Lean Manufacturing – Case Study on Production Line 2

Innovate GmbH - Wet Wipes

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Resumo

Os padrões sociais têm sofrido enormes alterações com os avanços da tecnologia. É neste campo que fábricas procuram maior eficiência produtiva para dar resposta às crescentes exigências do consumo. Consequentemente, as empresas procuram manter-se competitivas numa filosofia cada vez mais bio sustentável, e ao mesmo tempo flexíveis às diversas pressões de mercado, cumprindo novas exigências tais como: inovação, higiene, redução de custo, tempos de produção e desperdícios, sustentação de recursos naturais, eficiência energética, etc. Com efeito, torna-se imprescindível implementar estratégias para superar os crescentes constrangimentos.

É nesta perspetiva que surge o “Lean Thinking” com o objetivo de eliminar atividades desnecessárias, preservando e aumentando as de maior valor acrescentado. Desta forma, o “Lean Manufacturing” emerge como um conjunto de ferramentas e metodologias que intendem a uma correta análise e diagnóstico de eventuais fontes de desperdícios, fomentando no seu processo de busca e melhoria continua, a aplicação de técnicas que quando amadurecidas e implementadas, permitirão a sua redução ou mesmo eliminação, maximizando o valor do cliente.

Neste trabalho, foram utilizadas algumas ferramentas e metodologias para a análise da linha de produção 2 da empresa Innovate Wet Wipes na Alemanha. Em particular, o indicador “Overall Equipment Effectiveness” (OEE) utilizado para quantificar a produtividade e eficiência dos processos produtivos, de forma a identificar eventuais focos de maior necessidade de intervenção; a metodologia do estudo dos tempos e o uso do indicador de desempenho “Key Performance Indicator” (KPI) para realizar a medição da taxa de ocupação em etapas críticas no processo de produção; e finalmente a utilização da ferramenta “Value Stream Map” (VSM) para a criação de um mapa de fluxo de valor.

Identificados os possíveis focos de desperdícios, foram então sugeridas soluções recorrendo ao método de mudança de ferramenta “Single Minute Exchange of Die” (SMED) para uma melhoria nos processos de mudança de produto; ao método 5S para promover uma maior organização, limpeza e segurança no local de trabalho, culminando numa melhor e eficiente realização das tarefas; ao método Kanban para implementação de uma gestão mais eficiente de stocks; e ao método Poka-Yoke, com o intuito de criar mecanismos para evitar erros humanos e processuais. Por fim, foi elaborado um mapa de fluxo de valor futuro com eventuais alterações ao estado atual da empesa.

As soluções propostas neste trabalho perspetivam mudanças estruturais, processuais e comportamentais na forma atual da empresa, visando direta ou indiretamente uma maior eficiência nas atividades e processos, bem como uma redução de custos e tempos associados, tendo algumas destas soluções sido desde logo implementadas devido à sua pertinência e resultados efetivos.

Palavras-Chave: Lean Manufacturing, OEE, SMED, Kanban, Poka-Yoke, Value Stream Map, 5'S.

Summary

Social patterns have undergone enormous changes with advances in technology. In this area companies seek greater productive efficiency to meet the growing consumption demands. Consequently, companies seek to remain competitive in an increasingly bio-sustainable philosophy and at the same time, flexible to the various market pressures, fulfilling new requirements such as: innovations, hygiene, cost reductions, production times, waste, natural resources sustainability, energy efficiency, etc. Therefore, it becomes imperative to implement strategies to overcome those growing constraints.

In this perspective "Lean Thinking" arises, aiming to eliminate unnecessary activities, preserving and increasing those with greater added value. In this way, "Lean Manufacturing" appears as a set of tools and methodologies that intend, through correct analysis and diagnosis of possible sources of waste, fostering in its continuous search process the application of techniques that when matured and applied, will allow its reduction or even elimination, maximizing client value.

In this work, some tools and methodologies were used for the analysis of the production Line 2 of the company Innovate Wet Wipes in Germany. In particular, the indicator “Overall Equipment Effectiveness” (OEE) was used to quantify the productivity and efficiency of the production processes, in order to identify possible sources with major need of intervention. Time study, work method analysis and the implementation of the performance indicator "Key Performance Indicator" (KPI) were instrumented to calculate the occupancy rate (OR) measured on critical stages of the process. Finally, the tool Value Stream Map (VSM) was used to draw a map to visualise the current company state.

Once the possible waste sources are identified, solutions were suggested steered by the tool “Single Minute Exchange of Die” (SMED) to improve the whole changeover process; the 5S method to promote organization, cleanliness and safety in the workplace, resulting in a better and efficient performance of the tasks; the Kanban method for stock management; and Poka-Yoke with the aim of creating mechanisms to avoid human and procedural errors. In the end, a future VSM for the company is suggested.

The proposed solutions in this work prospect structural, procedural and behavioural changes in the current state of the company, aiming directly or indirectly a higher efficiency in activities and processes, as well as the reduction of costs and its associated times.

Some of the suggested solutions have been implemented due to their pertinence and effective results.

Keywords: Lean Manufacturing, OEE, SMED, Kanban, Poka-Yoke, Value Stream Map, 5'S.

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Abbreviations

OEE - Overall Equipment Effectiveness

VSM – Value Stream Map

SMED - Single Minute Exchange of Die

J.I.T. – Just in Time

KPI – Key Performance Indicator

TPM – Total Productive Maintenance

TPS – Toyota Production System

WIP – Work in Progress

OR – Occupancy Rate

PCE – Process Cycle Efficiency

PPM – Packages per Minute

1. Introduction

Globalization seems to be good for many developing countries that now have access to a huge variety of markets. Highways were built, new airline routes launched and connections between countries are shorter and faster. That was an evolution that markets followed and are still following as well.

The world is still growing where competitiveness between companies is increased by the rise of the average life expectancy, demographic growth and social behaviors, searching to satisfy the wishes and needs of their consumers through lower prices and high quality. In this context, Lean philosophy appears as a strategy that leads to a reduction of costs, lead time and waste, with direct effects on the productivity of a company. This is how Lean manufacturing contributes giving a set of tools and methodologies capable to respond to those needs.

For its implementation, this approach has as its starting point the necessity to understand, analyze and design flows to identify the value streams on the production system. Only then, it is possible to diagnose improvement hypotheses and understand which ones actually add value to the client.

In this way, the present work has the purpose to analyze and characterize the current state of a production line as well as define strategies and use tools to find solutions for possible problems and its root causes. The aims are continuous improvements on production Line 2 and foreseeing its impacts.

This work is focused on waste elimination along with establishment of standard work by changing usual procedures, to bring higher efficiency on work motion to the current production line, with perspective on a future expansion to other production lines.

Initially by historic-data-records, then time study and work method analysis, it was possible to obtain necessary information and data about the production line. Moreover, the OEE indicator to measure its manufacturing efficiency.

The study was based on the measurement of production, setup, waiting and feeding times as well as losses quantification inherent to the process, with focus on waste of resources. During observations, analysis and elaborations of hypotheses it was possible to promote changes that had an immediate impact on the productivity of the line and other changes that theoretically can promote further improvements.

By creating a VSM it was possible to visualise and identify some problems. As methodologies for its elimination, the SMED method was used with the purpose of reducing changeover time, the philosophy of the 5S which aims to improve the workplace organization and the Kanban method to manage and implement safety stocks, assuring continuous flows on the production. Finally, the poka-yoke method was implemented where mechanisms are developed to avoid the occurrence of errors and mistakes during production.

2. Cutting Edge

In this chapter it is intended to give an overview of the origins of Lean philosophy. It starts with the appearance of the first machines through the development of mass production systems and finishes with the emergence of Lean Manufacturing to its importance nowadays.

2.1 Historical Perspective

Although beginning and duration of the industrial revolution vary according to different historians, the industrial revolution was a huge process of economic-social transformations that began in Great Britain around the 18th century, which within a few decades spread out to Western Europe and the United States. The transition process involved the change from the productive main activity, through handmade or use of simple machines up to replacement of human energy by driving power and manufacturing production systems. The first big machines were built in England during the 18th century by James Watt for pumping water accumulated in iron and coal mines, increasing the production of goods (McNeese, 2000).

In the following years, manufacturers were basically concerned with the development of more sophisticated machines and large-scale processes. They had no concern about what happened between processes or how the processes within the factory were organized and sequenced, as well as how worker tasks were performed (Allen, 2017).

In the late 1890ies, some industrial engineers tried to improve the situation so far. Frederick W. Taylor brought the human work to a greater level of importance and higher efficiency, by looking at workers in an individual way and their working methods which later turned out to be "Time Study" and "Standardized Work" (Taylor, 2003). Those concepts were continually developed and improved by Frank Bunker Gilbreth and Lillian Moller Gilbreth, who contributed to the study of industrial engineering with their pioneer work in fields such as human factors (studying workers behaviors and motivations, and how they influence the result of a process), work time and motion study. They also invented Process Charting focused on visualizing a process as a means of improving it (Gilbreth & Gilbreth, 1921).

In the USA, around 1910 the first concepts of mass production emerged. Large-scale production of standardized products, through assembly line techniques, had been implemented by Henry Ford, sponsor on the development of mass production, developing the first production line to automobile which many middle-class Americans could afford. This method allowed to achieve high percentages of production per worker lowering the current prices on the market. However, this kind of production revealed itself as not flexible: its work methods were largely inflexible which led to a situation where customers' wishes and freedom to choose couldn't be reached. To keep lower costs, a limited amount of automobile types produced in great numbers was mandatory. The production system was unable to adapt to the growing pace, that reached a bigger variety of needs. Another weakness was the huge problem with quality revealed on products manufactured in large batches: detecting a defect could happen only after a big amount of produced units (Womack, Jones, & Roos, "The machine that changed the world", 1990).

In Japan 1955, Taiichi Ohno and Shigeo Shingo had the task of developing a new production system for Toyota Motor Company at the Nagoya facilities. During this time, these two engineers combined various concepts from Asian religions and philosophies with the best existing concepts of production, predominantly American. They began to embrace Ford production and other techniques solving its inconsistencies and weaknesses: notice the essential role of building inventories; bring product variety; enriching the value of the employees by developing the teamwork mindset; and the concept of cellular manufacturing. Their work on studying setups and changeover problems produced great results on reducing setups to shorter times as well as allowing small batches on a continuous flow and giving flexibility to the system. The productivity and quality gains were so high and evident that the success quickly spread out (Ohno, 1988).

In contrast to mass production, the Toyota Production System was based on continuous production flow without being dependent on long production cycles nor high stocks to be efficient (Melton, 2005). In Table 1, the main differences between the two production systems are resumed.

Table 1 - Main differences between the two production systems (Adapted, Melton 2005).

	Production Systems	
	Mass	**TPS**
Base	Henry Ford	Toyota
Labourer	Non-qualified Workers	Teams of multi-qualified workers
Equipment	Machines with single objective	Flexible machines
Products	Standardized products	Variety of products
Productivity	High productivity	Productivity according to demand
Quality	High quality due to standardization	High quality despite the flexibility
Philosophy	Quality enough	Perfection

In 1990, James Womack et al. wrote a popular book named "The Machine That Changed the World", presenting the groundings of "Lean Manufacturing" (Womack, Jones, & Roos, "The machine that changed the world", 1990).

2.2 The Present

Industrial activity has revealed an important role in the European economic reality, standing out as a key element for innovation and wealth generation (Reinert, 2007).

Companies face daily challenges in seeking innovation and flexibility to respond to a more diversified and demanding market by pursuing low prices with high quality, and at the same time in an increasingly sustainable perspective (Gulati, Sawhney, & Paoni, 2003). In order to maintain the quality of their products and services those constraints need to get over faster due to the high market dynamism. It is necessary to define strategies for growth, productivity and profitability without the need of big investments. Otherwise, companies might take the risk of not attending the new market requirements (Pinto J. P., 2014).

In this context, Lean philosophy proves to be useful to implement in a company. It is targeted to find strategies and track down methods for possible waste reductions present in productive processes which do not give any added value and are generators of increased costs (Holweg, 2007). Furthermore, Lean lowers associated costs and seeks for a more customer-focused approach to respond quickly to their requests while keeping quality levels (Hines, 1998).

2.3 Lean Philosophy

In Lean philosophy, key elements like continuous improvement and the pursuit of perfection must be a part of a daily company business culture. The same should be followed by its employee's routine, operating and creating value based on best process quality without waste.

Just like all methodologies, Lean methodology must be correctly implemented to have an impact (Arnheiter & Maleyeff, 2005). For this purpose, Womack and Jones published a book named "Lean Thinking: Banish Waste and Create Wealth in your Corporation" establishing its five basic principles (Womack & Jones, 2003).

1. Specify Value

In a first approach, it is necessary to define requirements and identify characteristics that customers will value and be willing to pay for, satisfying them with quality.

2. Value Stream Map

Analyze how the production process is performed, representing the required operations from arrival of raw material until the final product, thus defining the chain of processes and activities that contribute and add value to the costumers, identifying eventually waste sources or bottlenecks.

3. Generate Flow in the Value Stream

Generate smooth and continuous flows by eliminating waiting time between the respective production sectors, in order to reduce production lead time and, if existing, the reduction of intermediary stocks, alleviating or avoiding bottlenecks in the process.

4. Implement Pull Production

Implement a production philosophy directly linked to customer demand, producing only what is necessary and eliminating needs of stock production.

5. The Pursuit of Perfection

Always strive for perfection, adopting a culture to achieve and search for continuous improvement by avoiding unnecessary costs and wastes.

2.4 Lean Manufacturing

Lean manufacturing emerges as an alternative to Lean thinking for companies that seek for cost reductions without changing the underlying management and thinking, searching for operational excellence and cost reductions on associated processes.

What makes Lean management singular and particularly effective is that it has its focus on the elimination of all waste or any expenditure of resources that does not add value for the customer from all processes (Santos, Wysk, & Torres, 2006).

According to Ohno´s model those are the seven generic wastes (Ohno, 1988):

1. Over-Production against Plan

It results from the difference between what a company provides and what the market really needs. Excess or needless production only provokes unnecessary costs (Dennis, 2007).

2. Waiting Time of Operators and Machines

Waiting time is always associated with non-productive time, either on customer's or company's perspective, whether they are associated to equipment or labor in the different phases of the production process (Baily, Farmer, Crocker, Jessop, & Jones, 2008).

3. Unnecessary Transportation

Transportation is always necessary whether to supply material, transportation between different production stages or to deliver products to the customer. However, unnecessary movements mainly associated to companies' layouts are always made by time expense and costs (Autry, Goldsby, Bell, & Hill, 2013).

4. Waste in the Process itself

During the process some procedures and operations might be unnecessary or more than required (Autry, Goldsby, Bell, & Hill, 2013).

5. Excess Stock of Material and Components

All the excesses of production, raw materials and existing stocks, when compared to market demands, represent only an accumulation of finished or semi-finished products, resulting in excessive usage of storage space and consequently extra and higher costs, hiding possible production problems (Pinto, Matias, Pimentel, Azevedo, & Govindan, 2018).

6. Non-Value-Adding Motion

Related to unnecessary operators' movements. All the pointless movements that do not directly add value to the product are considered unproductive, whether they are related to wrong company layouts, positioning of tools and equipment, type of equipment, etc. (Dennis, 2007).

7. Defects in Quality

They occur when the final products do not meet the specified quality conditions. According to Crosby (1979), "Quality is free. It´s not a gift, but it is free. What costs money are the 'unqualify' things" (Ross, 1999).

On this list, a last one extends the Ohno´s wastes (Gibbons, Kennedy, Burgess, & Godfrey, 2012):

8. Under-Utilized People

The inefficient use of employees' skills who work day-by-day in the company seeking for continuous improvement (Gao & Low, 2014).

In the pursuit of sustainable solutions, a correct first analysis must be done before selecting the most appropriate Lean techniques and tools (Simcsik, 1993). However, changes can always generate some levels of insecurity and resistance (Melton, 2005).

2.5 Lean Tools and Methodologies

In order to develop the case study some methodologies and tools are used and therefore, respectively explained. Nevertheless, in Lean manufacturing besides a set of tools to implement changes, it is also about how to foster continuous and sustained improvement as well (Kochan, Lansbury, & MacDuffie, 1997).

2.5.1 OEE – Overall Equipment Effectiveness

Waste is always present in a business process. There is a difference between paid time for a resource and the time that a resource is adding value for the costumer. In these two categories, it is possible to define a loss considering equipment effectiveness. An efficient use of a company productive capacity is directly related to an increase of production availability, translating itself in a profit boost and customers satisfaction (Stamatis, 2011). In this continuous improvement perspective, the need to measure the level of achievement and industrial performance of a company arises (Mathur, Dangayach, Mittal, & Sharma, 2011).

The equipment losses are results from many sources, being activities that consume resources but do not mean an added value for the final product. In this context, Nakajima (1988) introduced and developed the Equipment Overall Efficiency model named OEE. OEE is a performance indicator used as a tool for measuring the equipment efficiency (Jonsson & Lesshammar, 1999). In the introduction of this model, six basic types of waste were grouped into three main pillars that are fundamental to the proper work of an equipment:

1. Availability Losses

Equipment defects or malfunction stops: replacement of machine parts or repair.

<u>Stops caused by adjusting or products changeover:</u> Whenever it is necessary to adjust equipment or make a product change.

2. Performance Losses

<u>Equipment short stops or waiting time:</u> usually due to a lack of material or improper running of the equipment.

<u>Reduced production speed compared to the speed that the equipment is dimensionated:</u> non-use of full equipment capacity.

3. Quality Losses

<u>Start-up losses during the beginning of production</u>: At the beginning of each production, adjustments might be required whether they are associated with downtimes or to the gradual increase of production speed until reaching a stable process.

<u>Quality Defects:</u> Products outside of the specifications and requirements of customers are usually related to the necessary finetuning or equipment repair.

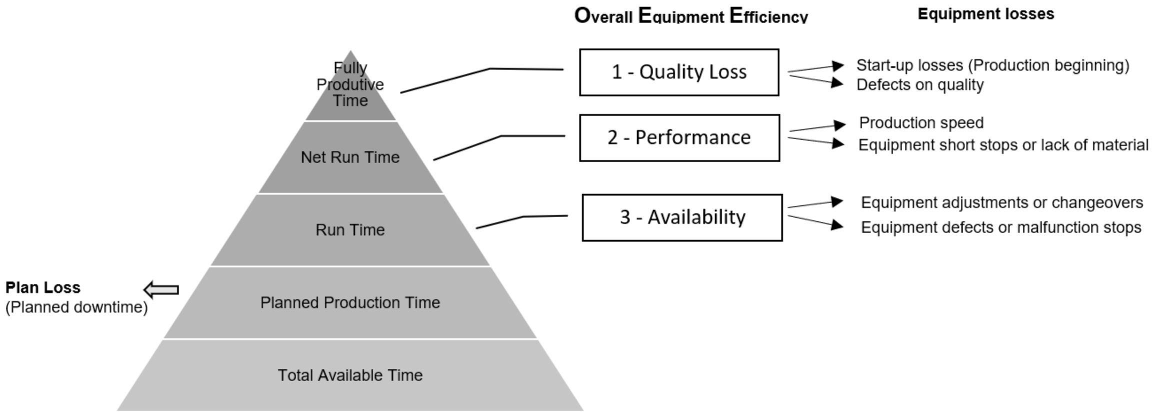


Figure 1- The six big losses associated to OEE indicator (Adapted Nakajima, 1989)

The analyses of these parameters allow companies to perceive the current state of their equipment and prioritize their main losses. In this way it is possible to analyse their root causes and outline strategies and objectives to promote continuous improvement actions for a consequent increased equipment performance and reliability (Ljungberg, 1998).

The calculation of each of the three factors is given by the following three different formulas:

$$\boldsymbol{Availability} = \frac{Planned\ Production\ Time - Stop\ Time}{Planned\ Production\ Time}$$

Formula 1 - Availability (portion of the OEE)

Where Stop Time is defined by all times in which the production was not running due to either unplanned stops like breakdowns or planned stops like changeovers.

$$\boldsymbol{Performance} = \frac{Net\ Run\ Time}{Run\ Time}$$

Formula 2 - Performance (portion of the OEE)

Where,

$$Net\ Run\ Time\ = \ Ideal\ Cycle\ Time \times Total\ Count$$

Formula 3 - Net Run Time (Performance: OEE Parameter)

And Ideal Cycle Time is the fastest cycle time, in optimal conditions that the process can achieve.

