in chapter 2. To meet the objectives exposed in this master thesis, there are four guidance objectives followed towards a successful proposal, which are the following:

- Determination of which tools and methods are useful for the company problems.
- Determination of the extent of methods and tools selected regarding each process or sector.
- Determination of hierarchy, if any, in the implementation plan of Lean tools.
- Development of a means for a textile company to gauge where their organization stands in terms of Lean.

4.1. Lean Manufacturing Project – Tools Analysis

The Lean Manufacturing Project consist of a plan to introduce the selected Lean tools in an organized manner to obtain as much as possible from these changes in a positive way for the company. LMP is structured in two phases, each phase will be covered and explained over each sub-section, mainly to show what has already been putted in motion while developing this study and the actions that require more time to implement and measure the impacts of them.

4.1.1. Value Stream Map

The company currently did not have a data collection methodology for its production processes, for this reason the value stream mapping tool was chosen to be able to develop this. This means also allows to observe in an integral way all the direct and indirect connections between each sector, aiming to expose with lean methodologies one of the problems presented in chapter 2 stated as the difficulties of the production planning and operations flow that generate lack of information causing preventable errors.

As detailed in chapter 3 section 3.5.1 regarding the VSM implementation, the first step is to set down on paper the process in question. Since the company did not have a proper flowchart, it was decided to move forward with this to have a solid basis for current and future analysis. To carry out the initial mapping of the current production processes, it was identified which product contained the greatest number of possible processes and followed the PO through the different stages until we obtained a complete overview of the factory operations. To identify NVA activities in the possible problems, identify the waste of LM. The scope of the exploration is the identification of activities and measurement of times.

In Appendix A is shown the current VSM for R&A Indumentaria with detailed information on the number of operators and material and informational flow developed over 4 months. This period was considered to diagram in detail the process from the time the sales order is received from the customer until the final product is delivered.

What can be perceived from the so-far developed mapping tool is that the communication arrows have a direct impact on different parts of the process. Also, there are some yellow warnings that can be seen in the current VSM that make it easier to notice where waste might be generated. The scope of this thesis did not seek to mitigate all of them, but to propose solutions for some of them, and in this way also to establish a shift towards Lean manufacturing. It is important to note that while the current VSM does not have quantitative time information so far, it is rich in qualitative information.

On a second phase, to go even further with this tool and exploit its full potential, the following steps should be considered:

<u>First Step</u> – Complete the current VSM mapping with the following parameters

- Total time per workday.
- Regularly planned downtime (meetings, lunch, breaks, etc.).
- Available time (subtract regularly planned downtime from the total available time).
- Quantity of work performed in one day by one person.
- Frequency at which work is delivered to the next process.
- Cycle time (the time that elapses from the beginning of a process or operation until its completion).
- Queue time (the amount of time a work unit will wait before a downstream process is ready to work on it).
- Exceptions to the process. These need to be addressed by the team at some point. For instance, one process may claim that someone from sales always disrupts them by requesting a special “hot” quote. This happens every day and consumes one hour. This would be noted and discussed with the team.

<u>Second Step</u> – Check with all the gathered information and the current VSM for indicators based on the data collected. These will help achieve the objectives set in the current diagnosis of problems within the comparison of cycle time and the rhythm of production (takt-time), Lead Time, Efficiency, Production capacity, and Labor Productivity.

Third Step – Identify all the Lean manufacturing tools that can be used to identify potential wastes. The brainstorming tool is a suitable option to breed different possibilities and generate a matrix where the main problem is related to the criteria of cost, time, and feasibility.

Fourth Step – Proposal for lean manufacturing tools, the best suitable resulting tools of the prioritization matrix will be applied.

Fifth Step – Development of the future Value Stream Mapping. Obtained the representation of the current state of the product or family, thanks to the current VSM design and determined the indicators of LM, the next step will be the design of the future VSM that consists of the identification of LMT that solve the problems, which will be evidenced with the results or improvements obtained in each process.

4.1.2. Root Cause Analysis

While to understand the company's problems it was enough to physically walk around and observe the plant to locate them, many times the causes of these issues are not so easily observable and require a deeper analysis. In these cases, being able to count on people in middle management who can contribute their point of view to the same problem to find a solution helps to broaden the vision of what would be the most feasible, quickest, and most efficient solution to take when seeking mitigation of the problem.

Having said this, and under the theory described in section 3.5.2 on the tool established by Ishikawa, it is recommended that R&A begin to apply root cause analysis to address a problematic situation in a more comprehensive way. A template for the use of this tool can be seen in Appendix E and the proposed methodology for applying this tool is highlighted below using one of the problems mentioned in section 2.3.4.

First Step - Gather a team of workers that are involved with the issue of matter in a direct or indirect way. Explain to them what the tool is about and the benefits of implementing it. Make people part of the process not only for the solution but for the understanding of the problem. This will also contribute to the generation of a Lean philosophy in the company.

Second Step - Locate the problem. Inform the team which situation is going to be analysed and try to narrow it down to something specific to have a clear view of what is trying to be solved. If consequential problems come along, it can be used many templates as needed, as long as it is stated one problem to each CED.

Third Step - Map all the causes regarding each M. Having a diverse team can contribute to a more complete diagram with several causes in each branch, which enriches the process of understanding.

Fourth Step - Weighting the causes of the problem. Once all the causes are identified the solution needs to be focused on eliminating the roots that have more incidence over the matter. Later, with other Lean methodologies, it can be analysed and implemented with tools generates the more beneficial outcome.

By applying this tool in the first phase of the LMP is expected that the problems presented in section 2.3 for the R&A company will be analysed through the experience of the different areas that impact in some way on it, be it the production sector or product development sector or the people in the T&A warehouse for example exposure of different causes will lead to a proper resolution of the problem that can entail the use of another lean tool.

4.1.3. Kaizen Project

5S

The Kaizen Project is a proposal for the application of 5S in the first phase of the LMP explained in the literature review in the previous chapter joined by the application of the Plan-Do-Check-Act. When trying to set the Kaizen method into practice, the PDCA approach as was defined section 3.5.3 has four clear action steps that can be used to structure the 5S application plan audits.

As it was previously mentioned the integration of the whole organization towards a Lean manufacturing philosophy requires engagement from the operatives until the high management. Creating the same values through the command chain is a key factor to facilitate future implementations. Being this said, the first action of the Kaizen Project is to have a General Assembly of 5S understanding. This activity will take place with one representative of each area, and the aim is to raise awareness of Lean manufacturing as well as Kaizen and the productive benefits that these concepts encompass. It is the responsibility of the manager that attends the assembly to pass on the knowledge learn and try to implement it daily. Consequently, for the next applications or introduction to modifications that must be adopted by several employees or sectors, the reception of the tools will be less resistant and more fluid. This meeting is a key starting point towards an organization with clear information flow, as well as creating awareness of the importance of eliminating different types of waste previously identified.

Later, the application of 5S to different workspaces in R&A with the integration of the workforce-related respectively will take place. If the whole sector did not attend the general assembly, it is planned to have a sector 5S training. The aim of targeting each productive area is to increase the performance of the operators and the sector productivity, through the reduction of search time and immediate accessibility to necessary material.

The methodology adopted was the one described in the literature review carried out, following five consecutive steps: 1) sorting; 2) tidying; 3) cleaning; 4) standardization; 5) discipline. Following the training of these concepts and their focal implementation in the productive process, it is included a 5S audit that will take place according to the 5S plan (see Appendix D.1). The rating obtained will be monitored by the engineering department who in this case will be the Kaizen Project organizer and responsible area to carrying out the activities mentioned above. If there were teams with a score lower than 80%, the application of the tool would be monitored, with a special focus on the difficulties demonstrated by each S.

However, although it may seem like it is only applicable to production, the system can be applied anywhere that needs improvement. This project complements very well with the VSM application as the latter helps to see where Kaizen implementation is needed most immediately.

There are requirements for the 5S system to work, which were revealed through the analysis of R&A experiences when compared to the 5S system literature presented in Section 3.5.3. These requirements were compiled into the following guide list to ensure that the Kaizen Project is thoroughly explained, and in Appendix D.1 there is a checklist with activities explained what aspects are evaluated in the previously mentioned audit and a recommendation of how frequently they should be reviewed.

