INTERDEPARTMENTAL POSTGRADUATE PROGRAM IN BUSINESS ADMINISTRATION (MBA)

Master Thesis

MINIMIZATION OF WASTE IN THE FOOD INDUSTRY BY APPLYING LEAN PRODUCTION PRACTICES

By

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Dedication

Dedicated to my family for their unstinting support throughout this academic program...

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I would like to express my sincere appreciation to my supervising Professor, Dr. Katerina Gotzamani for providing guidance and extensive feedback during my research.

I would also like to thank the managers and employees of the case company for their cooperation and overall assistance during this project.

Abstract

The elimination of waste is central to the philosophy of Lean Production. Defined as any activity that consumes resources but does not create value, waste is the target of all organizations in their strive to remain competitive. This Master Thesis deals with the minimization of waste in the food industry by applying Lean practices. In this field of academic research many surveys and case studies have been conducted and contradictory results have emerged in terms of the degree of Lean implementation and the Lean practices applied. The purpose of this thesis is to reveal the wastes that exist in the production process by investigating the case of a Greek food industry and then to propose the appropriate Lean practices in order to alleviate their impact.

The present study starts out by reviewing articles on Lean Thinking, on Lean Production tools such as the Value Stream Mapping, and on the Lean adoption in the food industry. Then it examines a given case of a Greek food industry, where, following the Action Research methodology applies the Value Stream Mapping tool at a product family in order to reveal wastes in the process and assesses the applicability of Lean tools towards waste minimization.

Following the approach mentioned above, this thesis concludes that Lean Production can be applied to minimize waste in the food industry and that the Value Stream Mapping tool can improve Lead Time and Work in Progress when applied in the food industry. Furthermore, among the findings is that the most applicable Lean tools in the food industry are VSM, Kanban, SMED, multi-functional employees, standardization, autonomous maintenance, product leveling, layout change, and supplier involvement. Finally, the limitations of the research are mentioned along with proposals for future research.

Keywords: Lean Production, Lean Manufacturing, Value Stream Mapping, Waste, Food Industry, Action Research.

Contents

List of Abbreviations

5S: Sort, Set in order, Shine, Standardize, Sustain

AR: Action Research

JIT: Just in Time

LT: Lean Thinking

SMED: Single Minute Exchange of Die

TPM: Total Productive Maintenance

TPS: Toyota Production System

VSM: Value Stream Mapping

WIP: Work in Progress

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1 Introduction

1.1 Background

Over the last decades, globalization has been linking companies all over the world affecting all kinds of transactions regarding raw material, final products and technology to name but a few. In this context, companies strive for competitive advantage by changing their operational strategies and applying new techniques. Cost reduction, increase of flexibility, and quality improvement are terms that promise to increase the efficiency of operations in an organization. In addition, every company regardless of the business sector seeks one thing: waste reduction or even better, waste elimination. Waste and the elimination of it is central to the philosophy of Lean Production or Lean Manufacturing (both terms are used interchangeably in the bibliography). Womack and Jones (1996, p.15) state "*Muda*. It's the one word of Japanese you really must know", explaining later in their book that Muda means waste and defining it as any activity that consumes resources but does not create value. According to the Lean philosophy, waste must be seen as anything exceeding the minimum amount of material and employee working time required to add value to the product (Bicheno and Holweg, 2009). The subject of the present Master Thesis is the minimization of waste in the food industry by applying Lean Production practices. The innate unique characteristics of the food industry which relate to food quality and food safety, play the most significant role in operations management. The Lean adoption in the food industry has been researched through surveys and case studies, and contradictory results have emerged. In certain articles, the results differ in terms of the degree of Lean implementation and the Lean practices applied (Dora et al., 2014; Khusaini, Jaffar and Yusoff, 2014; Bamford et al., 2015; Psomas, Antony and Bouranta, 2018). In the same field of research, this thesis attempts to reveal the types of waste that exist in a food industry's process, along with the Lean practices that will attack those wastes and decrease them. Towards this end, a given case of a Greek food industry is examined and the results as regards Lean application aim to contribute to the existing research on Lean implementation in the food industry context.