It is important to mention that Performance cannot be higher than 100%.

$$\boldsymbol{Quality} = \frac{Good\ Count}{Total\ Count}$$

Formula 4 - Quality (portion of the OEE)

The OEE value is calculated by multiplying those three factors seen in Formula 5 (Lee, Suárez, & Choi, 2010):

$$\boldsymbol{OEE} = Availability \times Performance \times Quality$$

Formula 5 - Generic formula to calculate Overall Equipment Effectiveness (OEE)

Applied to a global process, OEE can be useful for comparing efficiency across production lines. However, in the analysis of a production line when it is intended to measure and optimize a process for more than one equipment, some authors suggested to measure the OEE in a single machine to be suitable to drive an overall improvement of the system ("TPM. Collected Practices and Cases", 2005), with particular focus on the bottleneck operation of the process (Agustiady & Cudney, 2015).

Nakajima (1988) suggested reference values (Table 2) for the OEE indicator and its components:

Table 2 - Indicated OEE values

	Indicated Values
Availability	90%
Performance	95%
Quality	99%
OEE	85%

2.5.2 Time Study and Work Method Analysis

The majority of workers gets paid for their time on the job. Consequently, labor time costs are often a major factor on the total product or service costs. Thus, it is important to know how much time is required to accomplish a given amount of work. In this context, work study emerges as an important tool to examine the various factors affecting productivity and finding answers to them (Ravi, 2015).

Work study is the study and analysis of a specific job to find the most efficient method in terms of time and effort. It is also a generic term for two techniques: method study and work measurement which are used to examine the accomplishment of necessary jobs, Figure 2 (Chary, 2004).

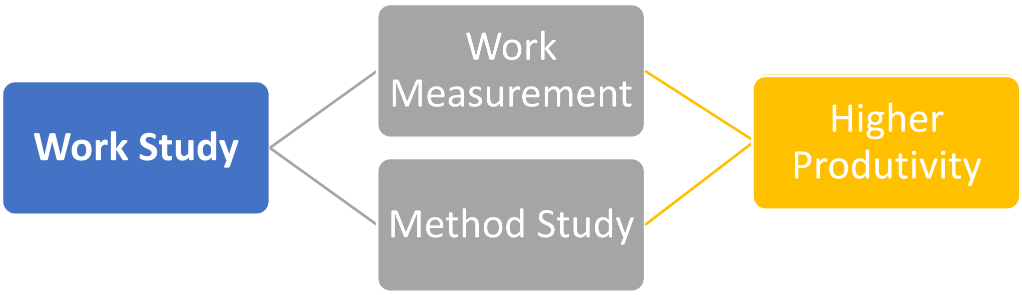


Figure 2 - Work study components (adapted Ravi, 2015)

Kumar & Suresh (2008) quoted in their book two sentences related to work measurement and method study:

“Work measurement is the application of techniques designed to establish the time for qualified workers to carry out a specified job at a defined level or performance.”

“Method study is the systematic recording, critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.”

In other words, work measurement represents the required time record to accomplish given tasks establishing its standard time. Method study is related to examine and record systematically the way tasks are performed in order to find possible improvements. Its goal is to develop and apply easier and effective ways of doing things, requiring least time and less fatigue to workers while reducing costs and standardizing work methods, mainly by eliminating unnecessary operations.

Ravi (2015) mentioned in his book that while performing a work study, method study is firstly done.

Method Study

By analyzing the current way of performing a task systematically, the goal is to develop a new and better way to do it: increasing the productivity by ensuring the best performance between human factors, machine and material resources achieving higher efficiency and avoiding unnecessary operations.

Figure 3 resumes the basic steps to perform a method study:

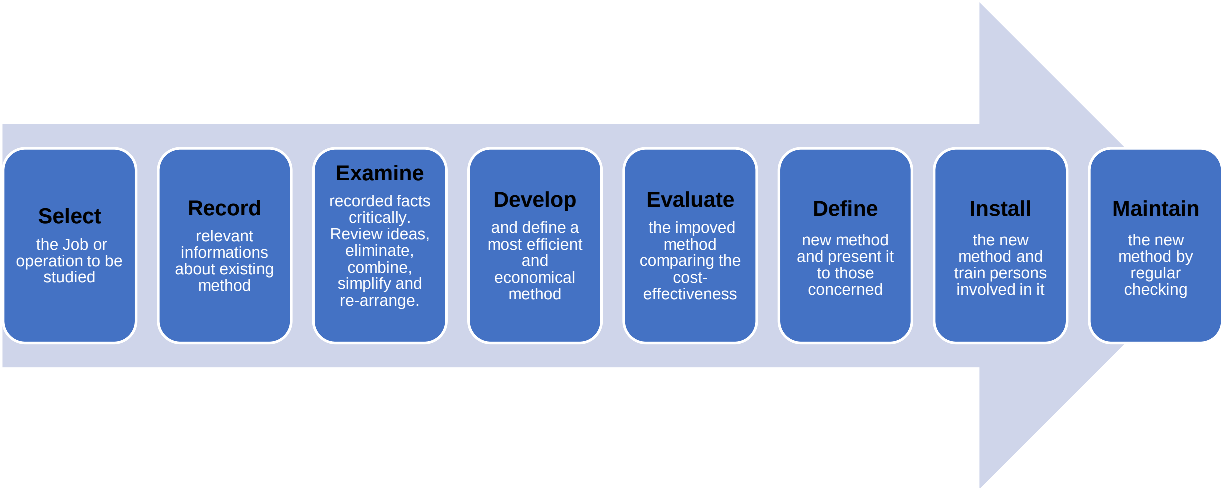


Figure 3 - Method study procedure (adapted Kumar&Suresh, 2006)

Method study involves two techniques: Visual analysis to get a general overview of the reality on the production line and Informal interviews which provide details about the way of working on each sector (Gomes, 2007).

Work Measurement

In order to measure the required time for a specific task from a qualified worker and consequently establish and determine standard times, different strategies can be used, Figure 4.

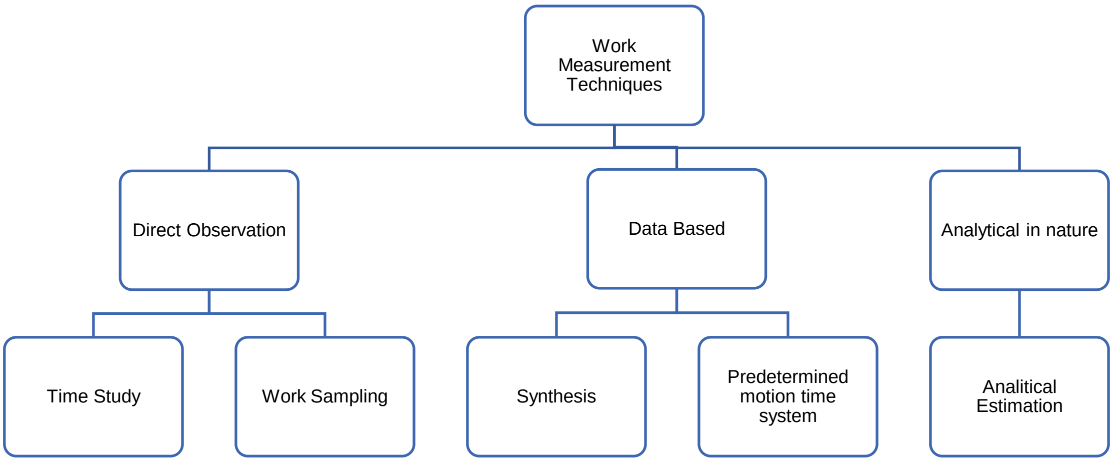


Figure 4 - Work measurement techniques

The used work measurement technique in this study was by direct observation, namely time study. In this strategy, the analyst evaluates the workers pace-performance rating directly observing and recording the time to accomplish a specific task using a stopwatch. This task can be even divided into work elements where time is separately registered. This kind of approach requires some time and is only justified when relatively long productions run or are repeated in the future: which meets the case in hands.

To implement the work study correctly, it is necessary to involve the whole company structure and to assure that all the developed improvement solutions are implemented after the study (Janakiram, 2010).

2.5.3 SMED – Single Minute Exchange of Dies

The time when the industry finds large and long lots of production is gone. The growing development and big competitiveness between companies with a huge range of products and options with exponential growth changed the customers behavior to the market (McIntosh, Culley, Mileham, & Owen, 2001). Consequently, there are less and less conditions to produce in large lots and the solution goes through small production amounts and the ability to respond quickly to customers. Therefore, changeover times must be reduced and preferably eliminated (Cakmakci, 2009).

SMED was developed by a Japanese industrial engineer named Shigeo Shingo with the goal of reducing changeover times in companies. The results were so significant that western automakers were positively surprised by the quality and cost of Japanese cars (Shingo, 1985).

In SMED, changeovers are separated in two kinds of elements: **Internal Elements** that must be completed while the equipment is stopped and **External Elements** that can be completed while the equipment is running. Therefore, the core of the SMED methodology is to convert as many changeovers steps as possible to external elements, simplifying and streamlining all elements following three operational phases:

<u>Phase 1</u> - Measure Changeover Times / Identify Internal and External Elements

The process starts by observing all the changeover process, identifying all the different required steps and sequences of operations. Finally, their respective partial and global times, Figure 5.

After this first phase, the operations are classified into two types: external and internal elements. Therefore, it is necessary to check which one of those changeover steps have to be done while the machine is stopped (internal steps) and which can be performed while the machine is still running (external steps).

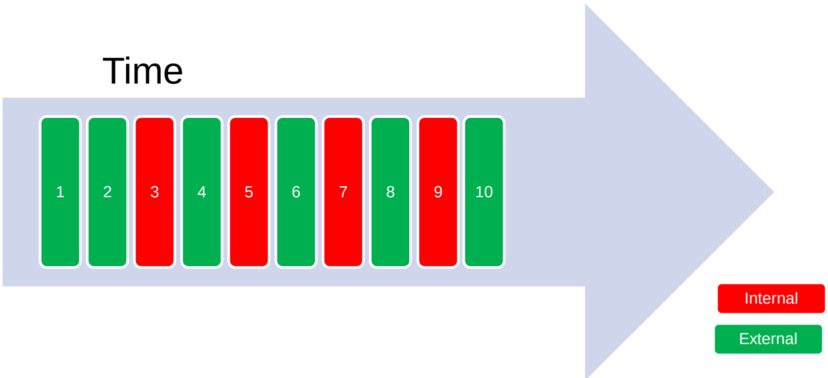


Figure 5 - Phase 1 illustration (SMED)

<u>Phase 2</u> - Reorganize Elements into External Elements if possible

Besides converting internal steps into external ones, it is also important to ensure that an external step is indeed done before or after the process interruption, Figure 6.

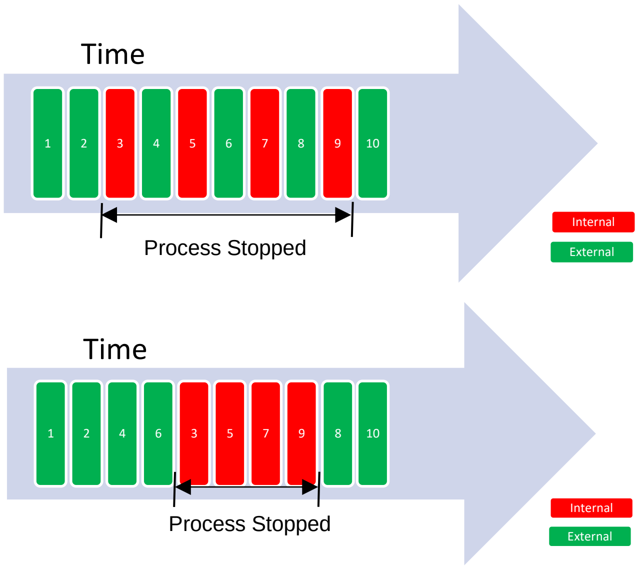


Figure 6 - Phase 2 illustration (SMED)

Phase 3 - Shorten Internal and External Elements & Standardize and Maintain New Procedure

Analyse all the procedure and check if it is possible to simplify and make shorter internal and external elements. Reduce stoppage time in process. Consequently, reduce overall changeover time and mostly the workload for workers doing the changeover.

The last step is targeted to fix new standards and document them as well as train all relevant workers in the new standards and do a process confirmation, otherwise it might be quickly lost.

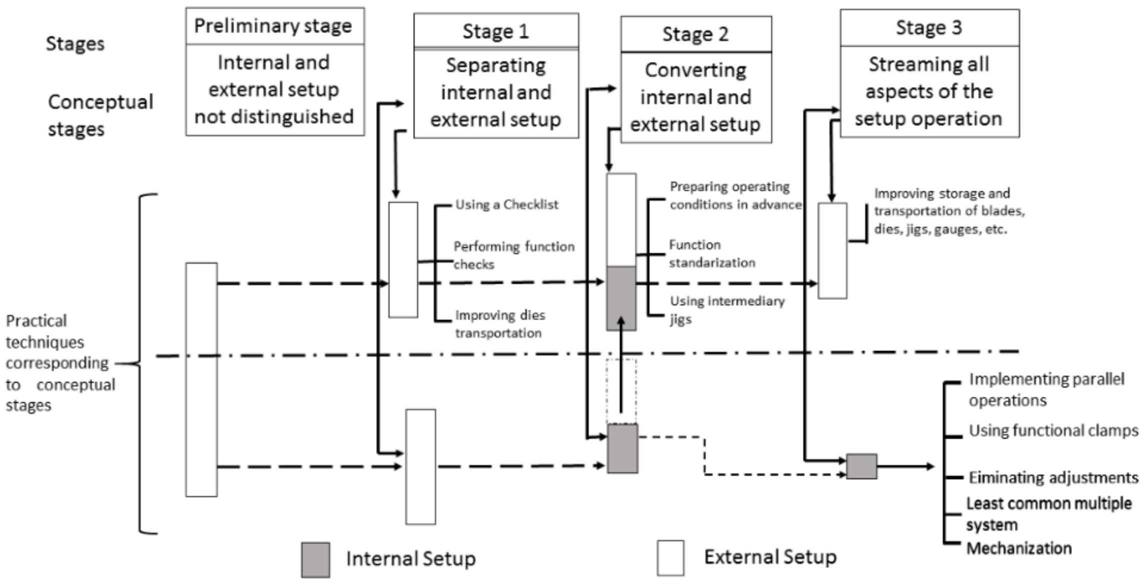


Figure 7 - Illustration of the different phases of the application of the SMED method. (Cakmakci, 2008)

2.5.4 Kanban

Kanban is a Japanese word which means "visual signal” and represents a visual method for controlling production (Ashmore & Runyan, 2015).

The idea was originally borrowed from the way supermarkets managed their stocks where store clerks only restocked a grocery item when nearly sold out (Ohno, 1988). This process sparked Toyota engineers to rethink their methods and pioneer a new approach by seeing that this method could eliminate the need of high inventories costs. In the early 1940ies, the first developed Kanban system was a simple planning system aiming to control and manage work, particularly inventory at every stage of production, matching it with demand which at the same time could be able to achieve higher levels of quality and output. By this method, Toyota reached a flexible and efficient Just-in-Time (J.I.T) production control system, increasing the production while reducing costs on intensive inventories. Those improvements have led to the idea of incorporating Kanban systems in manufacturing.

Kanban – Work in Progress (WIP) Limits

One of the key points of using Kanban is to reduce the amount of multi-tasking. In other words, to avoid time losses encouraging the worker to finish work at hand and only then proceed to the next piece of work (Hughes, 2016). Kanban allowed companies to use J.I.T production and the possibility of ordering systems, minimizing their inventories while still satisfying costumer demands.

Besides a visual work managing system, Kanban may allow seeing where work items pile up, which is a strong sign of a problem, most likely a bottleneck. In this way, Kanban is an important information system that allows the control of the production in every process, by regulating the required products in the necessary quantities and at the required time.

The classic introduction for a Kanban board model is to visualize the workflow through 3 columns: “To do”, “Doing” and “Done”, Figure 8 (Louis, 2006). In this columns, simple sticky notes are used to represent a simple task. However, depending on the complexity of the workflow, Kanban boards can show elaborate workflows. There are no limits to design Kanbans, they can take many forms and shapes but in many production facilities they use Kanban cards to control the process.

Figure 8 - Classic Kanban board

Pull-Push Type Productions Philosophies

In lean production, an important difference is to use pull production instead of push production (Rath & Strong, 2003).

A push production is based on production without having a specific costumer request ("make-to-stock"). In other words, this kind of production is used for producing parts in each individual production stage where the flow is pulled according to the rate of which parts are being more consumed between the production stage (Wallace, 2004).

Pull production is grounded "theoretically" only when the end costumer requests ("make-to-order"). It is based on replacing only what has been consumed where resources are provided grounded on forecast or schedules, Figure 9:

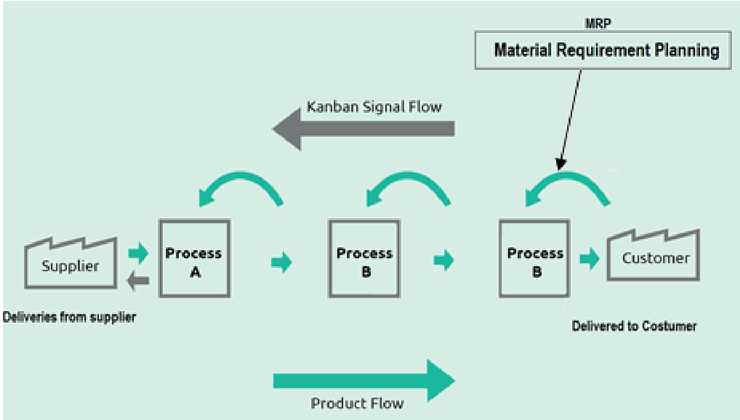


Figure 9 - Illustration of a pull system (Example)

The direction in which information and orders are being forwarded to is the big difference between push and pull systems. In the pull flow, information flows oppositely to the material flow imposed by the Kanban policy. Therefore, the work in progress has a fixed upper limit where you cannot have more resources than what is allowed by the number of Kanban cards (Japan Management Association, 1989).

Kanban lot sizes can be dimensionated according to Formula 6 (William, 2005):

$$N = \frac{DT(1+X)}{C}$$

N- Number of cards
D- Daily Demand
T- Lead Time (in Days)
X- Safety Stock
C- Quantity in a Container

Formula 6 - Calculate Kanban (Lot sizes)

2.5.5 Poka-Yoke

Poka-yoke is a Japanese term and it means “mistake-proofing”. In Lean manufacturing, poka-yoke can be represented by any mechanism that helps equipment and operators to avoid errors and mistakes, removing product defect before or when they occur. This poka-yoke concept was formalized by Shingo (Shingo, 1985).

In order to overcome the inefficiencies of inspection poka-yoke proposes the use of automatic devices and mechanism categorized as being either control (physical action to prevent defect) or warning (for example sound an alarm or light up, to tell a mistake has been made) seeking for:

I. Do not create a defect;
II. Do not accept a defect for the process;
III. Do not allow a defect to be passed to the next process.

Eight principles are mentioned in order to implement basic improvement for poka-yoke and zero defects (Shimbun, 1988):

1) Build quality into processes by reaching no defects when an error occurs;
2) All inadvertent errors and defects can be eliminated, pursuing ways to eliminate all error and defects;
3) Stop doing it wrong and start doing it right even when it takes more effort;
4) Don’t think up to excuses, think about how to do it right;
5) A 60% chance of success is good enough to give it a try;
6) Mistakes and defects can be reduced to zero when everyone works together to eliminate them;
7) Team work: ten heads are better than one;
8) Seek out the cause using ‘Five Whys’ approach to explore the root-causes underlying the problem and one H (“How do we fix it?”).

2.5.6 VSM - Value Stream Map

A Value Stream Map (VSM) is a visual method which illustrates graphically how material and information flow to deliver a product or service. With the help of this process, visualizing weaknesses or bottlenecks areas can be found and organizations are driven to improve and make the necessary changes (Lian & Van Landeghem, 2002).

VSM is a visual tool with a specific language that must be practiced to learn (Rother & Shook, 2003). Figure 10, shows examples of the symbology used on drawing maps.