First Step: Educate and train employees in the types of waste and 5s system: sort, set, shine, standardize, and sustain.

Second Step: Establish 5S teams according to each of the sectors described in section 2.2.3, which includes a facilitator willing to take responsibility and provide support and encouragement to the team.

Third Step: *Sort* items that do not belong in the workplace and remove them to a designated space marked with a red sign as “5S Waste Area”. Discard items need to be tagged with a red sticker/tag that indicates the date that was placed there. Red tagging not only removes unnecessary items from the workplace but acts as a warning because someone else may need the item and places it where it belongs. Keeping a record of how long the item is there is an indicator, that after three weeks if the item was not removed then it was indeed a waste.

Fourth Step: *Set* into place all the items needed to perform work, storing the items as close to the point of use as possible and in an orderly manner so that things can be easily assessed when needed.

Fifth Step: *Shine* or clean the sector including the mobiliary, machines, floors, or walls. Always look for the source of the filth to eliminate the source. Keep a clean place of work and try to arrange cleaning tools of easy access to any employee in each work sector, this will help with the routine of self-organisation and cleanliness.

Sixth Step: *Standardize* the items needed by the worker and all the materials processed in the area which have been *set into place.* The standards should be made so that it will become evident when any item is out of its place.

Seventh Step: *Sustain* improvements made by the 5S system, all the steps should be continuously carried out after their first implementation, always searching for new improvements.

Regarding the previously mentioned PDCA system, it can be merged with the Kaizen system when needed control over the different tools that want to be implemented. Having an organized methodology to implement them achieves a more efficient supervisor performance.

SMED & Work Standardization

The application of these two Lean tools is part of the second phase of the LMP as most of the information needed to use them is obtained through the other tools found in the first phase. For example, the root cause analysis merged with the areas highlighted as critical in the VSM will determine the main areas where operational procedures need to be standardized to reduce actions that do not add value to the product such as unnecessary movements or wasted time to perform the action because the tools are not accessible to the operator. The correct application of the SMED methodology will also be determined by actions of the previous phase, the 5S will have promoted the workers to understand each waste during the process and how to reduce or eliminate them by working together in the internal and external setup and be more flexible to adapt to changes that benefit the whole organization.

4.1.4. Stock Management for Threads

Every action in a production system has a consequential action over the neighbour process, ending in a supply chain with defects that produce NVA activities as it was explained previously. Not having a control over the threads inventory and not having an adequate method to plan and require this material inevitably leads to the situation described in the section of problems contextualization, where in order to find the desired thread the person required a total of 60 min to find the thread they needed, check that the quantity is sufficient according to what they had calculated to produce and then separate them in the reduced space due to overcrowding of boxes and clutter.

The conclusion reached in section 2.3.2 where the main problems are exposed, it is pointed out strongly the inefficiencies caused in several sectors of the company at the same time by poor inventory management. While the previous proposals have dealt with issues that help this cause by disposing of surpluses or indicating where something is out of place, the question that is answered by this proposal is: *How can it be eliminated the oversupplies? How can be assure that there won't be production stop due to lack of materials?*

Over the first phase of the LMP it was implemented a 7-waste analysis sheet register by the kaizen project supervisor where in different times of the day during a month an observation of the thread management was carried out and was noted down the actions related to Muda´s found at each visit. In Appendix F – Figure 47 it is shown the compilation of some of the manual survey records used in the visits to gather the necessary data that served to identify the main causes of waste generation. This action took place over 4 months and in total it was collected 32 sheets, the following lines encompass the main problems encountered:

- Operators did not know the available quantities of these materials with certainty.
- Lengthy times were spent trying to identify the material needed.
- Surplus, non-reusable material was found.
- Useable material was found in poor conditions.
- Paper records of what was needed were defective.

- Incorrect quantities sent to production.
- Incorrect yarns were taken to production or in the wrong quantities.

Afterwards each found action was attributed to a type of waste and a Pareto diagram was drawn up to focus the action plan on those wastes that were the most recurrent.

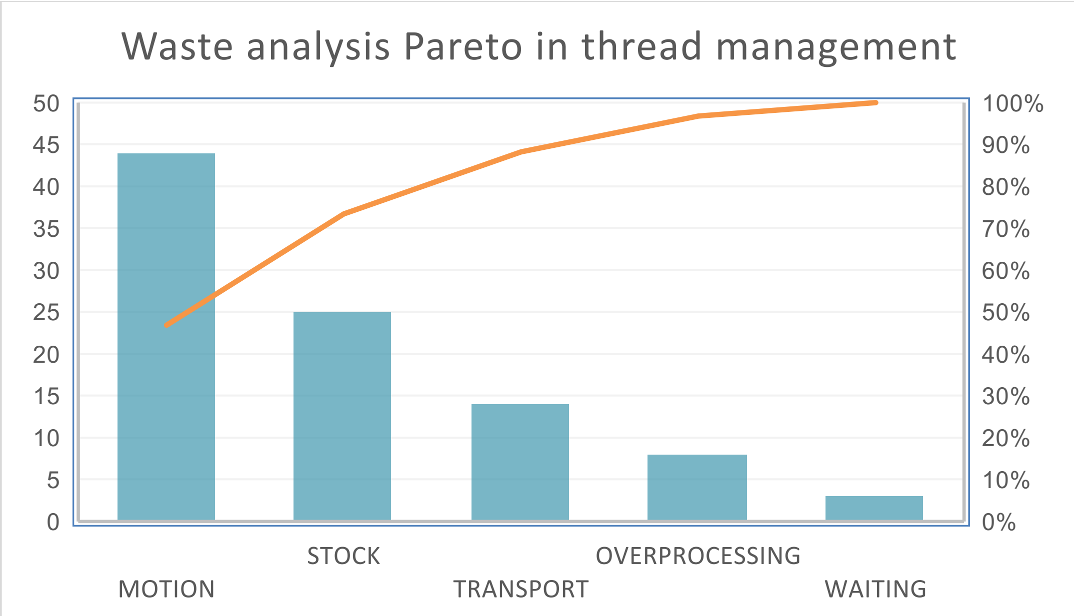

Figure 23 – Waste Analysis Pareto in thread management.

As observed in Figure 23, 80% of the process actions identify as wastes where related to three of the Muda's, Motion, Stock and Transport. Also, it is point of analysis that motion is the mainly cause of waste generation in that sector causing more than 46% of the total NVA activities. In comparison overprocessing summed to waiting actions do not reach 12% so these causes will be reviewed in the next cycle study where it will be possible to observe if, after mitigating the first ones, they are still present or if new consequences have been added. As it was previously established, the implementation of lean tools implies a cyclical action to obtain productive perfection.

The recommended action plan to follow in the first phase of the LMP to work under the lean philosophy of waste reduction and to seek productive perfection as well as to reduce costs is given by the following steps:

1) Virtual Thread Management Spreadsheet (*Planilla de Gestión de Hilos* – PGH, for the company reference in Spanish).