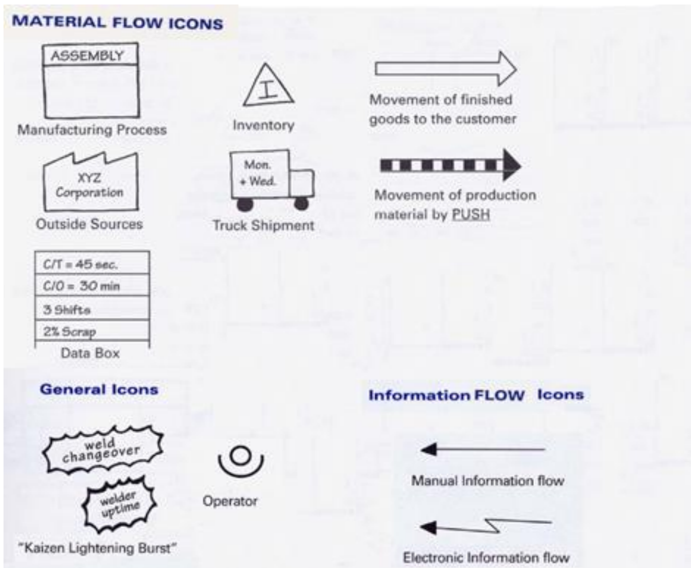


Figure 10 - Value Stream Map symbology (adapted Rother&Shook, 1998)

A VSM is basically composed in three distinct regions: Information Flow, Process Map and Timeline using a set of unique symbols to visualize the process (Nash & Poling, 2008), Figure 11.

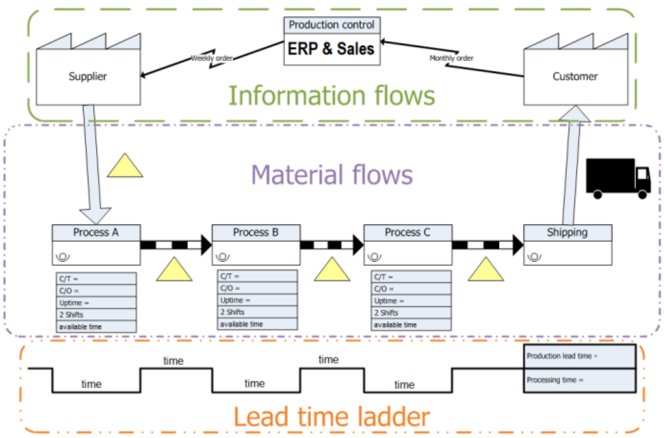


Figure 11 - The three basic parts of a Value Stream Map (adapted Daniel Penfield licensed under CC BY-SA 3.0)

1) **Process Map** is composed by the steps and information associated to the process in each stage;

2) **Timeline** is built according to how the process flows and its reference data;

3) **Information Flow** explains the interaction and activity between the stages in the value chain.

Drawing a VSM follows normally a process of four steps (Rother & Shook, 2003). Firstly, it is necessary to gather some information about the products production to proceed to the second step: drawing the current-state. The goal of the third step is the design and development of a future-state. The development of the current and the future state are overlapping efforts: while mapping the current state some ideas will come up, as well as though drawing the future-state some forgotten info must be important to attach in the current-state. Finally, it is essential to build an implementation plan, how to achieve the future state, Figure 12.

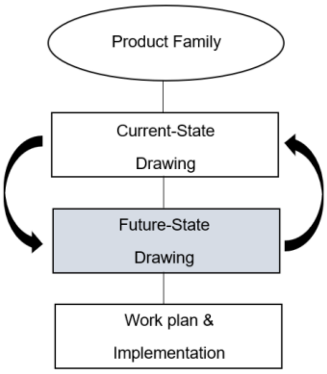


Figure 12 - Initial Value Stream Mapping steps (adapted Rother&Shook, 1998)

Lima et al. (Lima & Zawislak, 2003) state that a current-state VSM should have data like material and information flow, client demand, raw-material suppliers, process stages, cycle and changeover time, operator numbers and stock. Lead time might be reduced by its analyses and development (Saranya & Nithyananth, 2012).

Mapping usually takes time to prepare and validate because of its required data. However, a precise and detailed map is not necessary to build. Fine-tune must be performed as soon as the future-state implementation starts (Rother & Shook, 2003).

2.5.7 5S Method

5S Method is defined as a methodology for continuous improvement in order to get a safer, cleaner and more enjoyable workplace (Moulding, 2010).

5S represents five Japanese words that describe the steps of a workplace organization process: **Seiri** (Sort), **Seiton** (Straighten, Set), **Seiso** (Shine, Sweep), **Seiketsu** (Standardize) and **Shitsuke** (Sustain), (Bichai, 2015). It has its origins in post-World War II Japan around 1950 (Fabrizio & Tapping, 2006).

The 5S methodology is a tool targeted to help organizing a workplace by removing items that are no longer needed (sort), the practice of orderly workplace storage optimizing its efficiency and flow (straighten, set), cleaning the area in order to identify problems more easily (shine), implement organizing standards (standardize) and develop behaviors to keep the workplace always organized, implementing behaviors and habits to maintain the established standards over long term (sustain). These are sequential and cyclic activities starting with the letter “S” (Hirano, 1995), Figure 13.

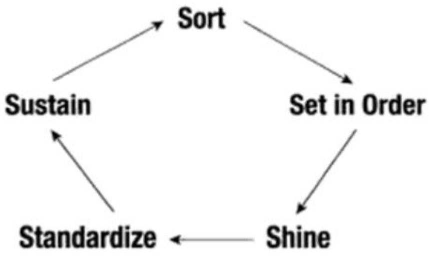


Figure 13 - 5S methodology (Fabrizio&Tapping, 2006)

Fabrizio and Tapping (2006) compared companies with living organisms that change and grow and if they do not make changes in response to their environment, they will fail.

2.5.8 The 5 Whys’ Method

The 5 Whys method is a technique to find the root causes of a problem. The method consists of starting to ask ‘why’ the problem occurred and then continually asking ‘why’ again as a reaction to the response, repeating the procedure five times or until it is difficult to find an answer (Rafinejad, 2007).

Toyota Production System used this 5 Whys strategy to find the root cause of an occurred problem quickly, where the number five is just a rule of thumb and the ‘why’-question might be required fewer or more times before getting to the root cause of the problem (Wang, 2008).

3. Applying Lean Manufacturing – Innovate Wet Wipes Production Line 2

The main goal of this study is to apply Lean manufacturing tools, concepts and methodologies in a production line belonging to the company Innovate Wet Wipes aiming to search for higher flexibility, efficiency and productivity.

After getting to know more about the company and understanding its production lines and respective products, the entire current state of production system was analyzed through historic and collected data on-site and its respective OEE values calculated.

According to the acquired knowledge and research results, a specific production line was selected where problems and its root-causes were diagnosed, analysed and solved. For that, strategies and Lean tools have been used in order to reduce or eliminate them.

3.1 Industrial Framework

A wet wipe is a moistened and folded piece of paper or cloth which is assembled into a wipes stack format. It can be found in huge sorts of packs with different shapes, forms and sizes (Das & Pourdeyhimi, 2014).

Wet wipes are a growing business initially designed to clean babies, remove Makeup and for the household (Williams, 1996). However, lately it boomed in the disinfection market due to its utility of being a quick and easy way to sterilize and clean any surface. Instead of carrying a bottle of cleaner and rags, wipes and its cleaning agent already diluted to the proper concentration coming in one convenient package, sparing time, money and annoyance (Cahn, 2003).

3.1.1 About the company

Innovate is a family firm founded in 1973 in The Netherlands. The growth of the market and range of products developed the business that initially operated with local costumers into an expanded and international one. Therefore, Innovate Wet Wipes raised up a second plant since July 2002 in Naumburg (Saale), Germany.

Within more than 15 years, Innovate Germany has been growing in products development with its own laboratory by production and marketing of wet wipes for many applications, aiming medical care products.

The facility has currently seven full-/ and one semi-automatic flow packing lines, with a yearly production capacity of 60 million packs, based on a two-shift-system production with more than 100 employees.

3.1.2 Company Layout

Inside the company there are two different production areas: Zone 1 and Zone 2. In each area, four production lines are working independently and being managed and supplied individually.

Due to the growth of the business, the company still has places under construction. However, the following layout represents the current company floor plan, Figure 14:

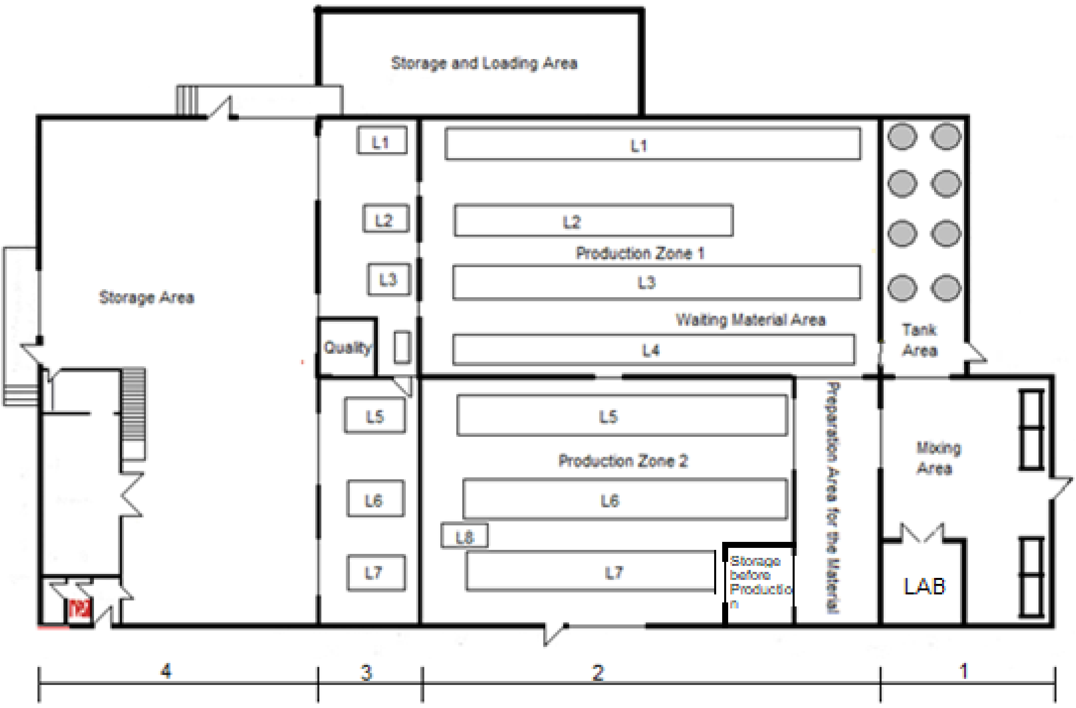


Figure 14 – Floor plan (Innovate Wet Wipes)

The workflow can be represented by dividing it into four process stages:

1. Corresponding to Mixing Area. At this point, lotions are prepared in the lab and later stored in huge tanks placed in the Tank Area. Afterwards, each one of those tanks will be used to feed a specific production line.

2. Production Zones 1&2. Inside these areas, required machinery is found running products according to its specification and necessary material: wipe-rolls, pre-produced dry wipe stacks, packing film and labels.

3. Packing Area. The packages get delivered to this area. If necessary, there are lid robots placed to glue lids on top of the packages where later on operators are packing them into cartons and palletizing the goods into pallets. Nearby, the quality control is periodically checking the product excellence by picking them randomly from the lines and performing pre-determined tests.

4. The Storage Area. It is the place where finished pallets are stored before loading the trucks.

3.2 Time Study

After getting to know the company and understanding its global operation process and production lines, a parallel analysis was carried out to pick a single production line to focus on in this study.

By calculating the overall OEE value on each line based on daily collected data like production plan, expected performances, operators' daily reports and its respective outputs, it was possible to obtain an overview of the entire production and identify potential improvement focus.

3.2.1 Applying OEE on Production Lines

The company operates in two shifts (8 hours each) and the daily production of each line was considered to calculate the OEE indicator. As seen in Formula 5, OEE values are the result of multiplying three factors.

1. Availability

Availability is the percentage of time in which a line actually produces and does not stand still due to e.g. breaks, changeovers or defects. By using Formula 1, it is possible to calculate the parameter Availability considering:

Planned Production Time represents the total available production time taking out the values of planned non-productive times (e.g. maintenance and breaks). In this case study, maintenance times will not be considered because during the performed analysis there was not carried any maintenance work.

Table 3, shows the times at which shifts begin and end. Its total sum is considered as Planned Production Time since no non-productive time is foreseen.

Table 3 - Company schifts schedule

	Shifts Schedule [Start and End Time]		Planned Production Time	Break duration
Shift 1	06:00	08:35	02:35	00:20
	08:55	11:30	02:35	00:25
	11:55	14:45	02:50	
Shift 2	14:45	17:35	02:50	00:20
	17:55	20:30	02:35	00:25
	20:55	23:30	02:35	
Planned Production Time:			16:00	

<u>Stop Time</u> results from the sum of times registered on reports written by line operators, Formula 7:

$$Stop\ Time = Troubles\ Stop + Changeover$$

Formula 7 - Stop Time (Availability: OEE Parameter)

2. Performance

Performance is determined by the ratio between final and planned output while the line is working without any interruption. The Performance ratio can be calculated by using Formula 2. Necessary values are given by Formula 8 and 9:

Run Time = Production Time – Short Stops Time – Speed Loss

Formula 8 - Run Rime (Performance: OEE Parameter)

Production Time = Planned Production Time – Stop Time

Formula 9 - Production Time (Performance: OEE Parameter)

<u>Speed loss</u> is the loss of productive time resulting from the difference between the speed at which the line is idealized at its maximum and the speed at which the line was actually running, Formula 10.

$$Speed\ Loss = \left(1 - \frac{Real\ Speed}{Idealized\ Speed}\right) \times Production\ Time$$

Formula 10 - Speed Loss (Performance: OEE Parameter)

<u>Short Stops Time</u> represents the loss of productive time which results from small stops performed by line operator interventions.

3. Quality

Quality is calculated from the ratio between good and total produced goods. Its ratio is given by Formula 4, whereas calculating the production time of good packages is possible by using Formula 11:

$$Production\ time\ good\ packages = \frac{Run\ Time}{Total\ Produced\ Packages(*)} \times Produced\ Good\ Packages(**)$$

Formula 11 – Production time of good packages (Quality: OEE Parameter)

Where,

Total Produced Packages is the recorded value by the line operator of the produced products amount.

Produced Good Packages is calculated through the number of palletized products registered by the shift leader.

3.2.2 Overall Results Analysis of OEE

The study was carried out during four weeks. During this period daily data was collected in order to calculate daily OEE values for each one of the six production lines. The reached average values for each line were then summarized thus allowing to have a global view of the entire production and to understand which line has the lowest value, Figure 15.

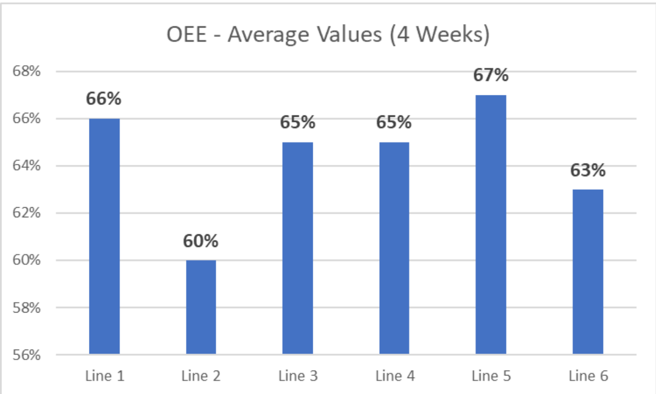


Figure 15 - Overall equipment effectiveness (OEE) applied on six production lines of Wet Wipes

In this way, after gathering the knowledge acquired “on the field” and getting a global overview over the production lines efficiency, Line 2 was strategically selected. Besides its lowest efficiency value of 60%, it is also the least automated and accordingly has a high dependence on workers.

3.2.3 OEE – Line 2 Values (4 weeks)

In order to easily visualize how calculated OEE values and its respective factors varied during the study period, Figure 16 shows its development. In the graph, along the days it is possible to find the values of the OEE (blue bars) and the respective factors availability, performance and quality represented by the different colored lines.

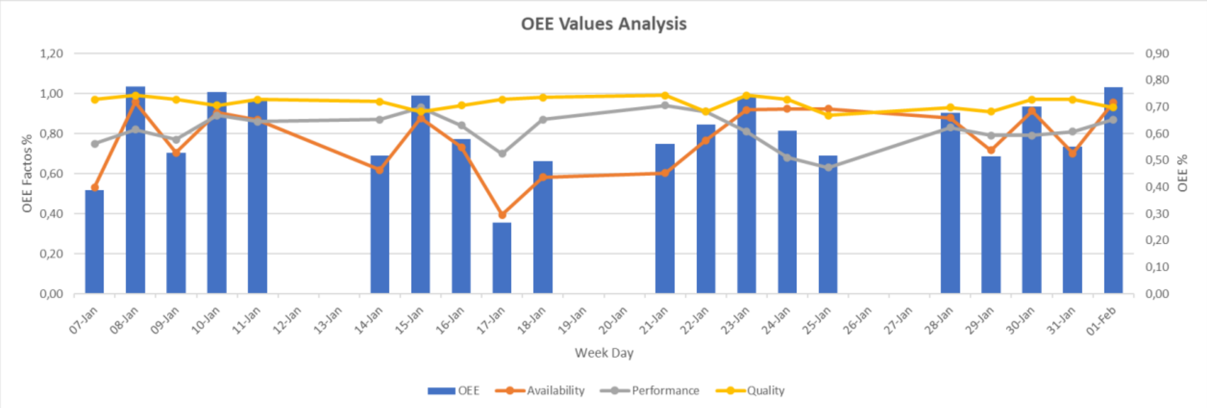


Figure 16 – OEE values Line 2 (4 Weeks)

By analyzing the graphic, it is seen that quality has a small impact on line efficiency, being between a range of 89-99%. That fact is justified by the possibility of repacking wet wipe stacks even when production problems occur such as weight problems, printer code, unsealed packages, wrong lid position, etc. In most cases, the wet wipes stack can be reused as long as its integrity and hygiene are assured. In this way it is possible to consider that quality, although improvable, has no significant influence on the efficiency of Line 2.

Regarding to OEE parameter availability, besides its visible instability, it is predominantly the lowest from all of the three parameters and thus having a greater impact on the efficiency of Line 2. As mentioned earlier on Formula 7 its calculation is directly linked to trouble stops and changeovers. Over field experience, historical records and notes, no planned maintenance or repairs took place. Consequently, all the lowest values mainly on the 7th and 17th of January were associated to complete new products-changeover and at 9th, 14th and 18th to small changeovers on running-products as different lotion or wipe stack size. Otherwise, only small stops associated with small changes such as changing the printer code were made.

Relatively to performance values there are clear variations over the course of the study. As defined in Formula 8, performance is directly influenced by speed loss and short-stop times, which are mostly related to the highly dependence on workers. Apart from different working rhythms, once those are not maintained the line will consequently stop for a few seconds until starting again. Furthermore, a lack of material was also considered as stop time (Formula 9), Figure 17.

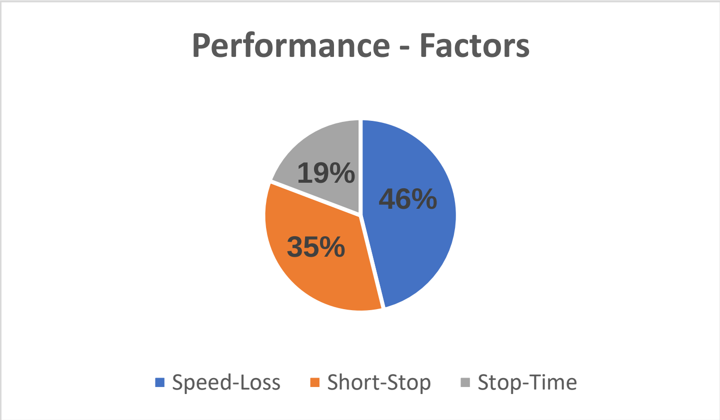


Figure 17 - Performance factors

In summary, not only the experience in the field but also the performed analysis of factors such as lower productivity, greater dependence on operators, product specificity and the lower OEE value, led to the choice of Line 2 for this case study.