R & A Indumentaria S.R.L.
MAESTRO DE MATERIALES

GESTIÓN DE HILOS

	Tipo	Proveedor	Marca	Medida	Unidad	Medida	Unidad	Color	Cód. Color	Material	Título	Código Interno
47	Hilo	Giuntoli	Tauro	120	CONO	4000	MTS	Negro	502	Poliéster (Algodón)	40/2	
48	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Gris Melange	506	Poliéster (Algodón)	40/2	
49	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Rojo	519	Poliéster (Algodón)	40/4	
50	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Bordo	520	Poliéster (Algodón)	40/2	
51	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Celeste	521	Poliéster (Algodón)	40/2	
52	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Azul Marino Oscuro	524	Poliéster (Algodón)	40/2	
53	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Verde Militar	528	Poliéster (Algodón)	40/2	
54	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Aero 1	530	Poliéster (Algodón)	40/2	
55	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Bordo 3	533	Poliéster (Algodón)	40/2	
56	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Aero 2	536	Poliéster (Algodón)	40/2	
57	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Azul Marino 1	543	Poliéster (Algodón)	40/2	
58	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Verde	548	Poliéster (Algodón)	40/2	
59	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Azul Marino 2	590	Poliéster (Algodón)	40/2	
60	Hilo	Giuntoli	Capri	120	CONO	4000	MTS	Rosa 1	606	Poliéster (Algodón)	40/2	

MAESTRO | PEDIDOS | INGRESO | CONSUMO | STOCK

Figure 24 – Thread Management Spreadsheet (PGH)

Figure 24 shows that the first sheet is denominated as *Maestro* (Master Sheet) where each type of thread is register with a unique code referencing the attributes of that specific material. The second sheet is *Pedidos* (Orders) where each purchase of material will be loaded so when new material arrives the sector operator can carry out a correct control of goods receipt by uploading the physical information on the third sheet of *Ingreso* (Material Receipt). When production request for material on the fourth sheet *Consumo* (Consumption) both the withdrawals of goods according to the OP and the return of yarns are loaded in the spreadsheet. This operation carried out in an updated and organised way provides the information on sheet five, a display of all the yarn stock, being able to differentiate materials, their location, and quantities.

2) Carry out a comprehensive survey of the current stock of threads and register them in the PGH with their correct nomenclature for easy recognition and communication between sectors.
3) Dispose of yarns that are no longer usable or in poor condition.
4) Dimension the available storage space and according to the quantities surveyed arrange them in such a way that the sectors can be recognised more easily. We recommend sectoring according to types of yarn, cotton, or polyester, and at the same time dividing them into colour ranges to make the visual recognition of the operators when ordering material more efficient.
5) Documentation of the location of each type of yarn in the PGH once it has been surveyed and physically located.
6) Designate a person in charge of the sector to keep control of income and expenditure, as well as the order and cleanliness.

Once this action plan has been carried out over a sufficiently long period of time (12 months minimum), the company will have substantial information of a material that previously did not have and that was contributing to hidden costs due to disuse and space usage. This will also gain operational efficiencies in the sector and generating new action that led to the implementation of other lean tools to generate a more continuous flow.

As in for the second phase of the LMP, the implementation of MRP system should be envisioned to optimize the information available in each inventory database for the raw materials such as threads, T&A, and fabrics. Given that there are already records, similar to the inventory of threads previously described, for the other raw materials, the implementation of this tool would increase the efficiency of stock management and requirement planning of material. This tool will help eliminate the errors cause by the production and planning implications that impact on production as well as with deduction of material overflows and the acquisition of it on time and correctly. This also contributes to the increase of the compliance indicator with the clients since the agreed delivery plan can be corroborated with greater certainty according to the availability of materials. In this way, delivery times can be adjusted according to the availability of materials and the client will not have to wait longer than expected for the goods.

4.2. Lean Manufacturing Project - Structure and Impacts

First Phase implementation

This phase consists of the implementation of certain actions of the previously explained tools to structure and follow a specific order because in this way it is possible to make progress with different tools that complement each other and do not overlap, so that the circle of continuous improvement is also optimal.

I. Current VSM - explicit in Appendix A.
II. Waste identification Sheet.
III. Kaizen Project – 5S.
IV. Stock Management – Spreadsheet and physical organization of deposit of threads.
V. Root Cause Analysis methodology.

Second Phase implementation

As a consequence of the implementation of these tools in the future, new application possibilities will open to positively enrich the impacts generated by the previous phase. The actions to be implemented in this second stage are:

I. Complete Current VSM and Future VSM.
II. Kaizen Project – SMED & Work Standardization.
III. Stock Management – MRP.

As future impacts cannot be measured simply by perceptions of the process and actual time measurements are mostly needed, this future stage seeks to quantitatively fix the percentage improvements that can be attributed to the implementation of the LMP.

Having said that, however, given the knowledge of Lean methodologies and considering the benefits explained in the literature review, it is expected that the impacts of LMP will increase productivity levels to 80% and the OTIF indicator to 95%. It is also expected that the cost reduction will be mainly reflected in the optimisation of operator time by generating more tasks in the same working day and in the reduction of raw material wasted or immobilised for long periods of time.

4.3. Lean Manufacturing Project - Discussion

As the first Kaizen general assembly took place, Figure 25, positive feedback was received from the employees on the concepts presented, their use, their purpose and the objectives that can be achieved with the 5S tool within a lean manufacturing framework. In fact, when the sectors were referred to start with the application of this tool, the communication between the parties was very effective and they were open and willing to collaborate with the improvement process. In the near future, the lean support team should supervise the topics covered and their development in the production process, especially in first instances, to establish confidence in the operators and to demonstrate that it is a change that the organization considers important. Managers played an essential leadership role in motivating and training their teams in the improvements implemented.

Figure 25 – Kaizen 1st General Assembly in R&A

Of the set of improvement tools and processes implemented, the new thread management process was the most easily accepted by the operational teams of the service areas. The process described in the previous section allows besides its main functions and proximal benefits, to future establish indicators for stock policies and monitor closely inventory of that material. It is also proposed that the control and processing of information be changed in several aspects, proposing tools that facilitate interaction between areas when necessary and avoid unnecessary interactions that can create inefficiencies such as phone calls for material requirements. To continue the philosophy of continuous improvement and striving for perfection a standard could also be established to allow monthly reporting of all raw material costs/receipts in addition to the MRP proposal to ensure dynamic management and control of all production.

Regarding the use of the threads stock management spreadsheet, although the operators in the sector understood its benefit as they were using it to manage all the T&A, the time required to upload data and control the physical and inputs and outputs of the threads implies the addition of tasks to what they were used to. Of course, having a more comprehensive control requires more attention and involvement in the process than what was previously instated and not established as a responsibility of the sector. This meant that it was not a straightforward implementation to adopt and required more time from the supervising sector on this issue to be implemented correctly.

The Lean Manufacturing Project is a project of organisational and process innovation for the company specifically context. The administration considered it to be well-structured and that the changes presented in these brief six months had a satisfactory outcome, moreover that the projected improvements were feasible and suited for the company future vision development. This translates into the acceptance for continuing with the implementation of the LMP.

V. CONCLUSIONS

This master dissertation aims to look at the development of lean manufacturing in the study company R&A Indumentaria, a textile manufacturing company in Argentina. During the 1st Chapter, the textile industry is introduced in a global context as well as in detail for Argentina, where the study company is located.

The objectives to be covered during the development of this dissertation are also established. The main objective is to raise productivity and lower the production costs for the company, and for this it is developed a methodology that responds to the identified problems in a real-life context, considering the risks and gains of its implementation and a projection of the results to be obtained in the company.

Throughout Chapter 2, the current functioning of the company was contextualised, from how the necessary information is generated to be able to operate to the integral description of each process carried out in the company. At the same time, carrying out the industrial practices in this company for six months allows for finding some weak points within the production process. Although the problems often seemed obvious, it was difficult for the company to carry out an integral analysis and avoid or eliminate certain problems that became routine steps in the daily operations.

The main problems to be eliminated with the adoption of Lean manufacturing for the presented company are the errors in the production planning and control process that generate an indirect impact on production inefficiency, especially the stoppage of items in production due to lack of materials as well as the overkill of others. This situation also impacts on the lack of timely delivery of goods to customers, reducing the indicator.

In Chapter 3, the aim is to frame the concepts proposed by Lean manufacturing of looking for waste and eliminating it, generating only actions that add value to the product, providing a bibliographic framework that supports a new alternative for R&A. At the same time, the presentation of lean tools, together with their theoretical development, allows reaching a broaden vision of the field of applications that this philosophy promotes. VSM, 5S, Stock Management, Kaizen, SMED are some of the tools described in this section.

The 4th Chapter is where the two parts mentioned above merge and generate debate and analysis to encourage the ideas and concepts of Lean manufacturing, also the data resulting from this study combined with an understanding of Lean principles enabled a new work methodology to be developed in R&A Indumentaria.

A Lean Manufacturing Project is presented for R&A Indumentaria where it is explicitly developed the tools selected to achieve the main objective for the company. It is presented in two implementational phases that structured the proceeding toward a lean philosophy and maximized the benefits obtained.