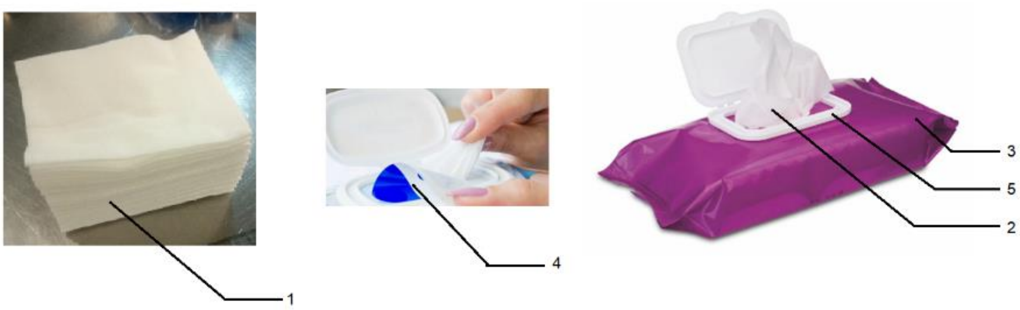
3.3 Production Line 2 – Case Study Description

This subchapter describes the required components for a finished package, the types of wipe-fold present on a wipes-stack as well as the types of package variations that may exist.

Subsequently, the different production stages are described and its process flow explained.

3.3.1 Products Feature

The product range is diverse and normally varies according to wipe dimension and folding type, building up a huge sort of combinations and possibilities for new product designs. Allied to this, a great diversity of packing films, lid shapes, types of drilling and labels enrich the creative freedom immensely. However, a finished package is basically composed by five components, Figure 18:



1. Wipe Stack (unfolded size, folding type and wipes amount)
2. Lotion (alcoholic, non-alcoholic based, etc.)
3. Packing Film (aluminum foil, PET, etc.)
4. Label
5. Lid (size and shape)

Figure 18 - Basic components of a package

Although the countless folding variety, Line 2 is focused on a special Z-Cross type folding. These dry wipe stacks are pre-produced in another company sector. There, folded wipe stacks are collected in sanitized plastic boxes, properly protected and stored in pallets.

In figure 19, Z-Cross folding is schematized in five steps from its beginning until the final wipes stack appearance.

(1) Unfolded Wipe

(2) 1st. Side Corner Folded

(3) 2nd. Side Corder Folded

(4) Middle Folded

(5) Wipes Stack

Figure 19 - Explaining the wipes folding on a stack

3.3.2 Product Family

Despite the diversity of products, it is possible to classify them into two families: Packages with and without lid, Figure 20:

Figure 20 - Package families

The production process is similar for both family products. However, the lid on the pack is an important variable in the production, mainly in changeover times: setting lid robots requires time and on the belonging glue machines, it is essential to have enough warmth to start the setup procedure. This operation usually takes about 60 minutes when fully turned off or 20 minutes when the glue machine is in standby mode.

3.3.3 Defining the Different Production Stages

In order to perform the case study, table 4 resumes the production stages which the wipe stacks follow until they are finished and ready to send to the client.

Table 4 - Stages description on production Line 2

Stage	Description
1 – Pallet with Dry Wipes Stacks	An operator brings the material stored in a pallet containing dried wipe stacks on plastic boxes. The pallet is transported to the line.
2 – Introduce Wipes Stack	An operator grabs a dry wipe stack pile and introduces each stack in the diving machine.
3 – Diving/Press Machine	The dry wipe stacks dive into a lotion bath and are pressed to remove lotion excess.
4 – Packing Machine	Wet wipe stacks are moved into a packing machine to be sealed.
5 – Metal Detector	Check the presence of metal elements inside the packages.
6 – Weight Checker	Check packages weight.
7 – Turning Packs	Turn packages downside-up.
8 – Lid Robot	A robot glues the lid on the packages top.
9 – Pack the Cartons	An operator picks the packages and puts them into cartons.
10 – Palettizing	One operator grabs the taped and printed cartons and assembles them into pallets.
11 – Stretch Wrap	When pallets are finished, a plastic layer is used to cover it.

3.3.4 Explaining the Different Stages of Production

In this chapter is described how the production flows through the different production stages, perceiving the whole production operations since the material arrives at the line until it is ready to be loaded in trucks and sent to the client.

Pallet with Dry Wipe Stacks

The material is stored in a mini warehouse created for standby material prepared to feed the respective production lines, Figure 21. These materials are organized in a big shelf identified individually with its line numbers or in the surrounding area when related to store pallets with dry wipe stacks and wrapped sets of wipe rolls.

The required materials are then carried out by an operator who is responsible for feeding the lines. Pallets with dry wipe stacks in plastic boxes, huge wipe rolls, packing film rolls and labels are transported to the respective line with the help of a manual palletizer.

Figure 21 - Mini warehouse (storage place before production)

Regarding to Line 2, one operator is responsible for supplying the line with pallets containing dry wipe stacks as well as packing a manual loading conveyor with full plastic boxes, Figure 22.

Figure 22 - Pallet with plastic boxes and its dry wipes stacks

These full plastic boxes are continuously emptied and it is necessary to tidy up the empty plastic boxes and replace them with new ones. Besides that, the same operator is also responsible to supply material for two other production lines: Line 1 and Line 3.

Depending on the product, each pallet can supply Line 2 within 36 to 60 minutes and loading plastic boxes on the manual conveyor is a quick job necessary in a relative short period of time.

<u>Diving Machine</u>

At this stage, another operator is responsible for picking up the piles of wipe stacks stored in plastic boxes (1), lay them in a table (2) and finally introduce each wipe stack individually (3) in the diving machine conveyor, Figure 23.

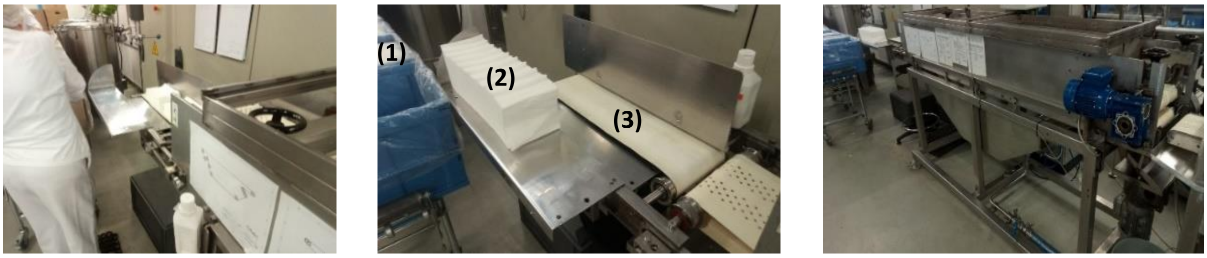


Figure 23 - Diving Machine (stage)

In the diving machine, each wipe stack is transported into a lotion bath absorbing it. Consequently, the process is followed by a pressing machine adjusted to squeeze the wipe stack for a wished weight, Figure 24.

Figure 24 - Pressing unit (stage)

<u>Packing Machine</u>

At this process phase, wet wipe stacks are transported to the inside of a packing machine (Figure 26), which is correctly installed and adjusted with packing film material, labels and printer code (Figure 25). The wipe stacks are then wrapped in a packing film with tube shape (Figure 27) and slightly pressed to withdraw the air to be finally sealed (Figure 28).

Figure 26 - Packing Machine (loading conveyor)

Figure 25 - Packing Machine (pack material)

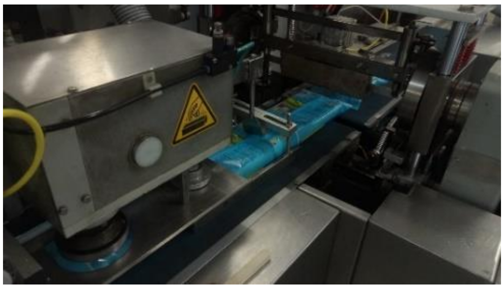


Figure 27 - Packing Machine (lengthwise sealing)

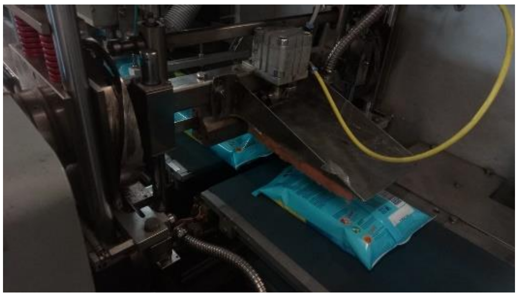


Figure 28 - Packing Machine (latitudinal sealing)

<u>Metal Detector, Weight Checker and Turning Machine</u>

After being correctly sealed, the packages are submitted to a couple of tests to ensure its quality, Figure 29. First, a metal detector is used to check the existence of metal elements in wipe stacks and detected packages are automatically rejected. Finally, the packages are verified by a weight-checker which confirms if the products are in the accepted weight range agreed with the customer: heavier or lighter packages are rejected. Once these tests are completed, packages are then turned downside-up by a turning machine, moving to the next stage.

Figure 29 - Weight-Checker, Metal Detector and Package Turning Machine

Lid Robot

After the packages are sealed, all quality tests verified and turned over they are then transported to the packing area. In this area there is a robot installed to glue lids on top of the packages, Figure 30.

These robot lids are manually supplied by the operator who is responsible for picking the full cartons and palletize them into pallets. These lids are transported on a conveyor belt where labels are automatically applied. A pneumatic piston picks the lid with its vacuum pad, passing through an intermediate phase where the glue gun is installed. Finally, the lid filled with glue is placed on top of the package.

Figure 30 – Lid Robot (transport and lid application)

Packing Cartons and Palletizing Pallets

Finished packages are then packed into cartons by one operator, Figure 31. Besides quality department, this operator plays an important role in the process because while packing, they keep the line driver informed about any problems or possible adjustments required on the packages.

The final cartons are then individually taped and on its sides a code is printed, Figure 32. These cartons are assembled in pallets by another operator (Figure 33) and finally moved to the storage area.

Figure 31 - Packing Operator

Figure 32 - Carton sealer, Labeller and Printer

Figure 33 - Final Pallet to Costumer

Stretch Wrap

In the storage area finished pallets are transported to the stretch wrap machine. In this machine, a layer of plastic film is applied to avoid pallets from moving while transporting and to protect them against humidity, Figure 34.

Figure 34 - Stretch wrap machine (stage)

Trucks are loaded with final goods ready for costumer's delivery.

3.3.5 Production Flow

The production process goes through several steps from the supplied material until the final product ready for the delivery to the costumer. The material is always tested before stored in the warehouse. However, the main inspection is done during production by workers responsible for the quality, operators and specific machinery.

In Figure 35, the scheme represents the actual production flow for Line 2 since the material arrives in the company until it is ready for delivery to the costumer according to the stages defined in Table 4.

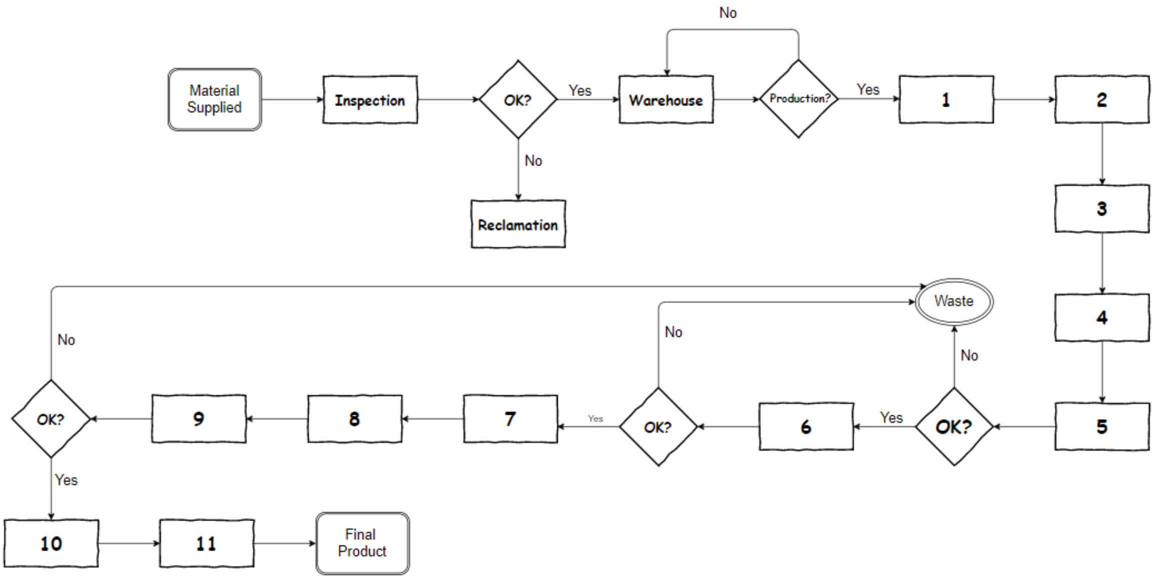


Figure 35 - Production Line 2 (flowchart)

3.4 Time Study and Diagnosis

In this chapter, values that represent the production line reality are quantified which are the result of instant observations and timing. According to the obtained data it was possible to check eventual improvement points and constraint stages.

3.4.1 OR - Occupancy Rate

OR is a Key Performance Indicator (KPI) that allows to see which stages are overloaded. It represents the relation between total production time and available working hours, Formula 12.

$$Occupancy\ Rate\ (OR) = \frac{Total\ Production\ Time}{Available\ Work\ \ Hours}$$

Formula 12 – Occupancy rate (OR)

The production on Line 2 is constantly changing between products of Family 1 and Family 2. However, despite its existent difference in lid-robot setup time, inside of each family there might also be huge product differences due to different lotions. In these cases, the diving machine needs to be washed and properly tested. Therefore, the study is done with average values, independently analysed, in order to obtain the most accurate values that represent the production.

According to the production data from the 24th of January until the 29th of January in 2019 (corresponding 3 working days, 2 shifts-system each) and assuming these values represent the global production, it is possible to know the average of packages per day, Table 5.

Table 5 - Production values from 24th until 29th of January

Family	TNP	AWD	DANP
1	48000	3	16000

TNP: Total **N**umber of **P**ackages produced
AWD: Available **W**orking **D**ays
DANP: Daily **A**verage **N**umber of **P**acks

By timing it was possible to determine the average cycle time values for each critical stage. In other words, the time elapsed between the beginnings of two subsequent pieces of an operation. It is important to note that not all of the cycle time on the different stages were measured because not all of them are influencing the producing pace. The machinery belonging to Line 2 is set to run based on an operator average speed. Therefore, its cycle time is not important for measuring the occupancy rate. Furthermore, procedures like palletizing and feeding the line are not considered due to its long duration time. For example, one pallet with dry wipe stacks can feed a line 30 to 45 minutes as well as one finished pallet ready to get delivered to the client, can take approximately the same. Thus, for each defined stage resulted its respective cycle time (Tc) in seconds, Table 6.

Table 6 - Cycle time (on critical stages)

Stage	Family 1 (Tc)
2 – Introduce Wipes Stack	2.9s
9 – Pack the Cartons	2.3s

In each stage, the theoretical number of available hours is obtained according to the number of operators and their shifts (2 shifts-system).

With the average cycle time on each stage, the analysis is performed in order to know the number of necessary working hours (NH) for the current production, Formula 13.

$$NH = T_c \times DANP$$

Formula 13 - Working hours (NH)

DANP: Daily **A**verage **N**umber of **P**acks
Tc: Cycle **T**ime (in hours)

While calculating the ORs, rejected products are considered. It is also necessary to spend working time even though the product does not reach the final consumer. According to the recorded production data, Line 2 has shown an average loss of 0.88% on rejections from metal detector, 4.48% in the weight checker and 2.64% in the packing of cartons.

For other production stages, the rejection rate is practically negligible although values in the diving machine and packing machine can assume some relevance when the machines are not properly running due to bad setups, the need of maintenance or even defects on raw material.

Figure 36, illustrates the required units to produce the daily 16000 packages.

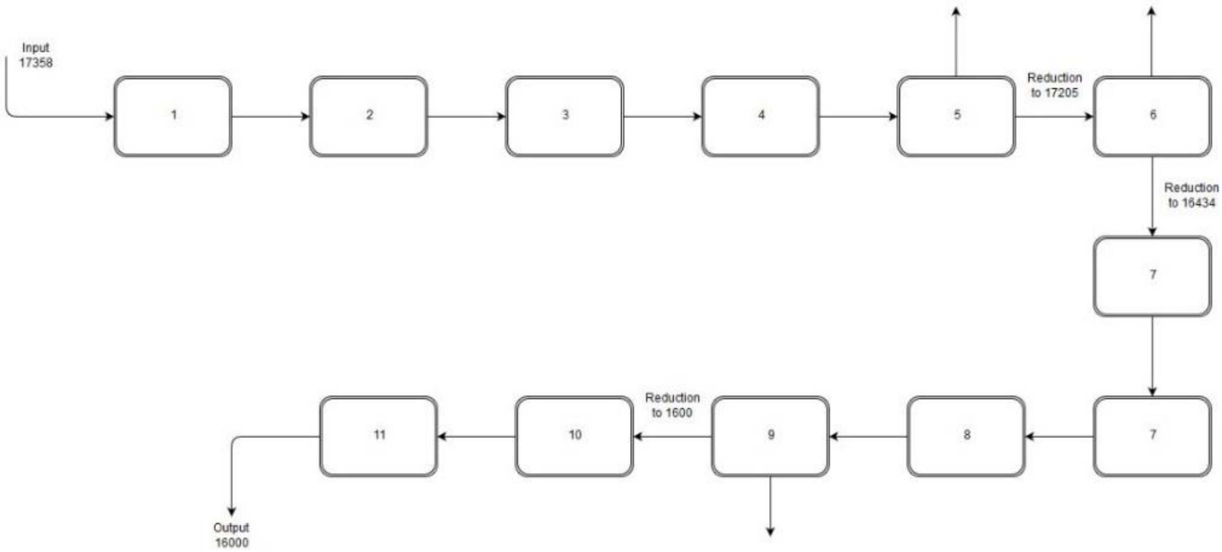


Figure 36 - Production Line 2 (average losses on the different stages)

In this way, it is possible to calculate the OR values and find out which stage is working close to its limit to produce the total amount of daily packages, Table 7.

Table 7 - OR values in critical stages

Stage	Family	NWP	AWH	NH	%OR
2 – Introduce Wipes Stack	1	1	16	13,98	87.39
9 – Pack the Cartons	1	1	16	10,5	65.62

NWP: **N**umber **W**orking **P**laces

AWH: Available **W**orking **H**ours (2 shift-system)

NH: Number of **H**ours

OR: Occupancy **R**ate

Analysing the obtained OR values both stages are operating near limit to accomplish the daily quantity. However, the highest value is found in stage 2 where the operator's performance is directly related to the production rate.

As verified on the workplace in stage 2, the operator needs to withdraw and hold carefully each wipe stack pile while keeping its integrity until landing on the table. That requires a lot of effort. Only then the operator introduces individually each stack. Moreover, when a plastic box is empty it is obligatory to move it to the side and repeat all the procedures again. Whereas at stage 9 the operator grabs each finished package and puts them into boxes while using some freedom to visualize the quality of the packages. However, this freedom can be decreased when the cartons are not already prepared to be filled up.

In conclusion, Line 2 is running near the limit and has no capacity to react to new or higher orders. Perhaps some improvements can be done in order to improve the rate on stage 2. However, to intend an increase of the production on Line 2, it is necessary to check if there is some kind of waste that can be avoided or even eliminated: in particular waiting time and changeover time.

3.4.2 Studying the Production Line

To elaborate this analysis instant observations were done to record the different phases on production, allowing to reach the percentage time values and quantify possible losses. The study was performed in different productions in order to present values as accurate as possible.

During effective production time the study was performed in 5-minute time intervals. However, during setup times shorter intervals of 1-minute were used to obtain an accurate time for each procedure.

In the analysis of the process there are four basic states to describe the production status:

Production Time**:** percentage of time the machine is producing.

Waiting Time**:** percentage of time where the machines are not running even though they are ready for it (non-added value).

Feeding Time: percentage of time where the machines are waiting for the material (non-added value).

Setup Time: percentage of time where machines are not running but are being prepared for the next production (changeover).

Compiling all the recorded data it was possible to resume the current values that describe the current state of the production on Line 2, Figure 37.

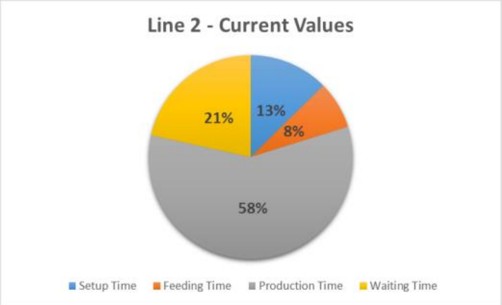


Figure 37 - Production Line 2 current state (time study)

According to the following graphic, only 58% of the time the line is producing and adding value to customers and company. The remaining slices are just non-adding value for the production:

21% of waiting time: is mainly related to employees' fatigue caused by the repetitive work on the diving machine while performing their job, punctual interventions like small adjustments on machines and no available material in the line (only due to dry wipe stacks): Figure 38 shows the occurrence percentage of each of them. Besides a lack of material, it is visible that punctual interventions have a great impact as well. That happens when all line machinery is ready to run but small adjustments are necessary such as adjusting the packages lid position, problems with wipe stack weight or even when a pile of wipes got stuck and the area must be cleaned as well, etc.

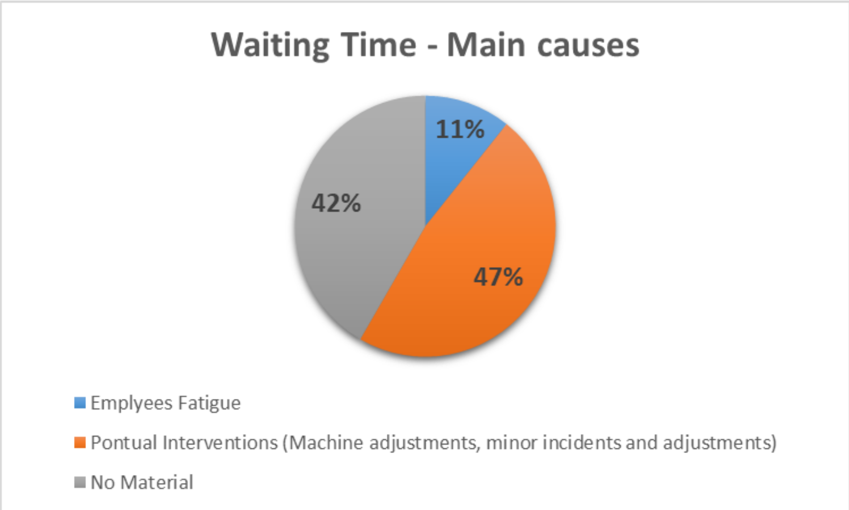


Figure 38 - Waiting time (main causes)

13% of Setup Time represents the product changeover time where it is required to wash the diving machine and set the machinery to the new material and technical specifications.

8% of Feeding Time is associated to the operator to whom relies the responsibility to supply the line with pallets containing plastic boxes with dry wipe stacks.

In the course of this time study, it was possible to verify that during changeover times most of the time no major adjustments in the machines were necessary. Only minor adjustments or material batch changes were required, mainly spending time on protocols and quality approval to start the new production.

3.4.3 VSM - Current State

To develop this study and describe the current production line state, a VSM was drawn aiming to have a better global visual representation of the material and information flow, Figure 39.

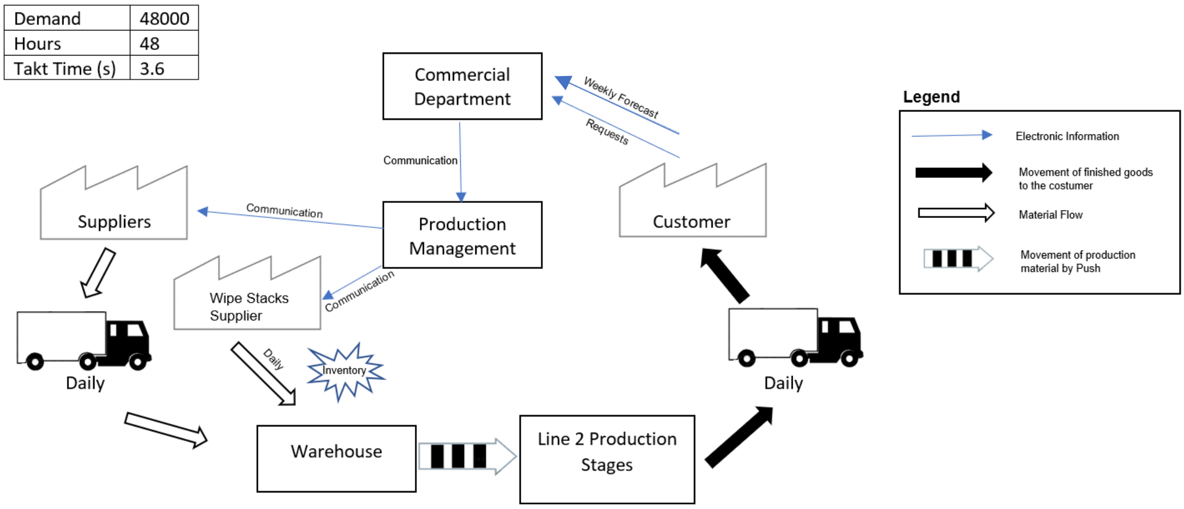


Figure 39 – Value Stream Map (current state schema, Part 1)

The map shows the material and information flow using a specific symbology to describe how the company is working and how the different production sectors communicate among each other. With this method, possible issues can be shown and targeted for an eventual improvement.

By using this tool, two relevant factors can be calculated: **Value Added Time** and **Lead Time.** Value-added time represents the operating time in which value is being added to the product. Lead time is the total required production time since the raw-material arrives to the company until the moment that is shipped to the client. In a perfect system, lead time would be the same as the value-added time.

The commercial department is responsible for the communication between the company and costumers. It is where future goods forecasts are predicted and customers' requests are replied to. As soon as everything is strategically decided the information is given to the production management that has the responsibility to spread and organize the production.

Raw materials are daily received in the warehouse, as well as daily pallets with finished products are sent to the respective customers.

Line 2 Production Stages – VSM

As represented in Figure 39, the material after warehouse goes to the respective production line and through various stages (Figure 40). Finally, the product is finished and ready to send to customers.

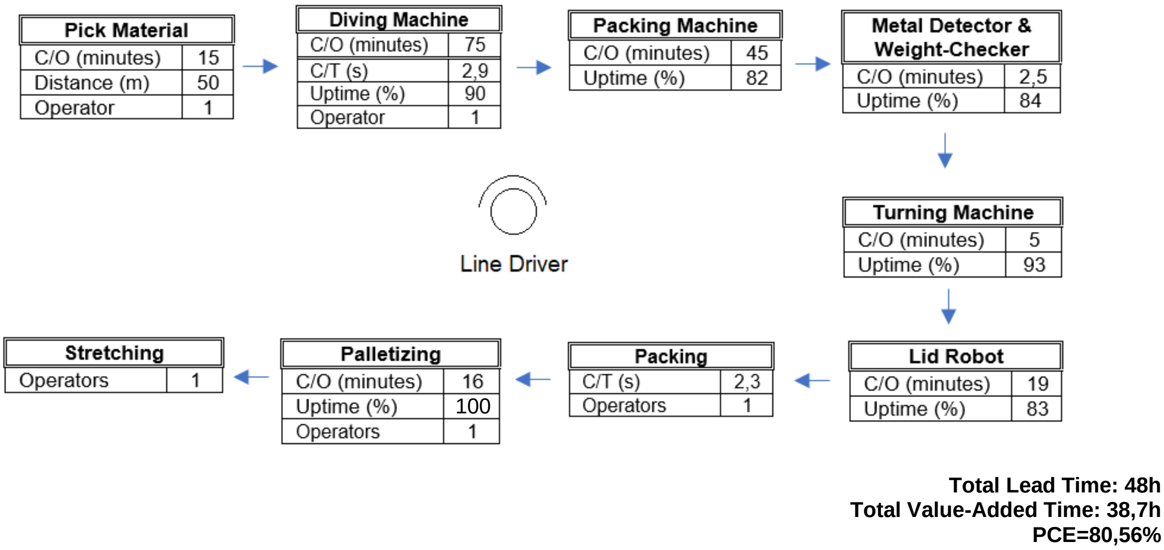


Figure 40 - Value Stream Map (current state, Part 2: Line 2 stages)

In this map the different stages on Line 2 (defined in chapter 3.3.3) are shown. Information like changeover time (C/O), operators' number, uptime and cycle time in critical stages (C/T) are also represented.

It is important to notice that operators are just required on some of the production stages. However, the line driver is responsible for the production flow, intervening in the production process when necessary (for example machinery adjustment).

Analysing the VSM

Lead time is an important factor related to production costs and global profits that shows if a company is competitive or not.

As shown in the VSM (Figure 40), the calculated lead time value is almost the same as the value-added-time. Assuming the material is already waiting in the warehouse, the lead time is only affected by the production run efficiency. That eventually explains the relatively high value of process cycle efficiency (PCE) which represents the ratio between value-added time and lead time.

This kind of production might have some issues. Once the raw material is not available the production is directly affected: material waiting time and delayed changeovers, leading to indecision in all the production planning process. In this way, it is extremely important to have a precise production plan so that in case of a faster production than expected, it does not involve stopping times associated to non-available material.

The communication between production management and commercial department is established in a single way leading to situations where materials are still on the way and the production still follows the production plan. That might be explained due to eventual delays or changes on commercial department, production management and warehouse.

Figure 40 also shows that one operator (line driver) is responsible for handling all of the production stages. Therefore, it is important to understand if eventual improvements can be performed:

1) Assuring that no lack of raw material happens especially at the wipe stack supplier (Figure 39) where no inventory or stock exists to avoid waiting times (Figure 37). There, the production only takes place a couple of days before according Line 2 needs.

2) Finding possible improvements for the reasons of non-productive time like stop-time which leads to lower value-added time (Figure 40) and therefore lower OEE values (Figure 16).

3) Checking the whole changeover process to know if it is possible to reduce its duration by avoiding unnecessary tasks and standardizing them to assure a constant process flow. Thus, reaching higher OEE factor availability by decreasing changeover times and therefore shorter lead time.

4) Checking the line and finding possible improvements that avoid bottlenecks on the different production stages, namely where the OR is near the limit (Table 7) and feeding-time when the worker has no capacity to feed the production Line 2 continually (Figure 37).

3.5 Diagnosis and Solutions

Based on the previous performed analysis, weaknesses were detected on the production Line 2. In this chapter, those issues are explored and its root-causes are diagnosed, presenting possible solutions by following specific methodologies, which aim improvements on the production system as well as reducing waste in a sustainable way.

3.5.1 The 5 Whys

While studying the times (Figure 37) it was observed that frequently too much time was spent on unnecessary motion, namely searching for information once workers regularly had to leave their workplace.

The root cause was not clear and to dig into it an analysis through the 5 Whys method was performed, where by questioning “why” the cause and a solution might be found.

Problem: The changeover took too long due to motion time.

Question 1: Why did the changeover require so much motion time?

Answer: The changeover depends on a single person, the line driver, who needs to be informed about tasks done by someone else.

Question 2: Why did it take so long to get the information?

Answer: The line driver while doing the changeover needed to walk too far to get information.

Question 3: Why did the line driver had to walk?

Answer: There was no quick and effective communication between the actors.

Question 4: Why is the communication slow and non-effective?

Answer: Performed tasks are not signalized.

Question 5: Why are tasks not signalized?

Answer: Actors are not in the same zone and therefore, not able to communicate.

Root Cause: No quick and effective communication between actors who aren’t in the same zone.

Possible Solution: Mobile phones and/or tablets.

Corrective Action: Integrate all the required gadgets on a communication platform.

Embed the Solution: Document the whole process requisites as well as identify all the actors responsible to perform the changeover which could be managed and controlled by a software system.

3.5.2 SMED – Single Minute Exchange of Die

According to the different used methods, it was possible to find the time percentage spent on changeovers in Line 2. In the 4-weeks study to OEE values (Figure 16), there were no stop-times regarding to trouble stops i.e., maintenance and big repairs. That led to stoppages only due to changeovers. During this study, several changeovers happened leading to an average value of 77% availability (Figure 16). In other words, in each 8-hour shift 2 hours are spent on changeovers. This value is lower than the value reached on VSM (37%) Figure 41, which means almost 3 hours of changeover. However, in VSM the time-period was much shorter.

Besides, through direct observations and experience on the field it was observed that changeover processes were mostly performed without standards, which indicated a potential focus for improvement.

For that, the SMED methodology was considered which aims fast and efficient tool change, optimizing operator steps for changeover, as well as all the operations included in the process. In this case, it is not a single tool but the complete line setup for a product change.

Initially, the necessary procedures were written down and its respective spent time recorded. After this first step, all operations procedures were classified as 'Internal operations' where machines cannot run and 'External operations' where machines can run.

The goal was to change possible internal operations into external operations and reorganize them in order to reduce the required changeover time, to give more flexibility, higher capacity and versatility on the production line.

3.5.2.1 Applying SMED on Production Line 2

Daily changeovers are quite usual on production Line 2. The required time between the end and the beginning of a new production is one of the biggest reasons that contribute for the lack of flexibility to answer the costumer's demands.

When analysed in a superficial way, during changeover process some clues were found that led to use of the SMED tool. Consequently, understanding all the changeover was important to search for some possible optimizations. The precise information for a product change always belongs to the shift leader. However, there are too many variables which can delay or anticipate a product change: running out of material, lotion, new urgent orders, etc.

It was expected that the required changeover time was mostly caused by useless motions of the operator: getting the necessary information, asking for the availability of material and finding enough conditions to start operations. Therefore, the study was performed for the most complex way of performing one changeover. Figure 41, represents all the operations steps related to the changeover performed by only a single responsible operator, the line driver.

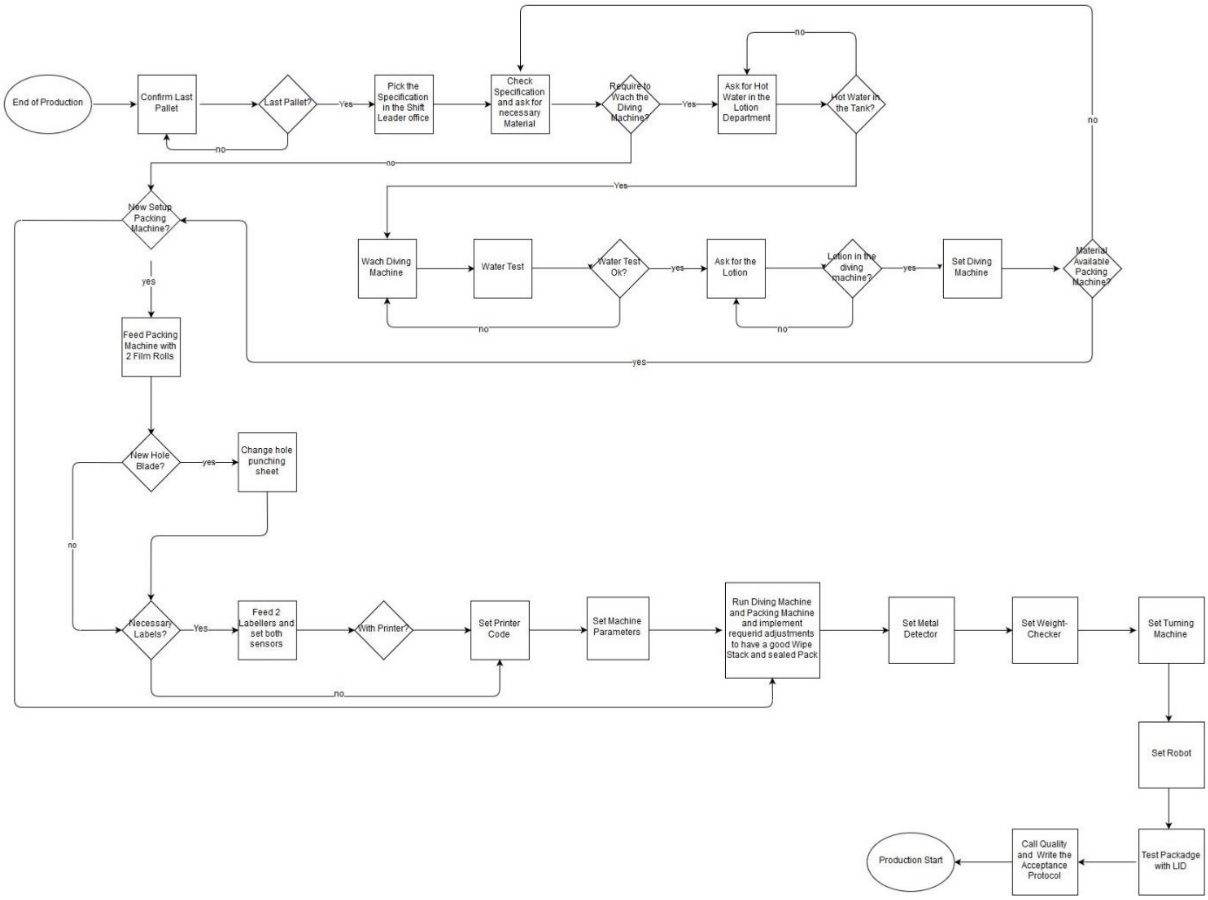


Figure 41 - Changeover procedures scheme (Line 2)

As known, changeovers are not avoidable. Thereby, they should have reduced times to allow a wide spectrum of products without the loss of productive capacity and large production breakdowns.

In this study, all operations were performed internally. That means the changeover is done with all machines stopped where each step had its measured time, Table 8.

Table 8 – Changeover steps and measured time (SMED)

Tasks	Measured Time
PRODUCTION END	
Confirm the End of Production	00:03:35
Pick new Product Specification & Write Protocol	00:15:25
Check Specification and ask for the new Material	00:02:50
Ask for Hot Water	00:08:35
Wash the Diving Machine	00:40:15
Water Test	00:05:45
Ask for Lotion	00:07:42
Set Diving Machine	00:11:30
Feed Packing Machine with Film (2 Rolls)	00:08:00
Change the Hole Punching Sheet	00:08:51
Feed Labellers & Set Sensors	00:16:10
Set Printer Code	00:12:07
Set Packing Machine Parameters	00:11:56
Fine tuning Diving Machine&Packing Machine	00:08:40
Metal Detector	00:07:28
Weight-Checker	00:04:03
Turning Machine	00:02:41
Set Robot	00:20:00
Set Carton Printer & Tape Machine	00:08:00
Call Quality and Write the Quality Protocol	00:14:00
PRODUCTION START after	03:37:33

TOTAL EXTERNAL	01:05:52
TOTAL INTERNAL	02:31:41
	03:37:33

<u>Phase 1:</u> Split operations between internal and external. This procedure does not involve costs and aims a better organization of the process

At this stage of the SMED method application, operations are classified in internal and external ones. Consequently, it is easier to visualize in which operations the machine requires to be stopped indeed.

The following Table 9, shows the external operations and its associated times while performing changeover.

Table 9 - External operations (SMED)

Tasks	Measured Time	Operation
PRODUTION END		
Confirm the end of production	00:03:35	External
Pick new Product Specification & Write Protocol	00:15:25	External
Check Specification and ask for the new Material	00:02:50	External
Ask for Hot Water	00:08:35	External
Water Test	00:05:45	External
Ask for Lotion	00:07:42	External
Set Cartoon Printer & Tape Machine	00:08:00	External
Call Quality and Write the Quality Protocol	00:14:00	External
PRODUCTION START after	**01:05:52**	
% Total Time	**30.28%**	

Considering the calculated results, approximately 30% of the time is spent on external operation, within the expected limit (Cakmakci, 2009).

This spent time is directly linked to a bad process organization, mainly spent on motion. Consequently, decreasing or even the elimination of these times is directly connected to a reduction of 30% of the time where the production line is stopped.

On the other side, the following Table 10 shows the internal operations and its associated times while performing changeover.