In a first instance, to eliminate daily events that do not generate value and that the company is not able to solve it was developed a current VSM, a visual management tool. The next step to follow in relation to this tool is to quantify each process so that later the necessary indicators can be developed to measure the performance achieved in greater detail. Also having in mind, the future VSM development there where some facts established so that it would be drawn to have and end-to-end pull system based, creating flow between operations. To reach such vision, all improvement activities should be identified and prioritized, leaning to implement first the easy targeted tools, re-analyzing the whole process and the continue with the remaining waste elimination.

Combining the VSM tool with the implementation of the Kaizen philosophy generates a significant improvement in the other issue exposed, inventory management, by supplying information at the time of use, increasing the transparency of processes, and promoting management through data and facts. Additionally, the 5S principle has made it possible to achieve efficiency at the production front through a process logic that eliminates unnecessary tasks and organises the spaces where materials are located, guaranteeing greater safety and workflow.

Not least, as a future challenge, the company must sustain these tools and demonstrate throughout the organization the support from top management to maintain and improve the results of the performance indicators.

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Appendix A - Value Stream Map

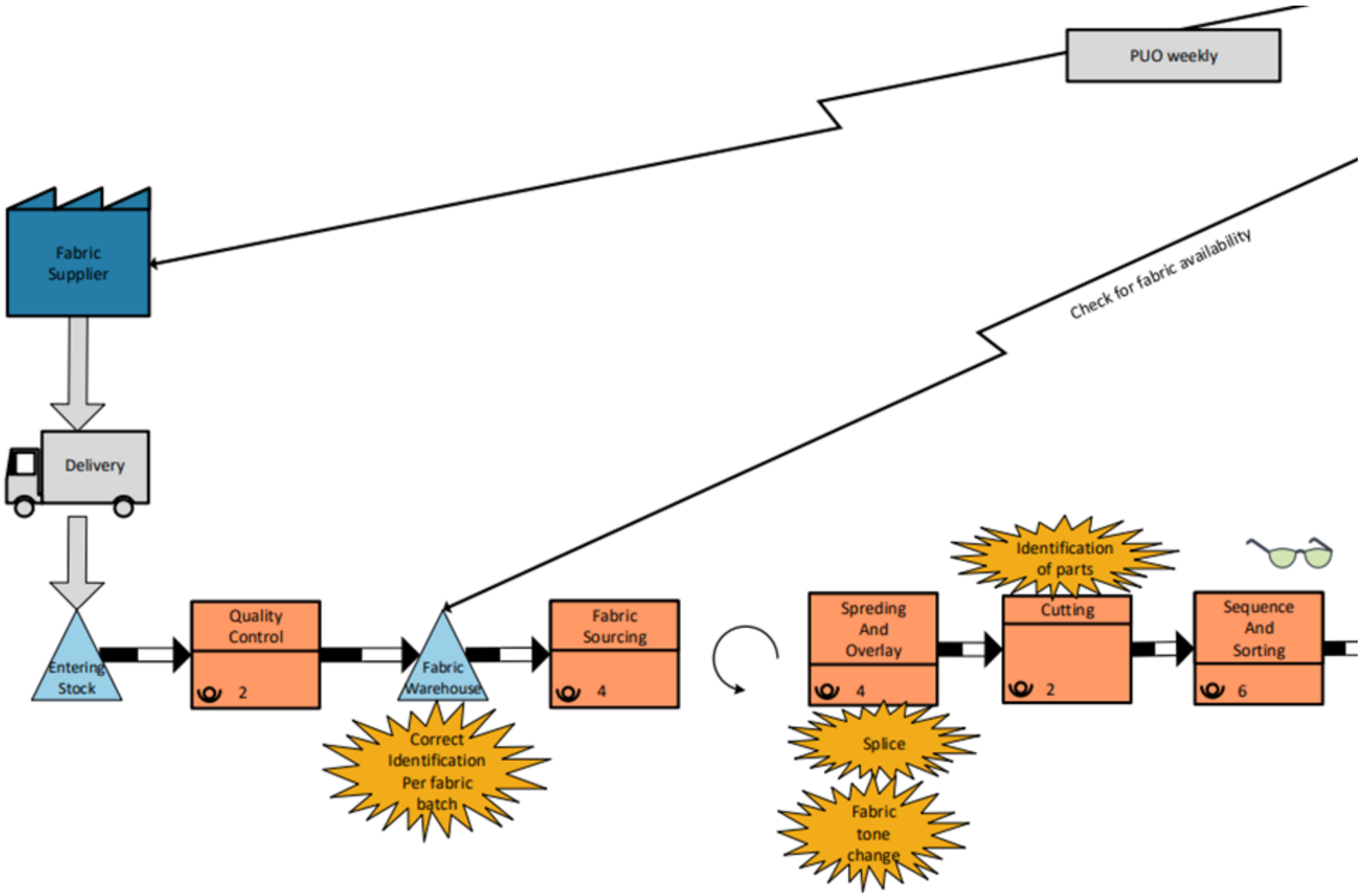


Figure 26 – R&A current VSM (left side)

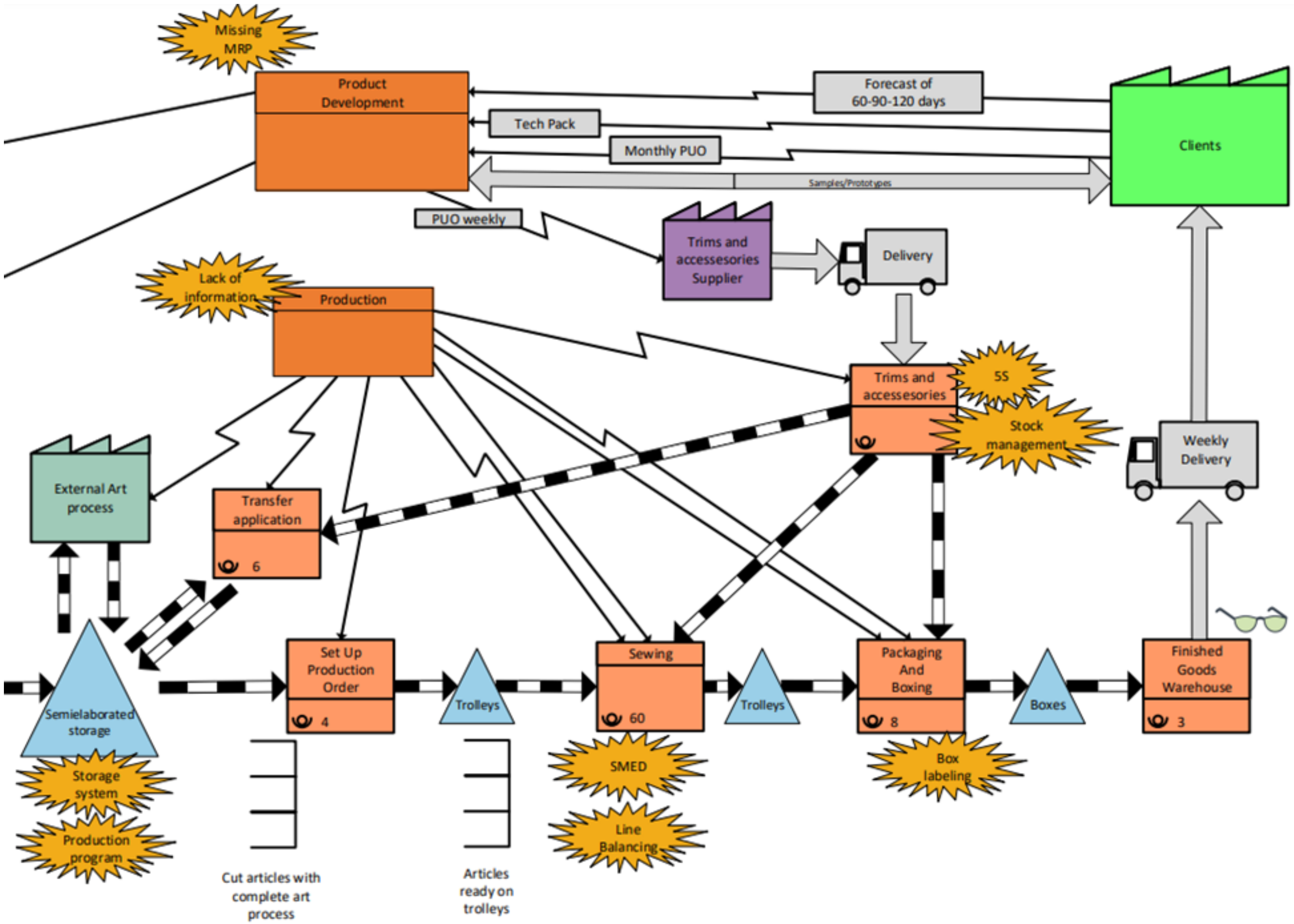


Figure 27 – R&A current VSM (right side)