Table 10 - Internal operations (SMED)

Tasks	Measured Time	Operation
PRODUTION END		
Wash the Diving Machine	00:40:15	Internal
Set Diving Machine	00:11:30	Internal
Feed Packing Machine with Film	00:08:00	Internal
Change the Hole Punching Sheet	00:08:51	Internal
Feed Labellers & Set Sensors	00:16:10	Internal
Set Printer Code	00:12:07	Internal
Set Packing Machine Parameters	00:11:56	Internal
Fine Tuning (Diving Machine&Packing Machine)	00:08:40	Internal
Metal Detector	00:07:28	Internal
Weight-Checker	00:04:03	Internal
Turning Machine	00:02:41	Internal
Set Robot	00:20:00	Internal
PRODUCTION START after	**02:31:41**	
% Total Time	**69.72%**	

The result shows that procedures where stopped machines are required only assume 70% of the current time spent.

Phase 2: Change Internal into External procedures

Feeding Packing Machine with Film

The packing machine has the capacity to use two packing film rolls, with an automatic change system integrated. This automatic system activates a pneumatic when the film is ended which presses and glues the new film roll. Furthermore, this new film roll needs to be prepared with two-sided tape and a plastic cover inserted, where a metal plug gives the sign that it is time to change.

Although considered an internal operation, the production line only operates with one roll at a time. Therefore, the next roll can be prepared only after the line is already running sparing time to other procedures on changeover, Figure 42.

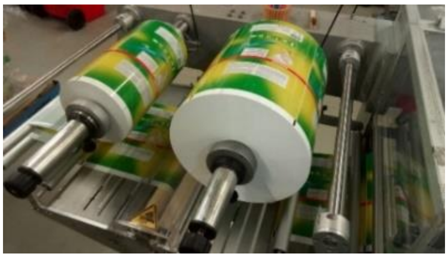


Figure 42 - Packing machine (packing film rolls)

It is important to note that the alignment due to label and printer position when the new roll is changed must be taken into consideration and verified during the process.

Adapting this new procedure, it is possible to reduce 50% of the time spent while performing changeovers, Table 11.

Table 11 - Feed packing machine (estimated time)

Tasks	Actual Time	Estimated Time	%Reduction
Feed Packing Machine with Film 2 Rolls	00:08:00	00:04:00	50.00%

Turning Machine

The purpose of this machine is to turn the packages downside-up for the lid application. However, it is normally adjusted to work like a simple transport conveyor when lids are not required because it is occasionally a source of bottlenecks when a package is not properly turned, Figure 43.

Figure 43 - Turning package machine

In order to avoid the time spent in adjusting this machine (Table 12) an optimization could be done and stabilize the process of turning packages for all the productions. In this machine, packages are only supported and transported by thick plastic cables. After analysing the turning process, the transportation method was the main bottleneck source: when changed the product, i.e., package dimensions, those cables were no longer supporting the packages on the right holding points. The suggested solution uses a simple conveyor belt instead.

Table 12 - Turning machine (estimated time)

Tasks	Actual Time	Estimated Time	%Reduction
Turning Machine	00:02:41	00:00:00	100.00%

Metal Detector

At this stage, the time is spent on preparing four sample packages with metal elements individually identified with coloured labels, Figure 44. These four samples are used as rejection models to check the correct working of the metal detector.

Most of the time, older samples from a previous production are not stored which delays the process. When it happens, the diving machine and packing machine need to be already installed and run properly in order to produce some packages to use as samples.

Figure 44 - Metal detector

The possible solution for improving this process is to always keep four samples from the previous production and record the last set parameters. The quality worker would be then responsible to prepare those packages with coloured labels, bring them to the basket on top of the metal detector, test the metal detector and, if necessary, set the last recorded parameters. Fine set would be performed while running. Therefore, a complete reduction is expected, Table 13.

Table 13 - Metal detector (estimated time)

Tasks	Actual Time	Estimated Time	%Reduction
Metal Detector	00:07:28	00:00:00	100.00%

<u>Phase 3</u>: Definition of new operating procedures to reduce internal and external times

At this phase, the possibility of reducing times is studied. According to the collected information, it is possible to propose several suggestions that lead to shorter changeover times.

<u>Communication between actors</u>

- Avoiding unnecessary line driver motion

Most of the registered external time is spent on operators' motion, namely to confirm the end of production, pick new specification and ask for material and lotion. Those are tasks that consume time and should be eliminated. Therefore, once the production is over, the communication between operators: line driver and shift leader, should be quickly done and preferentially without any need of motion. Consequently, after finished productions, the line driver would spend time only writing the protocol, checking new specification and setting machinery. All the remaining tasks would be performed without compromising the line driver job, only focused on procedures where the machines effectively need to be stopped.

By improving the communication between actors (solutions are suggested in the following chapter) an estimated reduction is resumed in Table 14.

Table 14 - Estimated reduction (motion)

Tasks	Actual Time	Estimated Time	%Reduction
Confirm the end of production	00:03:35	00:00:30	86.05%
Pick new Product Specification & Write Protocol	00:15:25	00:00:00	100.00%
Check Specification and ask for the new Material	00:02:50	00:00:55	67.65%
Ask for Hot Water	00:08:35	00:00:00	100.00%

- Approval of diving machine cleanliness

In every changeover on the diving machine, old lotion must be removed where hot water takes place to wash it. Later, to assure the cleanliness of the diving machine a water test is necessary. For that, the line driver goes to the quality office, picks a plastic bottle, walks again near the diving machine and fills it up with water from the inside of the diving machine tank. Once the plastic bottle is filled up, the line driver walks again to quality and both perform the test and wait for its results.

As soon as the test is within the expected values, the line driver is allowed to ask for lotion. Otherwise, the diving machine must be washed performing all those steps all over again.

By implementing a sort of flagging system (detailed explanation in chapter 3.5.2.3), the line driver could sign to the person who is responsible for quality and who is now in charge to go to the diving machine and perform the water test, releasing the line driver to be available for other changeover procedures, Table 15.

Table 15 - Estimated time for approval of diving machine cleanliness

Tasks	Actual Time	Estimated Time	%Reduction
Water Test	00:05:45	00:00:00	100.00%
Ask for Lotion	00:07:42	00:00:00	100.00%

- Quality protocol approval

When the changeover is finished, the line driver walks to the quality worker, asks for the protocol checklist and starts filling it in. Once done, again the line driver goes to the quality worker and asks for their final check approval.

Currently the protocol checklist is filled in firstly by the line driver and only after call, checked and approved by the quality worker. That kind of communication delays the process.

Therefore, it is suggested to flag all those process steps, where the line driver while performing the setup could fill in the checklist and when done, send a sign to the quality worker to perform the final approval. In this way, it is expected to reduce the spent time by around 30%, Table 16.

Table 16 – Estimated time to quality protocol approval

Tasks	Actual Time	Estimated Time	%Reduction
Call Quality and Write the Quality Protocol	00:14:00	00:04:12	70.00%

Forklift Operator – Machine Training

The carton printer and carton machine setting are currently performed by the line driver. While setting the printer, the new model must be loaded and its position must be checked. The position is adjusted by moving the printer head up-down and setting the delay time parameter for the longitudinal position in the carton.

Regarding the carton machine, it is necessary to adjust the width and height of the machine entrance to a new carton size.

In this new perspective, after a finished production the forklift operator besides being responsible for removing the old material, cleaning the working place and bringing the new material, is also in charge to set these two machines. Through a short training it is expected to reduce this time by 100%, Table 17.

Table 17 - Estimated time to set carton printer

Tasks	Actual Time	Estimated Time	%Reduction
Set carton printer & Tape machine	00:08:00	00:00:00	100.00%

Tiding changeover place (5S methodology)

- Changing the hole punching sheet

Punching sheets are used to perforate the packaging film enabling the withdrawal of wipes inside the packages. Its changes present different duration times mainly caused by punching sheets already worn or overstoring in the same place, making it difficult to identify between good and bad ones, Figure 45. In the worst-case scenario, the line driver went to the workshop to pick and write down the new acquired punching sheet, spending way more time.

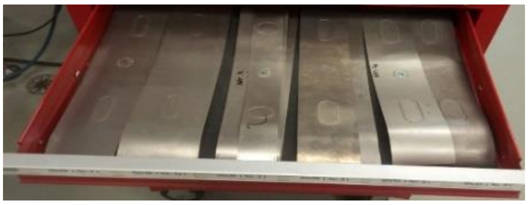


Figure 45 - Hole punching sheet (old toolbox)

Therefore, to avoid this problem it is important to have a small tool cabinet to store only necessary tools. This tool cabinet would require periodically inspection and only allows two punching sheets samples: used and new. In case of a wasted one, this punching would be simply thrown away and replaced with a new one.

After this work analyses the required tools were listed and approved in order to reduce the time spent on searching for tools and keeping the workplace clean, organized and standardized, Figure 47.

Figure 46 - Line driver required tools

Those tools can get organized in shadowboards on each drawer of the toolbox (Figure 47), making it easy and quick to find, Table 18.

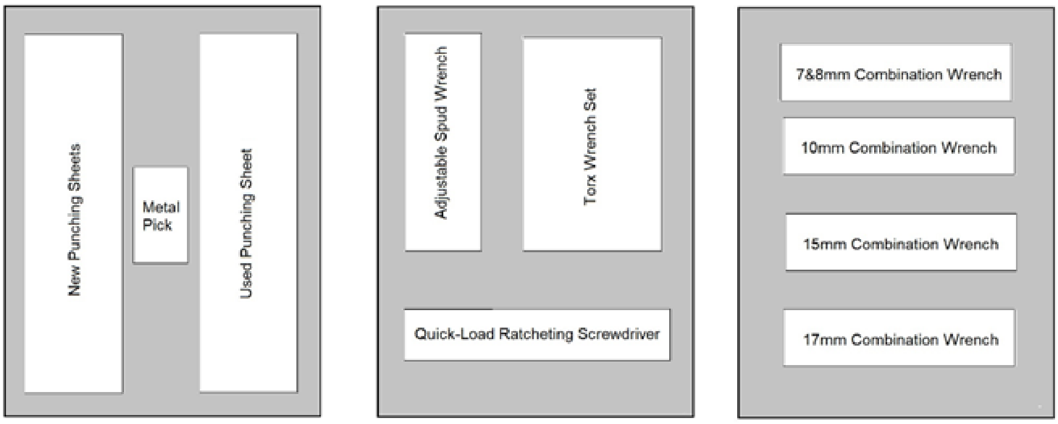


Figure 47 - Toolbox drawer

Table 18 – Estimated time to change the hole punching sheet

Tasks	Actual Time	Estimated Time	%Reduction
Change the hole punching sheet	00:08:51	00:02:15	74.58%

Through this measurement, 5S philosophy is promoted contributing to a structured, organized and standardized environment, Figure 48.

Figure 48 - Production line toolbox (new toolbox)

Code printer (pre-preparation)

During the packing machine setup, a new printer code must be set according to the new product specification. In addition to the production day, the printer code usually has the lotion number and other information agreed on with costumers. Unfortunately, those information are written in a generic way on the product specification and each time the printer code is changed, the line driver normally asks and has to wait for it in the quality office.

In case of a completely new code layout, the line driver walks to a computer placed on the other side of the room where the new printer layout is created and loaded to the respective production line.

In this new approach, the quality office is responsible to previously check, create and approve the printer layout. Then, save it in the data-base and load it in the respective line. Furthermore, between quality office and the operator in the 'Lotion&Water station' the lotion number must be found and written in the delivered product specification. In this way, the line driver only starts the new printer code and introduces the given lotion number, reducing the time for approximately 90%, Table 19.

Table 19 - Estimated time to set printer code

Tasks	Actual Time	Estimated Time	%Reduction
Set Printer Code	00:12:07	00:01:15	89.68%

Shorter specifications made for line drivers

The amount of information written in the product specification was too much and unnecessary for the line driver. For some products, technical specifications were available but almost never attached to the product specification provided by the shift leader. On both specifications, detailed information was available making it difficult to read and analyse, Figure 49.

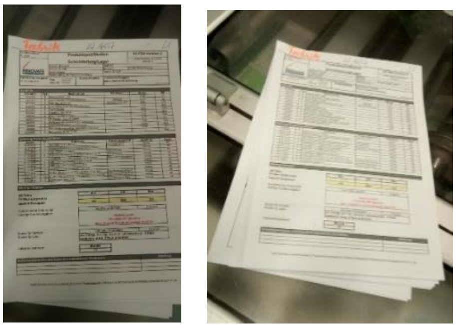


Figure 49 - Product specification

In order to simplify the process, it was proposed to write down new specifications specifically for setting machinery, where only essential technical information is found. This new specification layout would be the subject of continuous improvement and led by the technical leader and discussed with the line drivers, Figure 50.

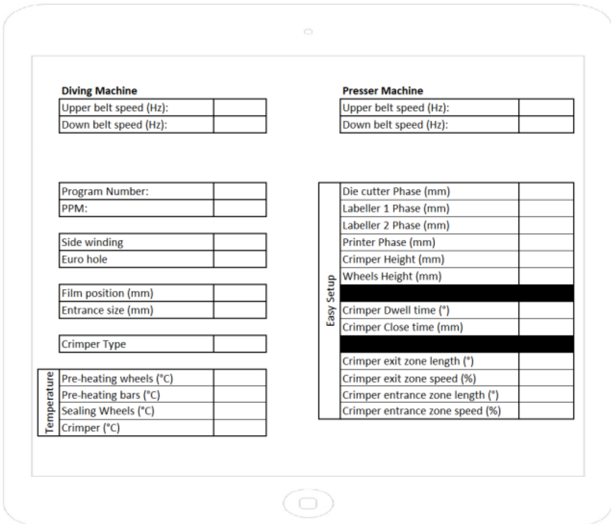


Figure 50 - New product specification

This specification could be visually automatically provided (detailed explanation in chapter 3.5.2.3) after finishing the production, allowing a quick product overview. Significant improvements on the machine setup are expected with special focus on fine tuning where the settings are close to optimal, Table 20.

Table 20 - Estimated time to setup the machines

Tasks	Actual Time	Estimated Time	%Reduction
Set diving machine	00:11:30	00:08:30	26.09%
Set packing machine parameters	00:11:56	00:09:12	22.91%
Fine tuning in diving machine & Packing machine	00:08:40	00:03:40	57.69%

3.5.2.2 Expected Improvement - SMED method

After applying the SMED methodology, new times are reached contributing for a notable operational improvement compared to the current one. Regarding to the external operations a reduction of 87% is estimated, Table 21.

Table 21 - Expected Improvement on external operations (SMED)

Tasks	Measured Time (Current)	Estimated Time	% Total Time Reduction	Operation
Confirm the End of Production	00:03:35	00:00:30	86.05%	External
Pick new Product Specification & Write Protocol	00:15:25	00:00:00	100.00%	External
Check Specification and Ask for the new Material	00:02:50	00:00:55	67.65%	External
Ask for Hot Water	00:08:35	00:00:00	100.00%	External
Water Test	00:05:45	00:00:00	100.00%	External
Ask for Lotion	00:07:42	00:00:00	100.00%	External
Feed Packing Machine with Film 1 Roll	00:08:00	00:04:00	50.00%	External
Set Cartoon Printer & Tape Machine	00:08:00	00:00:00	100.00%	External
Call Quality and Write the Quality Protocol	00:14:00	00:04:12	70.00%	External
EXTERNAL OPERATIONS	**01:13:52**	**00:09:37**	**86.98%**	

Concerning internal operations, the following Table 22 shows a reduction of 27%.

Table 22 - Expected Improvements on internal operations (SMED)

Tasks	Measured Time (Current)	Estimated Time	% Total Time Reduction	Operation
Wash the Diving Machine	00:40:15	00:40:15	0.00%	Internal
Set Diving Machine	00:11:30	00:08:30	26.09%	Internal
Change the hole punching sheet	00:08:51	00:02:15	74.58%	Internal
Feed Labellers & Set Sensors	00:16:10	00:16:10	0.00%	Internal
Set Printer Code	00:12:07	00:01:15	89.68%	Internal
Set Packing Machine Parameters	00:11:56	00:09:12	22.91%	Internal
Fine tuning Diving Machine & Packing Machine	00:08:40	00:03:40	57.69%	Internal
Metal Detector	00:07:28	00:00:00	100.00%	Internal
Weight-Checker	00:04:03	00:04:03	0.00%	Internal

Turning Machine	00:02:41	00:00:00	100.00%	Internal
Set Robot	00:20:00	00:20:00	0.00%	Internal
INTERNAL OPERATIONS	**02:23:41**	**01:45:20**	**26.69%**	

Once the analysis is done for the worst case possible which often happens weekly, a reduction of 47% on changeover times is expected, Table 23.

Table 23 - Estimated Reduction (after SMED)

Tasks	Total Measured Time	Expected Time	% Total Time Reduction
Complete Changeover	03:37:33	01:54:57	47.16%

External activities are almost all associated with communication and organization problems mostly spent on motion. Therefore, after a meeting with the involved team, three hours was defined as a goal for the next months.

3.5.2.3 New Process Dynamic implemented by a Control/Overview platform

Through field experience and while performing a more detailed analysis through SMED method, it was detected that too much time got wasted on actions such as requesting or searching for information, which led to longer changeover times and a surplus work compensated through unnecessary workers movements.

Thus, in order to understand the root cause of the problem, 5 Whys methodology was used diagnosing inefficient communication between actors even though they are almost in the same zone.

A possible solution for this problem, the use of a shopfloor communication platform was proposed to prevent operators to leave their workplace and if possible, where information can be easily and quickly achieved. Preferably able to be visualised.

In this way, the idea of developing a visual-control and overview-system has emerged with the purpose of creating a fluid process during changeovers to avoid unnecessary movements performed by the line driver.

During the production, the line live-status is available on two big screens connected in a data-bank (master): one screen is placed in the packing area and another one in the production area. In this master, five tablets are connected via Wi-Fi and can interact among each other. These five tablets are distributed between the operators who are responsible for the changeover process, Figure 51.

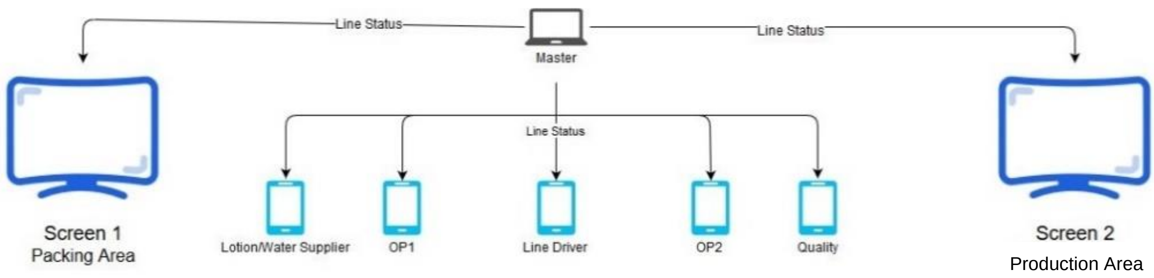


Figure 51 - Shopfloor communication platform

Some scenarios may occur that they may lead to the end of production: running out of material, out of lotion or the customer demand is coming to an end. All of this information is updated from the involved staff and approved/resumed by the shift leader, in coordination with production management and commercial department. Disturbances during production time might occur and through this communication platform, all the connected users can interact and see what is currently happening in the line. On the other hand, that would guarantee a smooth line operation and a fast communication between the different sectors.

Briefly explained, the communication platform for Line 2 would consist of the interaction between six users: shift leader (master), quality person, lotion/water supplier, operator 1 (forklift operator), line driver and operator 2 (responsible for supplying material to Line 2), Figure 52.

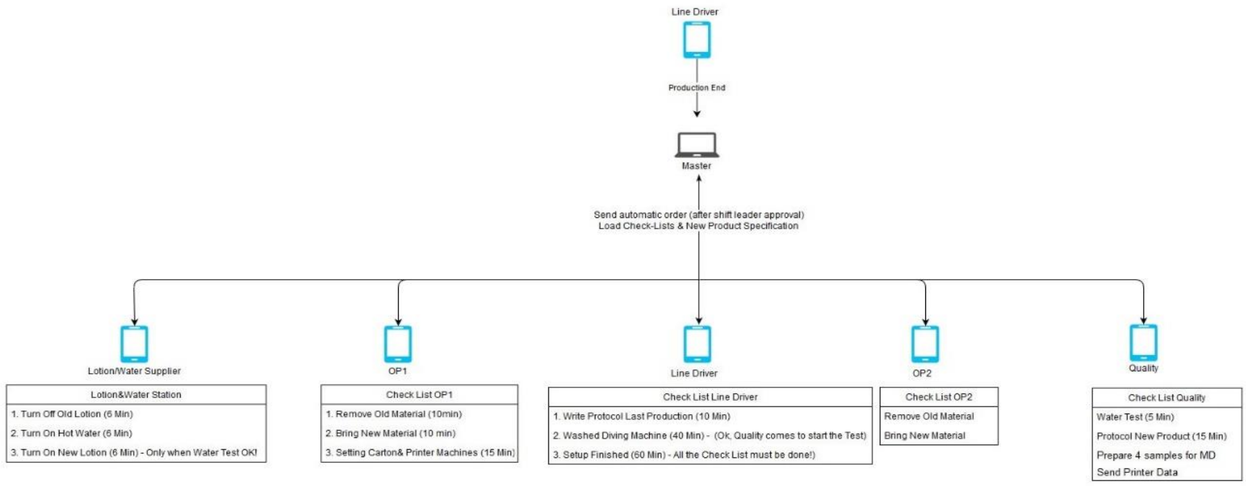


Figure 52 - Shopfloor communication platform (tasks scheme)

Assuming the production is finished, the line driver sends a sign marking the production end. After being recognized by the shift leader, the changeover process begins automatically loading the tasks belonging to each one as well as its completion expected time: this information is individually available at the tablets and generically on both screens. The changeover clock starts running and if the time is exceeded, a notification is sent and the concerned worker might justify the reason. Note that these times are adjustable and may be subject to modifications. Nevertheless, the goal is to get the most accurate time and realize some problems that may exist, Figure 53.

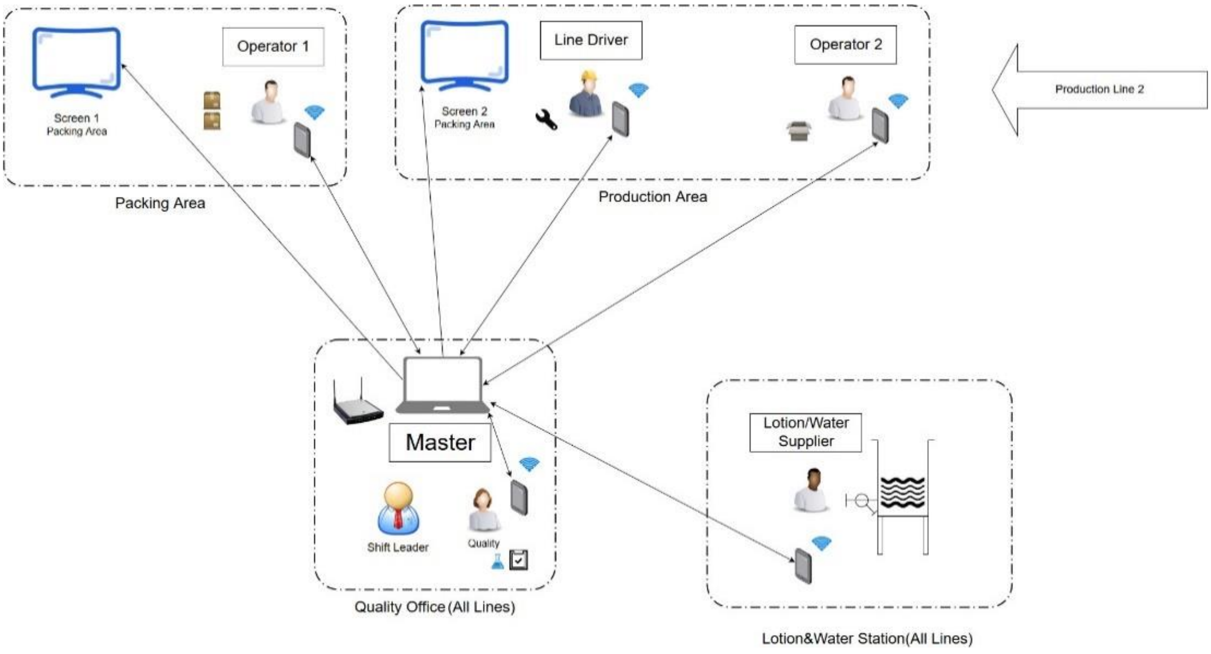


Figure 53 - Shopfloor communication platform (users' interactivity)

Line driver - this operator is responsible for defining the conclusion point of the production. When finished, the main task is to write the previous production report and start the changeover as soon as possible. Therefore, hot water in the line is required to start washing the diving machine and material to set the packing machine: tasks depending on operator 2, quality and lotion/water supplier.

Operator 1 (forklift operator) – during production, this operator is responsible to pick the cartons and palletize them. By finishing a customer demand, this operator is responsible for keeping the line driver informed about how many packages are left to finish the production or if some material is soon running out of stock like cartons, lids and labels. As soon as the production is finished, the line driver signs the production end and when approved by the shift-leader, a list of tasks and its respective times are loaded. Thus, marking the changeover beginning. Operator 1 has to remove the material no longer needed, cleans the work area and brings new material. Later on, he sets the printer and carton machine[1].

Operator 2 – while the line is running, this operator is in charge to feed the line with material: bringing the pallets with dry wipe stacks, packing films and labels. In case of running out of stock, this operator has the responsibility to communicate to the shift leader that no more material is available. Once the production is finished and the changeover starts, this operator removes the materials from the previous production and he brings the new ones.

Lotion/Water Supplier - has the responsibility to feed the line with lotion or water. As operator 2 and 1, this operator also has the responsibility to send information if the lotion is finished. Hence the production is ended, it is necessary to disconnect the lotion tank and connect the line with hot water, enabling the washing process on the diving machine. When no more hot water is required, two conditions will be necessary to connect the lotion tank with Line 2: once the diving machine has been washed, the line driver sends a sign to the quality worker allowing the water test; in case the test is acceptable, a notification is sent to the lotion/water supplier to open the lotion. Consequently, the line driver will wait for the available lotion notification to finish the setup on the diving machine and during this time he is able to set other machines on the production line.

Done all the necessary settings, the line driver sends finally a sign marking that the setup is ready to be checked by the quality office. However, it is only possible in case all the other operators' tasks are finished. If not, the line driver can check what is missing and understand why it is not possible to conclude the tasks.

Quality - during the production time the quality worker is responsible for withdrawing some samples and write down a checklist to verify the products quality. Once finished the production, the quality worker is in charge to check all the required printer data for the new product and send it to the line driver. Preferably, this operation should be done before changeover starts. After that, he brings four samples from the previous production, prepares and tests them on the metal detector. In case of malfunctions, previous parameters registered from prior production should be used to set the metal detector. If still not running, the line driver is then informed. Whenever the diving machine is washed and signed by the line driver, the quality worker picks a plastic bottle and tests the water. If not approved, the washing process must be signed and performed again.

[1] In order to improve readability, only the male form is used in the text, nevertheless all data apply to members of both genders.

Finally, when the line driver signs the finished changeover, the quality worker should go and approve the check list to start the production.

3.5.2.4 Cost Analysis - SMED Method

After applying the SMED methodology, some solutions were elaborated and described. To verify the feasibility of the proposed solutions, a cost analysis was performed. The following Table 24, shows the associated costs for the required tools, material and software implementation:

Table 24 - Cost analysis (SMED)

ITEM	Qty.	Estimated Price
Conveyor belt (turning machine)	2	92.99€
Torx Wrench Set	1	12.75€
Quick-Load Ratcheting Screwdriver	1	22.05€
Adjustable Spud Wrench	1	28.57€
Combination Wrench	1	14.45€
Metal Pick 10units pack	1	2.83€
Tool Box	1	44.75€
Samsung Galaxy Tab E	5	178.59€
TV Panasonic TX-55EX600E	2	679€
Software Integration	1	6500€
TOTAL:		**9062.33€**

The application of the proposed SMED solutions prefaces a value of 9062.33€.

According to the reality of the company and the expected benefits of implementing the proposed solution, the investment should have been returned guaranteed. The implementation of the proposed solutions should lead to quick and efficient product changes, as well as ensuring a better production flow. As calculated, 1h and 42 minutes less time in each changeover is expected.

Considering the estimated weekly average, at least two complete changeovers per week occur in Line 2. Assuming 20 cents of profit in each pack and an average speed of 28 packages per minute, it is possible to estimate the amount of time required to pay the investment, Table 25.

In accordance with the estimated weekly profit, 9062.33€ investment could be amortized in 8 weeks. Therefore, the gains are considerable and its implementation on the other remaining seven production lines can be considered.

Table 25 - Estimated payback amount

Average setups per week	2
Production time gained per changeover (after SMED)	01:42:00
Total gained hours (per week)**:**	**3.40**

Estimated profit per package	0.20 €
Average Line Speed (ppm)	28
Estimated Profit (per week):	**1142.40 €**

3.5.3 Kanban Method

Currently, the company is getting dry wipe stacks based on costumers' demand but only shortly before the production on Line 2 takes place. As already mentioned, the dry wipe stacks production is done in another facility of the company as represented on VSM (Figure 39). When Line 2 is running, most of the time dry wipe stacks are still being produced to comply the production. This approach has its limitations and goes beyond the J.I.T.. Thereby, it was marked on the VSM diagram as a point to take into account: once a problem occurs on the dry wipe stack supplier, the non-existence of safety stocks consequently slows down or stops the production on Line 2; in the worst case, even leads to a non-expected and premature product change, creating an unsustainable cycle in the production.

By performing the time study, according to the defined line states, 21% were related to waiting time, Figure 37. From this value, 42% was due to no available material in the line: dry wipe stacks. Figure 38. Additionally, through the 4 weeks OEE analysis and by evaluating the three factors that influence parameter performance: speed-loss, short stops and stop time; stop time reached 19% that is only due to a lack of material, Figure 16.

Furthermore, the stack wipes supplier works in three shifts because its production amount is slower than the performed-on Line 2 (two shifts). In this kind of situation, unexpected problems of the supplier have a direct impact on the production. Therefore, it is important to find a productive system that has enough safety stocks to keep the production on Line 2 safe of running out of material.

In this perspective, the idea to apply the Kanban method came up, which intends to promote a pulled production rather than pushed, achieving reduced stocks and in this study case, shorter lead time by avoiding a lack of material. Hence, this study intended to create safety stocks, reduce unnecessary stocks and improve the communication between the sectors.

3.5.3.1 Kanban Card

Figure 54 shows the current situation: a sample-sheet is attached to each produced pallet where it is possible to find the following information: material number of mother-roll (1), the finished wipe stacks product number (2), singular unfolded wipe dimension (3) and the amount of each wipe stack (4). Additionally, the quantity of wipe stacks per plastic box (5), plastic boxes amount (7) and its respective total (6). The pallet number (9) is written on a gluing sticky note in the sheet by the responsible operator, followed by his respective signature (10).

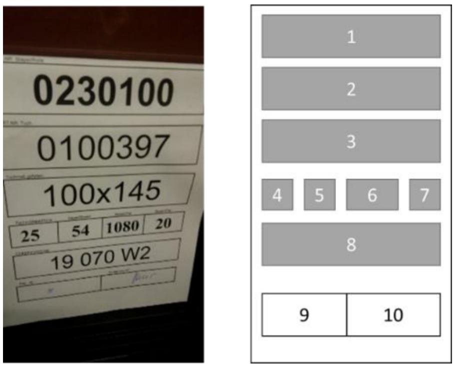


Figure 54 - Pallet identification

There are plastic boxes to store the produced dry wipe stacks. When filled up, the boxes are then piled in pallets and its amount identified, Figure 55. Everything is performed according to what the dry wipes stacks supplier could produce: either until the end of raw-material, machine problems or finished demand.

Figure 55 - Kanban Card (pallet place)

In this way a change of the philosophy of production is suggested with the purpose to create and keep safety stocks. Under these circumstances, it is important to build a system that leads to the production of safety stocks, keeps the stocks above a minimum level and controls the necessary stocks to produce, to avoid a lack of material, production stops and no precise control or overload of the amount of wipe stacks.

Therefore, it is suggested to use a detailed Kanban card (Figure 56) with the necessary information to produce a given lot of wipe stacks. In this case, each Kanban card represents a complete pallet.

	ARTICLE NUMBER	ITEM DESCRIPTION		
	XXXXX			
XXXXXX	RAW-MATERIAL LOT	NUMBER OF WIPES PER STACK	FOLDED WIPE SIZE	XXXXX
	LOT NUMBER	WIPE STACKS QUANTITY	KANBAN NO.	
	TOTAL NO. KANBAN´S			

Figure 56 - Kanban card to announce on each pallet

The first line belongs to the essential information about the article number and its respective description. Additionally, the second line would be used only for secondary information like the raw-material, number of wipes per stack and folded wipe dimensions. On the third line, there are data about the lot number, corresponding wipe stacks quantity and its respective Kanban number. At last, the total number of Kanban´s. It is important to note that only the lot number could be changed on the Kanban card, which is given by the raw material batch.

On this new approach, a pulled production system is implemented where only the customer can request the entry of a Kanban into the production system by starting the production of new goods, or new lots of products.

These cards also have the function to define the urgency of each request. For that, two types of Kanban are suggested: green and yellow. Whenever a yellow one has been set, it should get taken into consideration for the next demand. Thereby, the yellow is the point where the stock of the material is under the limit which needs to be compensated the next time or when the supplier has some production freedom.

The needed number of Kanban cards is given by Formula 6 and depends directly on the number of packages the customer demands as well as lead time and a safety factor. On average, Line 2 produces 16000 wipe stacks/day and the lead time to obtain the amount that the customer demands is three days (VSM map, Figure 39). The safety stock in percentage is 8% to compensate process average wastes, Figure 36. Each pallet contains 1080 wipe stacks,

Figure 55. Thus, the number of Kanban cards is 48. That means that in the circuit 48 Kanban cards have to be present, Figure 57.

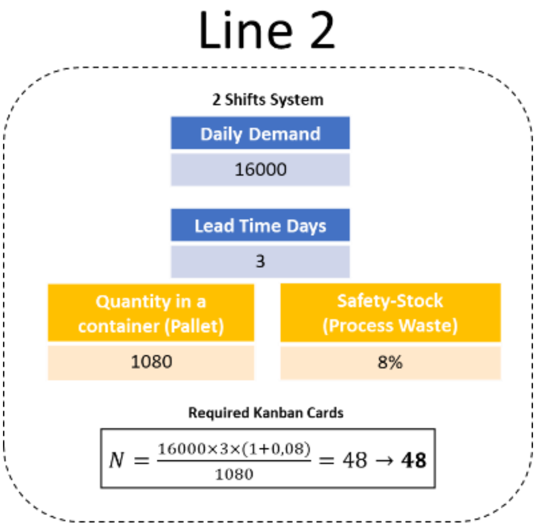


Figure 57 - Kanban cards estimation (Line 2)

3.5.3.2 New Productive Dynamic

During the time study and OEE analysis it was possible to diagnose that a lack of material was always related to no available wipe stacks on the line. As a sign in VSM, a potential focus of improvement was identified: the dry wipe stack supplier that is part of the company. In that area, a machine operator is responsible for producing dry wipe stacks which is running in 3 shifts. There, the production is less than what Line 2 requires which often leads to material stockout. Therefore, the necessity to run with enough safety-stocks emerged.

To calculate the needed number of Kanban cards, an average output of 14400 on wipe stacks supplier was included considering its historical data, Figure 58. To dimension the safety stock amount, it was considered that Line 2 and the wipe stacks supplier have the same changeover time which is a good approximation: a faster changeover on Line 2 can be performed in one hour while on wipe stacks supplier one hour is the average changeover value. Therefore, lead time is given according to the waiting time in Line 2 in case of no safety stock and a start at the same time. Considering this situation, 10 Kanban cards must be added to the system, Figure 58.

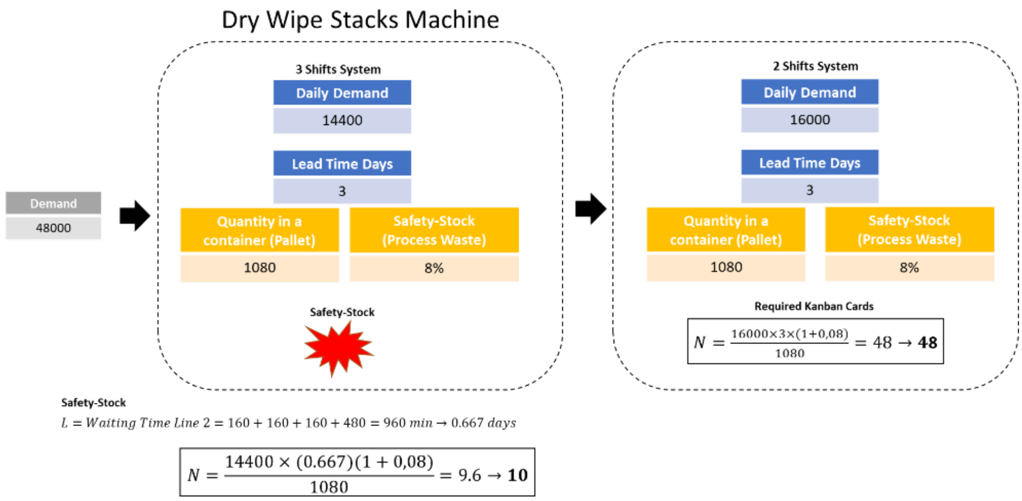


Figure 58 - Kanban cards estimation with safety stock

When calculating the needed amount of Kanban cards, it is necessary to implement a new system dynamic. The pallets with dry wipes stacks are produced and fixed according to client demands (Kanban Cards, Figure 58), implementing a pulled production where the warehouse plays the main role by managing the Kanban cards and following a specific dynamic, Figure 59.

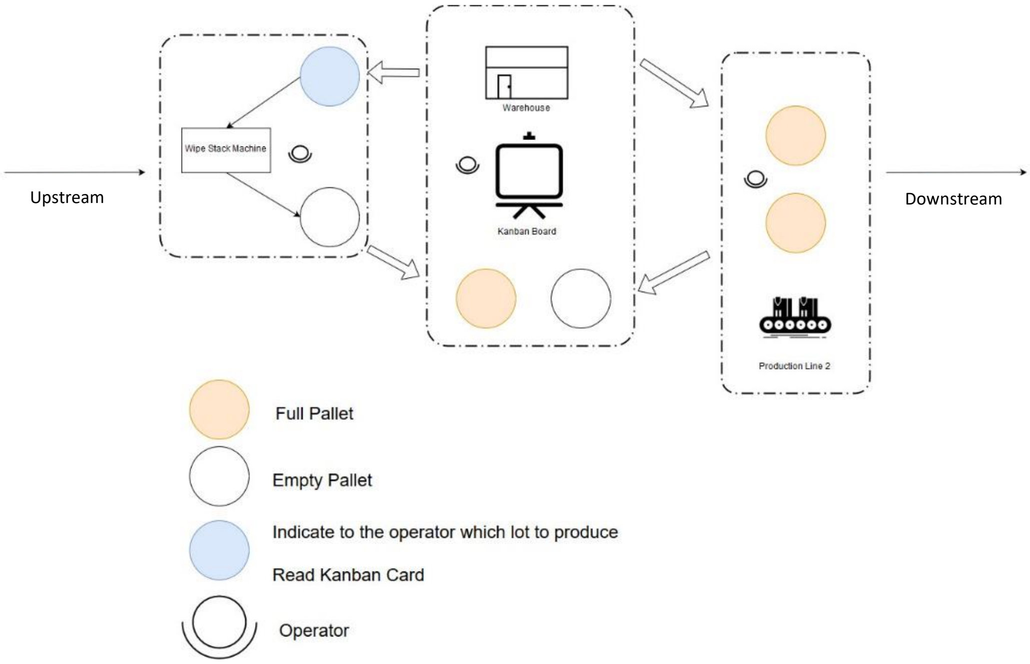


Figure 59 - Kanban (new productive dynamic)

- The operator who is responsible to produce dry wipes stacks receives Kanban cards from warehouse containing the necessary information and specifications. In its turns, the production process daily provides the warehouse with full pallets and respective Kanban cards.