Appendix B - Layout Design with process Flow and material transformation

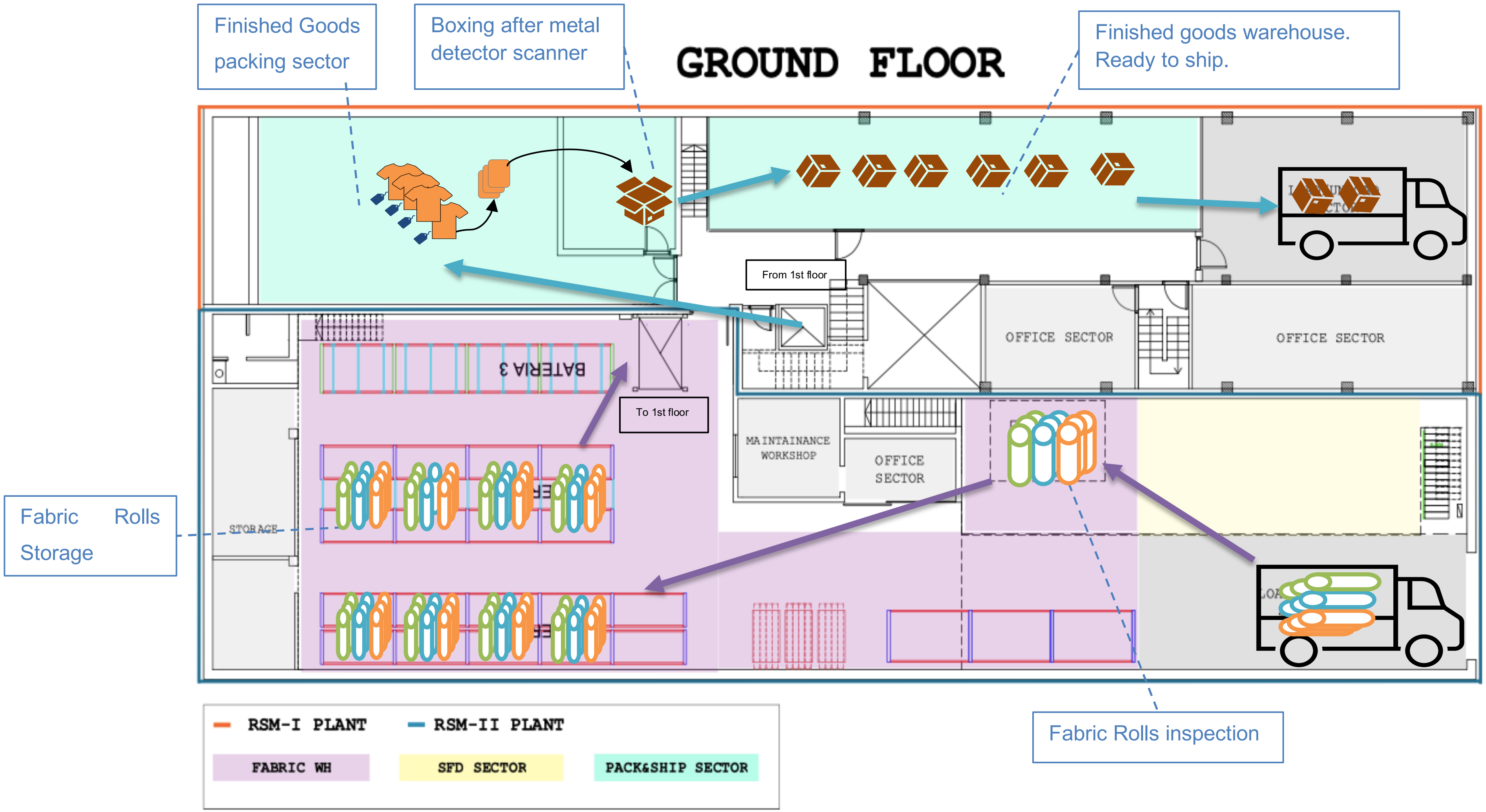


Figure 28 – Material Flow and transformation diagram (ground level)

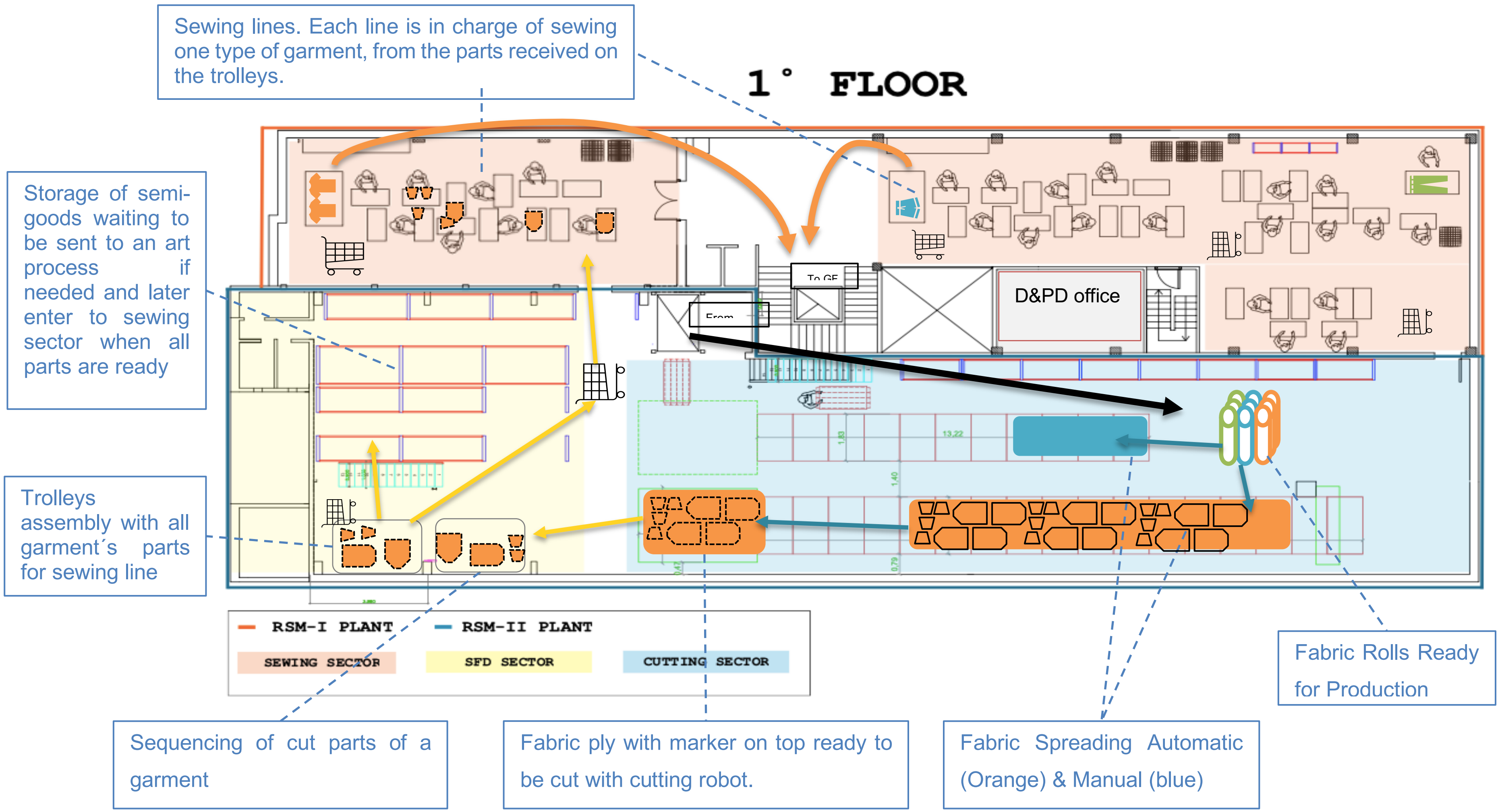


Figure 29 – Material Flow and transformation diagram (first floor)