- On the other side, from the downstream, the production on Line 2 removes its Kanban cards and corresponds full pallets from the warehouse which are continuously emptied and returned by the operator responsible to provide Line 2 with material.

- The warehouse manages the Kanban system where it is extremely important to work synchronous with the commercial department and the production management. By receiving a new customer demand, Kanban cards will be placed on the position “Demand”. Once the new demand takes place, the cards on position “Safety Stock” are sent to “L2” and the cards on position “Demand” are given to the dry wipe stacks supplier to start its production. This is where the crucial phase lies: under each product name, an area will signal if the stock is below the indicated. If so, the order to be sent will be higher to restore the stock in safety level again, Figure 60.

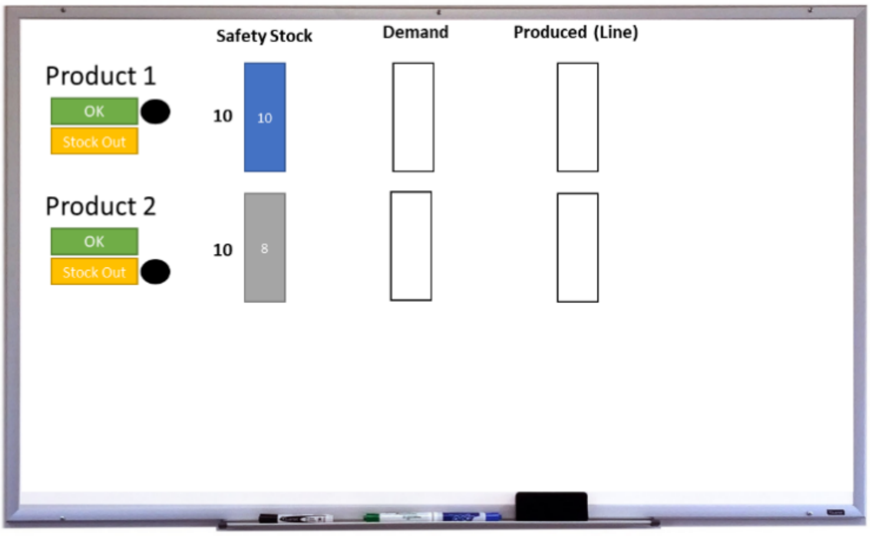


Figure 60 - Kanban board (example)

By using this Kanban system, it is expected to assure the production in Line 2 as long as the product stock levels are kept. However, once the safety stock is reached (yellow “Stock Out”), a mark signs that it is necessary to replace the stock. Otherwise, it will lead most likely to waiting times on Line 2.

Another important detail is that most of the products on dry wipe stacks supplier just have different materials which makes the changeover faster. Therefore, by performing the same in all available products and its minimum safety stocks, Line 2 will most likely run all the time without any lack of material. However, this measurement may take some warehouse store-space, but in this study the stocks will not be over dimensioned and a warehouse extension is planned to be built in the next months.

In case of new products, decisions must be made consulting Line 2 forecast productions. On the “Stock Out” (yellow), the production of wipe stacks is mandatory otherwise the production on Line 2 will be compromised.

3.5.4 Poka-Yoke

In lean manufacturing, poka-yoke can be represented by any mechanism that helps equipment and operators to avoid errors and mistakes. In order to overcome the inefficiencies, poka-yoke proposes the use of automatic devices and mechanism to avoid them.

3.5.4.1 Applying Poka-Yoke on Line 2

On the production Line 2 and at the diving machine stage, an operator is responsible to give the production pace by introducing dry wipe stacks. To have a constant and smooth process, the packing machine is configured for an average speed with up and down acceleration tolerance, so that the line continuously produces. Unfortunately, due to operator fatigue/impatience speed fluctuations occur that lead to stop times or in the worst case, line congestions in case the operator is too fast.

As diagnosed on the time study – Waiting Time (Figure 38), 47 % of the waiting time is partially due to wipe stack that got stuck between stages that stop the production. Two possible bottlenecks may be found: between diving machine and presser; presser and packing loading conveyor. At these intermediate points, the operator's visibility field is reduced.

To overcome the problem, in this study a sound alarm is suggested that marks the precise pace for introducing wipe stacks as well as two fixed cameras positioned at those bottleneck points. The cameras will enable the operator to see what is happening in a screen installed in his front while introducing dry wipe stacks, Figure 61.

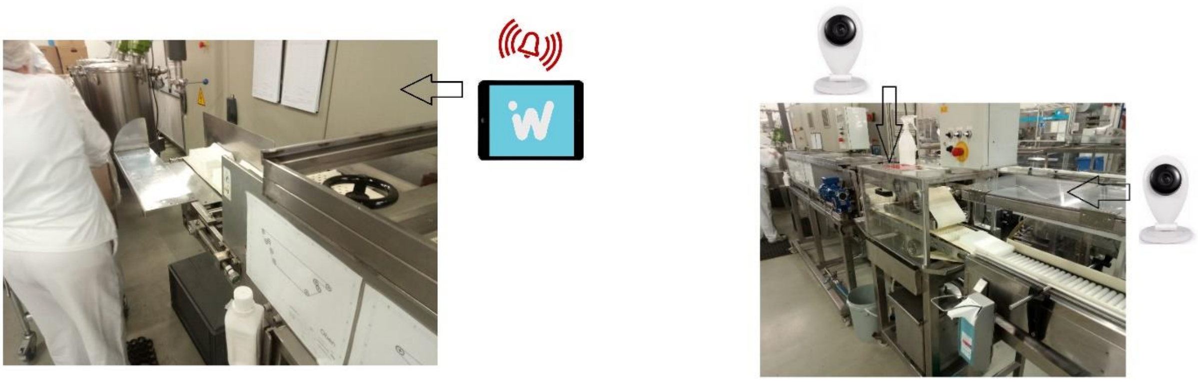


Figure 61 - Poka-yoke on production Line 2

3.5.4.2 Cost Analysis – Poka-Yoke

The required material to implement this solution is quite low. However, it is important to understand if this solution involves high costs. Nevertheless, when wipe stacks got stuck, they normally lead to stop times which takes never less than 10 minutes to solve. In the worst case, parts of the machines may be disassembled to remove all the wipes safely.

Although it is an incidence that can vary between never and several times, since it depends directly on the worker, in long term the suggested solution can avoid those bottlenecks. Either the operator is able to perform faster or slowly his tasks when afraid, this surveillance system will give the right pace and the possibility to visually check blind spots periodically, which will avoid unnecessary congestions on the line that lead to stop time. When not disposing such a solution, operators will always need to move two steps back and one to the side to check those blind spots. Consequently, losing performance and increasing fatigue.

In order to perceive the associated costs to apply the suggested solution, an estimated budget is done, Table 26.

Table 26 – Cost analysis (poka-yoke)

ITEM	Qty.	Estimated Price
Samsung Galaxy Tab E	1	178.59€
Camera IP Wifi Mini	2	59.49€
TOTAL:		**297.57€**

According to the recorded time spent on cleaning where the line needs to be completely stopped and considering that it happens minimum once a day, a minimum reward of 15 minutes each day is predicted. Assuming the company makes a profit of 0.20€ each pack and an average speed of 28PPM, a return of 420€/week is expected, Table 27.

Table 27 - Amortization analysis (poka-yoke)

Average incidences a day	1
Production time gained	00:15:00
Total gained (hours per week:	**1.25**

Estimated profit per package	0.20 €
Average Line Speed (ppm)	28
Estimated Profit (per week):	**420.00 €**

The investment value is relatively low and compared to the expected benefits, its application should be definitely considered.

3.5.5 Other Solutions

During the time-study in production, some variations in weight were diagnosed as waiting time (Figure 38), where 47 % of the waiting time is partially due to wipe stack weight variation. Therefore, an analysis was performed to find out the reasons for that.

As shown in Figure 62, the production could run for hours always in the range established by the costumer, as for times fluctuations started to occur.

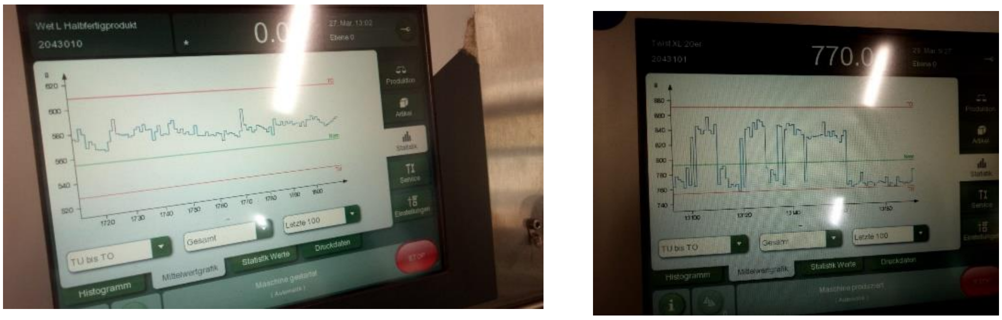


Figure 62 - Weight problems (Line 2)

By examining the wet wipe stack inside of each rejected package, which weight variation happened, it was noticed that these ones did not show a perfect shape, Figure 63.

Figure 63 - Wipe stack shape (Line 2 weight variation)

To solve the problem, the operator always adjusted the speed of the upper and down conveyor on the diving machine, until reaching the perfect point. It was visible that at a certain point, both conveyors were no longer having the same speed, creating unstable shapes on the wipe stacks. Consequently, once again the 5 Whys method was used to reach the root cause:

<u>Problem:</u> Wet wipe stack weight variation.

Question 1: Why did the weight variation happen?
Answer: Visually, the wet wipe stack had a deformed shape.
Question 2: Why did it have a deformed shape?
Answer: The speed in both conveyors was not the same.

Question 3: Why wasn't it the same?

Answer: Because the operator changed it to get a perfect stack shape.

Question 4: Why did the operator change the speed?

Answer: Because the traction between shafts and conveyors were no longer the same.

Question 5: Why were they no longer the same?

Answer: Because the conveyors got bigger by time and its traction with the shafts is only reached by its tension.

Root Cause: Friction between shafts and conveyors.

Possible Solution: Another shafts surface texture.

The conveyors motion was implemented through tension. Overtime, these conveyors began to expand and the tension was no longer enough to get all the spinning power from the shaft. To solve the problem, it was necessary to apply manually more tension through two expansion screws.

In order to improve the traction between the conveyors and the shafts, it is suggested to create a rough texture on all shafts installed in the machine. In this way, it is possible to create a higher friction between the conveyor and shafts, Figure 64.

Figure 64 - Diving machine (shaft rough texture)

When performing the conveyors change on the diving machine, no scheme was available to prove the correct up/down conveyor path. When removed, the operator was no longer sure about the correct way to set it through the shafts. Therefore, by using again the poka-yoke method a drawing was performed where the operator could easily see it, Figure 65.

Figure 65 - Diving machine (conveyor's scheme)

4. Expected Improvements - Production Line 2

4.1 Production Time

After studying the line through lean manufacturing tools and methodologies, improvements on times are expected. Figure 66 shows those results.

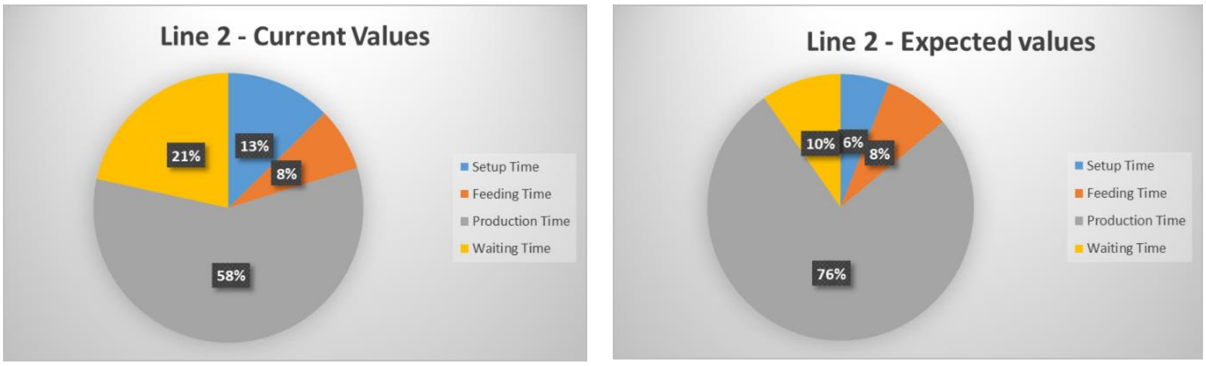


Figure 66 - Production Line 2 (previous and expected-time comparison)

Comparing the previous obtained values:

<u>Setup Time</u>, regarding to product changes, after applying the SMED methodologies might have a reduction of 47% due to shorter changeover time. The new time is achieved by implementing new standards and procedures in the organization leading to more efficient and quick decision processes.

<u>Waiting time</u> is mainly associated to employees' fatigue on the diving machine. Punctual line driver interventions in some machines belonging to the process and no material

in the line, will eventually experiment a reduction of 55%. This reduction is mainly associated to the poka-yoke and Kanban card method with the proposed solutions. However, the time related to the line driver machines interventions will remain a great cause of waiting time.

Relatively to the Feeding Time, associated to the operator who supplies the line with dry wipe stacks, an improvement is not so easy to handle. Once the operator is responsible for other lines, times can occur in which the material might fails to work in the manual loading conveyor or, in the worst case, there isn't material available on the line. However, a better organization between operators can reduce the problem.

Therefore, the production might feel a sustainable growth up to 76%.

4.2 VSM - Future State

In this study, some changes of the company's organizations are suggested with the purpose of a faster and efficient flow, either focused on material or information (Figure 67). Therefore, it is suggested to implement safety stocks on the wipe stacks provider which are managed according to the demands for the production on Line 2.

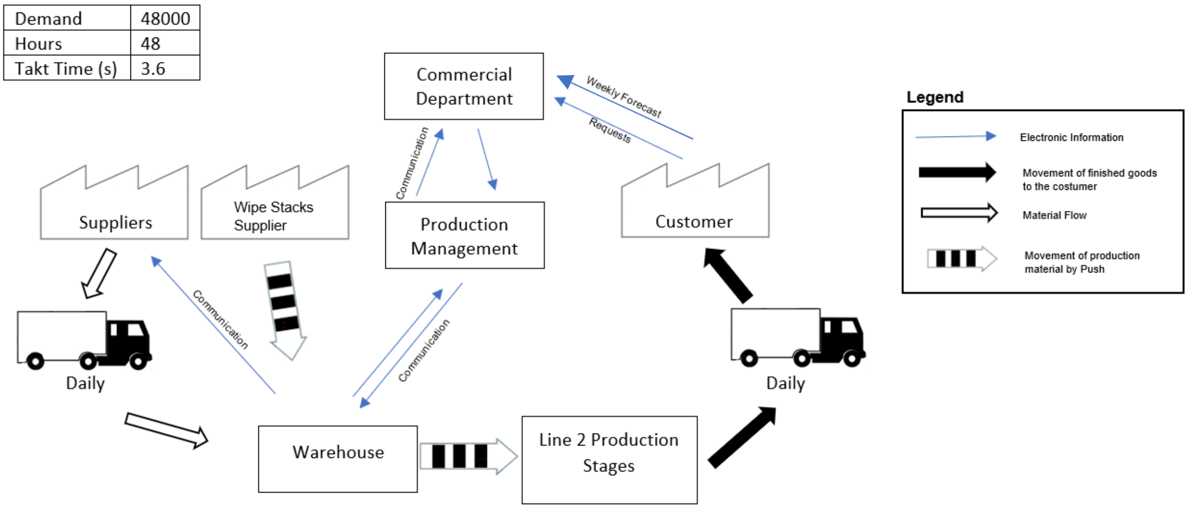


Figure 67 - Value Stream Map - Future State

The raw material supplier will be shipping to the warehouse daily. In this case, the necessity of having stocks is not mandatory. Its dimensions and consumption rhythms give flexibility to daily shipments. The only condition is to purchase the material to arrive having enough time before it is required in production: mainly packing film rolls and labels. According to these factors, it is suggested that the managements of raw materials must be done by the warehouse. There, experience on production consumption is an acquired knowledge.

Therefore, it is expected to have a better efficiency on the buying procedures without misunderstandings between warehouse-production and management-commercial department.

Considering this, commercial department and production management would work as one: the commercial department focused on answers to customers and production management with the central role of checking the productions line availability and perfect planning, while choosing products that are similar to shorter changeover times: products and its similarities are the key to success on implementing this new production system approach. Usually, products are selected in a non-productive way causing delays on changeover. One example of it are products with totally different lotions which require a lot of time cleaning the line. Some lotions are so difficult to wash that the use of hot water only is not enough to remove it.

With all those changes, it is expected to improve the lead time as well as to give more capacity and organization to the company.

5. Conclusions

This study consisted of the analysis of the production Line 2 from the company Innovate Wet Wipes, based on the elaboration of diagnosis to identify critical points and present possible solutions for them.

Through the application of Lean manufacturing tools and methodologies, several problems were identified, namely production problems caused by reliance on operators, nonexistence of controlled stocks and inefficient communication between planning and controlling the production activity. Along with this, the time spent on motion in search of information and its confirmation was causing longer changeover times.

With the suggested solutions, it is tried to deal with the problems in an objective way and to bring a new behavior for the responsible workers on the line of production building up a new concept of work.

According to the analysis performed by means of SMED methodology, presented in section 3.5.2, all the changeover procedures on production Line 2 were written down and its respective time spent recorded. Over splitting all the procedures and organizing them into ones which required stopped production and not, it was possible to rearrange and work individually in each one, gradually decreasing changeover time. With the obtained results, a substantial reduction on the final setup time is confirmed, contributing to an increase of flexibility in the line, whenever a changeover is necessary. The production will not stop for so long which leads to a continuous material flow and less waiting times.

Regarding to the suggested implementation of a Shopfloor communication platform, described in section 3.5.2.3, it is intended to control and visualise all the necessary steps on a changeover and facilitate communication between workers. The purpose of this recommended platform is having more information about the inherent processes on the changeover and a better perception from its times spent. In this way, useless motion times are eliminated, encouraging a better work organization to each sector directly or indirectly linked to the production line. Despite timed tasks, the responsible persons can directly interact and are forced to act as well, providing fast and effective communication which benefit workers, the company and customers.

Concerning the Kanban method suggestion in section 3.5.3, it is intended to change the way of producing dry wipe stacks. Through an effective communication between production, warehouse and dry wipe stacks suppliers, it is possible to generate safety stocks, boosting the production driven by the customer's wishes, which regulates the existing stocks. It will also be easier to promote a continuous material flow and streamlining all production dynamics.

Relatively to the poka-yoke on section 3.5.4, it is suggested as an effective control tool to avoid mistakes that might occur due to operator fatigue, recognizing and avoiding errors that are part of being human.

The solutions proposed in section 3.5.5, suggesting another shafts surface texture and drawing a belt scheme for the diving machine, are a perfect example of the finding that simple things can improve the process significantly. By detecting problems and investigating their causes as well as working out possible solutions.

With all these solutions, it is expected to contribute to a higher flexibility on the production Line 2 due to a shorter changeover time, an effective communication level and a better process flow balanced on stocks by implementing a pulled production system.

A production system with less time wastes and shorter changeovers is an asset that results in a productive and competitive company.

Given the complexity of factors affecting the efficiency of production lines, it is possible to do more detailed studies on various aspects. However, the pursuit of simple and efficient solutions is the company's goal. In this way, the study is focused on situations that are considered most relevant, in an objective way, so that it has the maximum practical usefulness.

During the work time at Innovate, it was possible to identify many solutions that proved to be meaningful in their application. Consequently, some of the remaining proposed solutions that are presented in this study, will reveal as important to increase the production efficiency.

I believe that I have acquired a lot of practical knowledge under real industrial production conditions, which together with my prior knowledge of Lean principles, have greatly increased my cognitive potential for a future as a mechanical engineer.

5.1 Future Work

As future work, the development of a dynamic presser is proposed.

The weight of the wet wipe stacks provided by the diving machine is sometimes a bit unstable even after solving the problem with conveyors speed. The way wipe stacks are folded and its cloth tension, affect the lotion absorption level. Therefore, it is recommended to build up a machine that is programmed to weigh the wet stack before pressing, adjusting it automatically through the right pressing values according to the tissue specification.

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