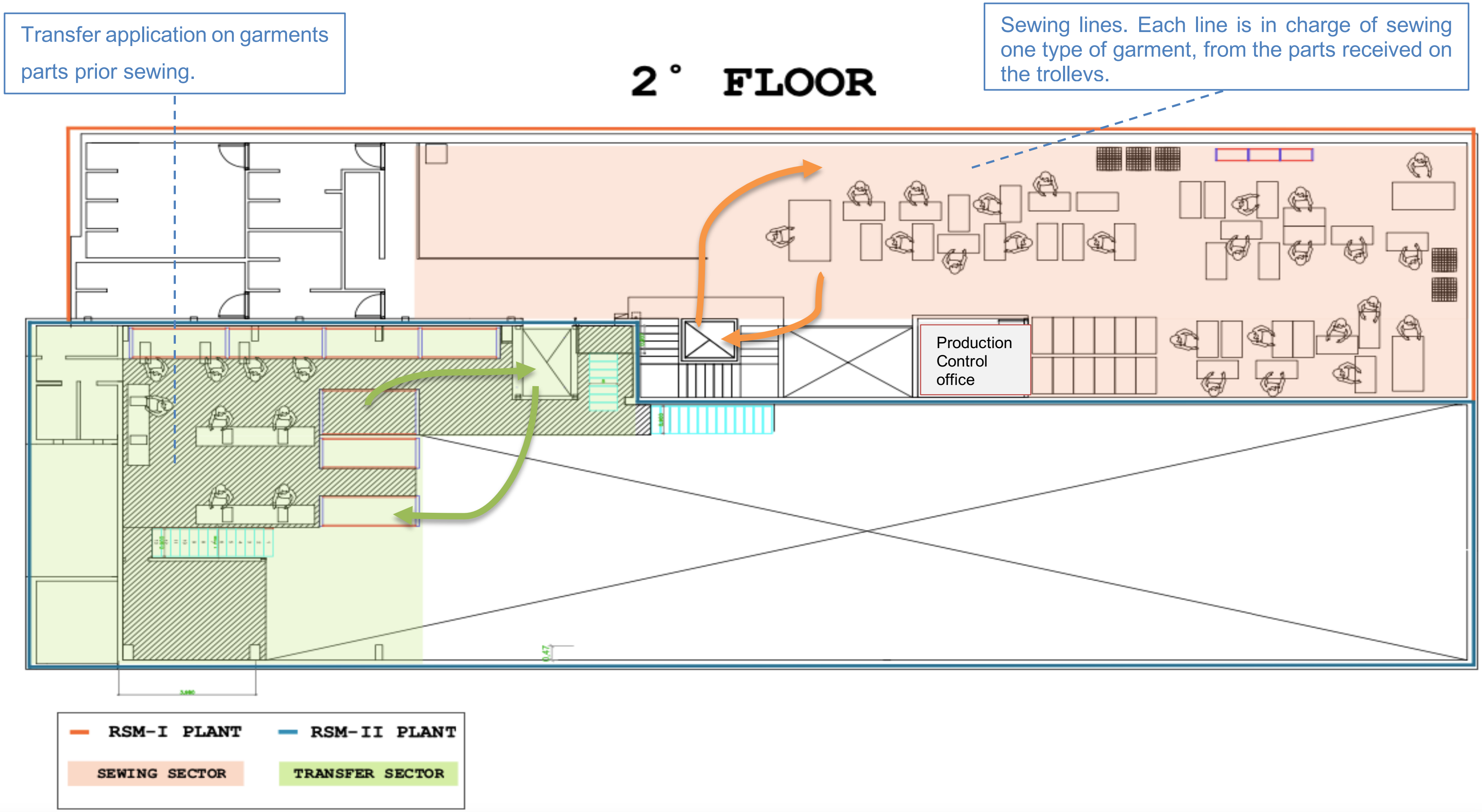


Figure 30 – Material Flow and transformation diagram (second floor)

Appendix C – Process Documentation Photos

Figure 31 – Inspection Fabric Machine

Figure 32 – Fabric Warehouse.

Figure 33 - Spreading and Cutting Sector

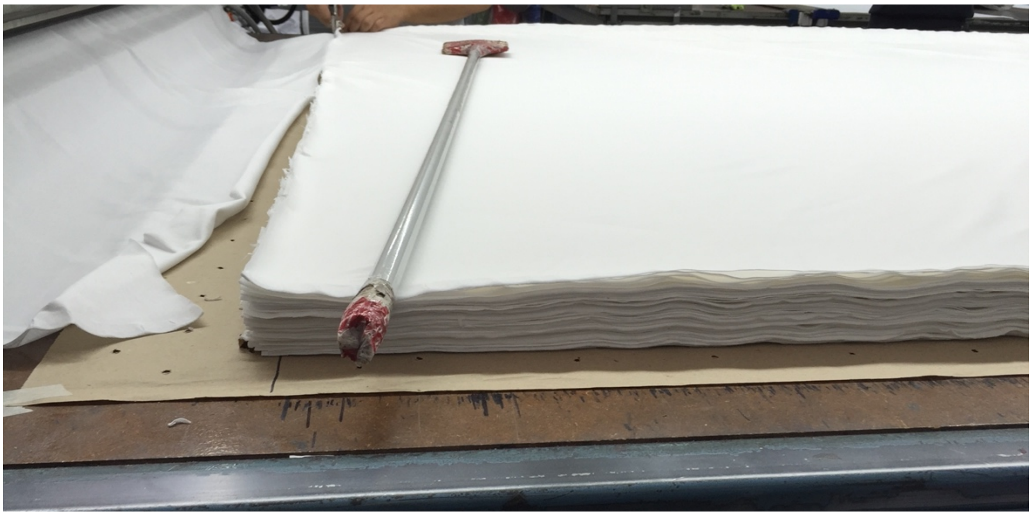


Figure 34 - Ply of fabric after spreading process.

Figure 35 – Cutting Sector & Sequencing Table

Figure 36 – Cutting Robot

Figure 37 – Ply of fabric cut waiting to be sequenced

Figures 38 & 39 – Marker used to identify cut parts; the information shown in the paper: Article Number; Size; Number of parts for that size; PO number; Type of fabric.

Figure 40 - Trolleys ready with garment parts

Figure 41 - Semi-Elaborated product store

Figure 42 – Sewing line

Figure 43 – Heat transfer application automatic machine

Figure 44 – Heat transfer application sector

Figure 45 – Trims & Accessories Warehouse

Appendix D.1 -5S System Maintenance Plan

Table 4 – 5S Maintenance Plan

SORT			Status																											
#	Activity	Frequency	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	Check that there are no unused items, otherwise place them in the red zone and identify them with the label.	Weekly																												
2	The red-labelled area is marked and identified.	Weekly																												
3	Verify that each of the objects within the red area have its identification label.	Weekly																												
4	Dispose of all items older than 30 days in the Red Tag area.	Monthly																												

SET IN ORDER			Status																											
#	Activity	Frequency	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	Verify that all productive materials are in their assigned place and container.	Daily																												
2	Verify that all equipment and tools are in their assigned place and in good condition.	Daily																												
3	Ensure that auxiliary materials are in the appropriate cabinets or devices and in order.	Daily																												
4	Cleaning materials must be kept in the assigned place.	Daily																												
5	Verify that operators use their safety equipment.	Daily																												
6	Verify that the documentation provided is up to date in the assigned place and visible.	Weekly																												

SHINE			Status																											
#	Activity	Frequency	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	Keep production areas clean of paper, fasteners, staples, and other production parts.	Daily																												
2	Check clean equipment and tools according to TPM plan, as well as structures, columns, protections, lamps.	Monthly																												
3	Reporting and eliminating auxiliary energy leakage	Daily																												
4	Ensure the collection of waste from the respective bins.	Daily																												
5	Ensure that all employees' food and beverages are kept in the places for this purpose.	Daily																												
6	Maintain a clean and organised coordination office.	Daily																												

STANDARIZE			Status																											
#	Activity	Frequency	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	Randomly carry out one of the 5 "S" activities with each of your collaborators.	Daily																												
2	Ensure that corrective action is taken on 5 "S" audit deviations.	Daily																												

SUSTAIN			Status																											
#	Activity	Frequency	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
1	5 "S" system documentation up to date and in a visible place on the control panel.	Weekly																												
2	Schedule and deliver 5's talks and meetings for all operators.	According to meetings																												
3	Review and update with your manager the 5 "S" plan in your control section.	Monthly																												

Appendix D.2 - 5S System Audit

Table 5 – 5S Audit

Kaizen Audit - 5S

Audit Pointing & Results Obtained

Points for each question: In order (2) ; Partially in order (1) ; Out of order (0)

Sort

	Activity	Status	Evaluation	
1	Is the area free of unnecessary objects?	X	0	
2	Is the area of unnecessary objects delimited and identified?	Δ	1	10%
3	Are unnecessary objects with their red label found?	O	2	
4	Is the red area free of objects older than 30 days of confinement?	Δ	1	

Set in Order

	Activity	Status	Evaluation	
1	Are all productive materials in their assigned place and container?	O	2	
2	Are all equipment and tools in their assigned place, in good condition and with their calibration in order?	O	2	
3	Are the auxiliary materials in the appropriate drawers or devices and in order?	Δ	1	10%
4	Are the cleaning materials in the assigned place?	X	0	
5	Do all operators use the appropriate safety equipment?	X	0	
6	Is the current documentation on the line, with the formats in their assigned place and height?	Δ	1	

Shine

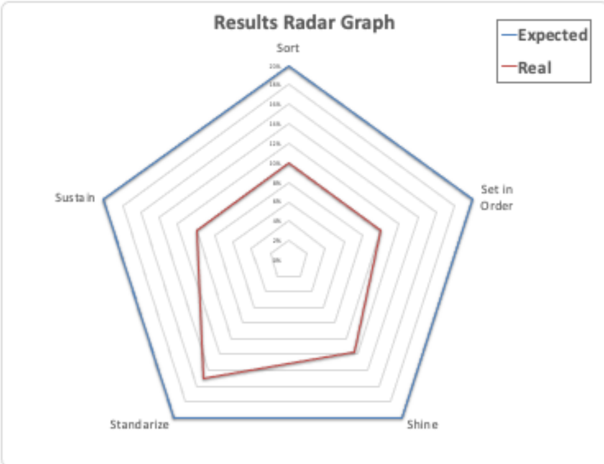
	Activity	Status	Evaluation	
1	Are production areas kept clean of paper, fasteners, staples and other production parts?	Δ	1	
2	Are all equipment and tools cleaned according to the TPM plan, as well as structures, columns, guards, lamps?	O	2	
3	Is there evidence of leakage reporting and has it been eliminated?	X	0	12%
4	Are all the required waste bins in place and not revalidated?	?	3	
5	Are the food and beverages of the collaborators located in the places for this purpose?	X	0	
6	Is the coordination post clean and organised?	Δ	1	

Standarize

	Activity	Status	Evaluation	
1	Is there evidence of continuous employee training?	O	2	15%
2	Are deviations from previous audits documented and corrected?	Δ	1	

Sustain

	Activity	Status	Evaluation	
1	Is the 5 "S" system documentation up to date and visible on the dashboard?	X	0	
2	Has the 5S training programme for operators been implemented?	Δ	1	10%
3	Is the action plan up to date and correctly implemented?	O	2	



Result	57%

S	Expected	Real
Sort	20%	10%
Set in Order	20%	10%
Shine	20%	12%
Standarize	20%	15%
Sustain	20%	10%

Symbology	
Out of order (0)	X
Parcially in order (1)	Δ
In order (2)	O

Sector: | Shift: | Resposible for audit: | Date: | Next Audit Date:

Appendix E - Root-Cause Analysis Template

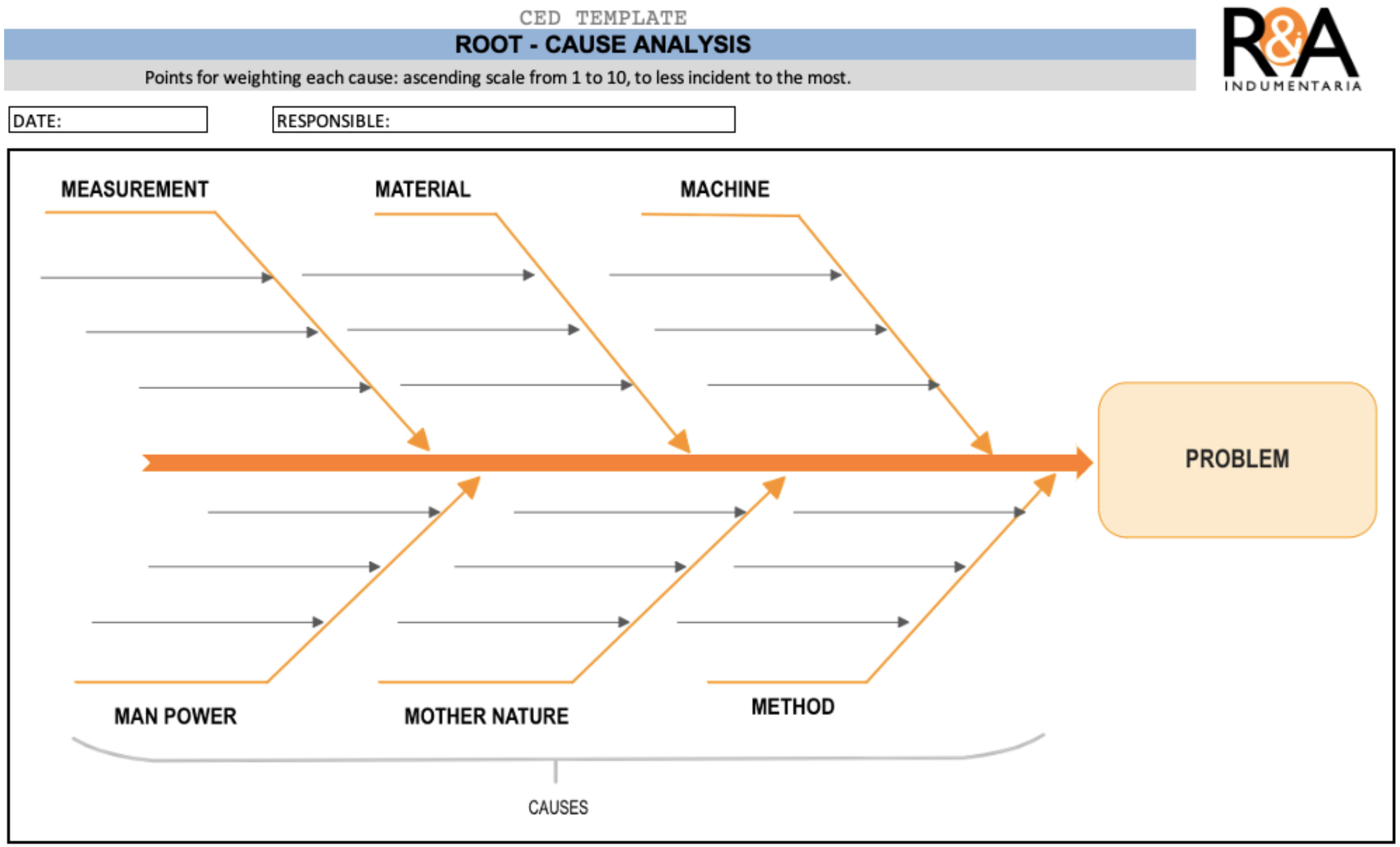
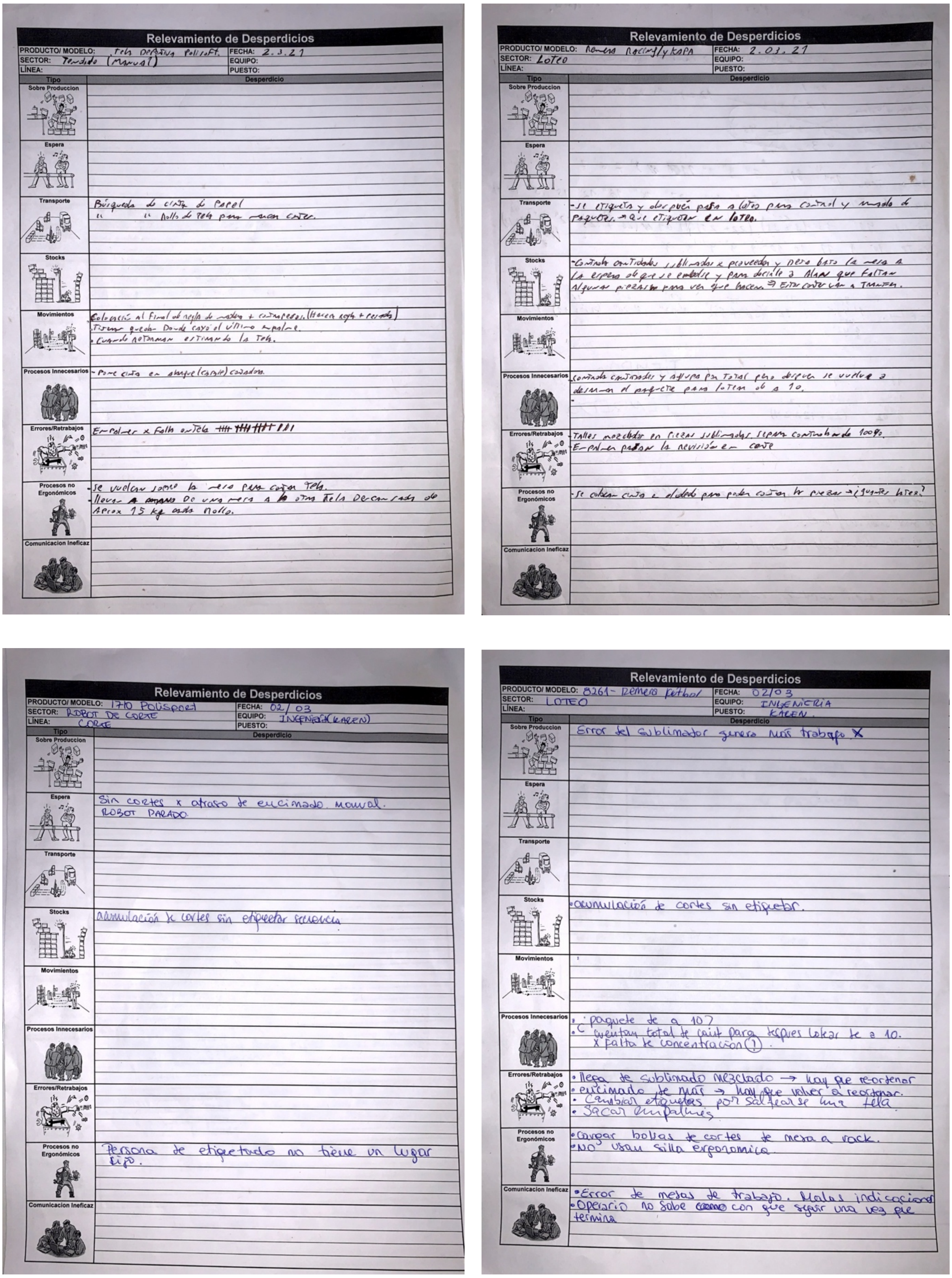


Figure 46 – Root Cause Diagram

Appendix F - 7+1 Waste Data Survey Record



Relevamiento de Desperdicios

PRODUCTO/ MODELO: Tela Deportiva Polisoft.	FECHA: 2.3.21
SECTOR: Tendido (Manual)	EQUIPO:
LÍNEA:	PUESTO:

Tipo	Desperdicio
Sobre Produccion	
Espera	
Transporte	Búsqueda de cinta de papel " " rollo de tela para nuevo corte.
Stocks	
Movimientos	Colocación al final de regla de [illegible] + [illegible] (Hacen [illegible] + [illegible]) . Tienen que [illegible] donde cayó el último empalme. . Cuando retornan estirando la tela.
Procesos Innecesarios	- Pone cinta en [illegible] (cable) [illegible].
Errores/Retrabajos	Empalmes x falla en tela |||| |||| |||| |||
Procesos no Ergonómicos	- Se vuelcan sobre la mesa para cortar tela. - llevan a mano de una mesa a la otra tela descansada de Aprox 15 kg cada rollo.
Comunicacion Ineficaz	

Relevamiento de Desperdicios

PRODUCTO/ MODELO: Remera Racing/y KAPPA	FECHA: 2.03.21
SECTOR: Loteo	EQUIPO:
LÍNEA:	PUESTO:

Tipo	Desperdicio
Sobre Produccion	
Espera	
Transporte	- Se etiqueta y después pasa a lotes para control y armado de paquetes. → Que etiqueten en loteo.
Stocks	- Controla cantidades sublimadas x proveedor y pero [illegible] la mesa a la espera de que se embolse y para decirle a [illegible] que faltan algunas piezas para ver que hacen → Esto cuesta [illegible] tiempo.
Movimientos	
Procesos Innecesarios	Contando cantidades y agrupa por total pero después se vuelve a desarmar el paquete para lotear de a 10.
Errores/Retrabajos	- Talles mezclados en piezas sublimadas. Separa controlando de 100%. - Empalmes pasan la revisión en corte
Procesos no Ergonómicos	- Se colocan cinta en el dedo para poder contar las piezas → ¿guantes látex?
Comunicacion Ineficaz	

Relevamiento de Desperdicios

PRODUCTO/ MODELO: 1710 Polisport	FECHA: 02/03
SECTOR: ROBOT DE CORTE	EQUIPO: INGENIERÍA (KAREN)
LÍNEA: CORTE	PUESTO:

Tipo	Desperdicio
Sobre Produccion	
Espera	Sin cortes x atraso de encimado manual. ROBOT PARADO.
Transporte	
Stocks	acumulación de cortes sin etiquetar secuencia
Movimientos	
Procesos Innecesarios	
Errores/Retrabajos	
Procesos no Ergonómicos	Persona de etiquetado no tiene un lugar fijo.
Comunicacion Ineficaz	

Relevamiento de Desperdicios

PRODUCTO/ MODELO: 8261 - Remera fútbol	FECHA: 02/03
SECTOR: LOTEO	EQUIPO: INGENIERÍA
LÍNEA:	PUESTO: KAREN.

Tipo	Desperdicio
Sobre Produccion	Error del sublimador genera más trabajo X
Espera	
Transporte	
Stocks	• acumulación de cortes sin etiquetar.
Movimientos	
Procesos Innecesarios	• ¿paquete de a 10? • Cuentan total de cant para después lotear de a 10. X falta de concentración (!).
Errores/Retrabajos	• llega de sublimado mezclado → hay que reordenar • encimado de más → hay que volver a reordenar. • Cambiar etiquetas por saltearse una tela. • Sacar empalmes
Procesos no Ergonómicos	• Cargar bolsas de cortes de mesa a rack. • NO usan silla ergonómica.
Comunicacion Ineficaz	• Error de mesas de trabajo. Malas indicaciones • Operario no sabe con que seguir una vez que termina

Figure 47 – Waste survey carried out in R&A Indumentaria