1.2 Purpose and Research Questions

The purpose of this thesis is to reveal the wastes that exist in the production process by investigating the case of a Greek food industry and then propose the appropriate Lean practices in order to alleviate their impact. A Lean tool called Value Stream Mapping is used to uncover any type of waste present in the procedure, thus acting as a starting point for Lean application. To fulfill the purpose of this research the following three research questions will be investigated:

1. Can Lean Production be applied to minimize waste in the food industry?
2. Can the VSM tool be utilized to improve Lead Time and Work in Progress in the food industry?
3. Which are the most applicable Lean Tools in the food industry?

1.3 Methodology

The present study follows a qualitative approach by studying a certain case of a Greek food industry in order to fulfill its purpose and answer the research questions. However, due to the fact that the author gets involved in the process and proposes solutions to improve existing procedures, Action Research (AR) is the selected methodology (Coughlan and Coghlan, 2002). Data collecting takes place by direct observation as the main method with interviews and archival records complementing the procedure. Gathering data from different sources also serves as triangulation, aiming to tackle the precision issue of the AR methodology. The VSM tool uses this production data in order to create the current state map and identify the types of waste that exist in the process. Then the current state map is analyzed, and the future state map emerges, visualizing possible improvements in the process. Finally, an action plan encompassing the appropriate Lean practices is proposed to the case company in order to reach the improved future state.

1.4 Disposition

The structure of this thesis follows hereinafter: The first chapter is the introduction of the thesis' subject where the purpose and the research questions are defined, the research methodology is briefly described, and relevant background information is mentioned. The second chapter is the literature review where the basic terms of Lean Production are presented, the Value Stream Mapping tool is analyzed along with other significant Lean practices, and relevant articles and their findings are cited. The third chapter, the research framework, refers to Lean production in the food industry context and presents the unique characteristics of the sector, the degree of Lean adoption, and the barriers that inhibit Lean implementation. The fourth chapter is the methodology where the research strategy and the data collection methods are described, and the case company and the production line under examination are presented. In this chapter, the VSM tool is applied and the current state map is analyzed. The fifth chapter presents the results of the VSM tool by visualizing the future state map and proposing the relevant action plan. Finally, the sixth chapter includes the basic findings of this thesis, mentions the limitations of research, and proposes areas for future research.

2 Literature Review

2.1 Lean Production History

Before World War II, the production system adopted by the biggest industries in the world – the ones of the automotive sector – was Mass Production. The main characteristic of Mass Production is the production of big capacities of standardized products at low prices. However, this system takes its toll on product cost and variety. Large batches mean large inventories which lead to increased needs for bigger warehouse space. Moreover, the high cost of switching between products has an inevitable impact on product diversity (Womack, Jones and Roos, 1990). Taiichi Ohno, Toyota's industrial engineer, recognized those flaws of Mass Production and successfully developed the famous Toyota Production System (TPS) by the implementation of which Toyota was able to produce in high variety and small volumes (Holweg, 2007). Despite the fact that the TPS was initiated after World War II, the term Lean Production was introduced not earlier than 1988 when Krafcik emphasized the differences between the "Buffered" Mass Production System adopted by Ford and the Toyota "Lean" Production System (Krafcik, 1988). In the years that followed, the numerous publications about Lean Production on the one hand and the undeniable success of Japanese transplant operations in the United States on the other, proved that the Lean Principles and Practices were actually transferrable to other countries (Holweg, 2007).

2.2 Lean Principles

An early definition of Lean systems is that they use less resources to produce the same results and augmented value to the customers (Womack, Jones and Roos, 1990). Moreover, Shah and Ward (2007, p.7) proposed that "Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability".

The Lean Thinking (LT) employs 5 key principles to identify and eliminate activities that represent waste and to promote activities that create value (Figure 1): a. Define value, b. Identify the value stream, c. Make the value flow, d. Implement pull-based production, e. Pursue perfection (Thangarajoo and Smith, 2015).

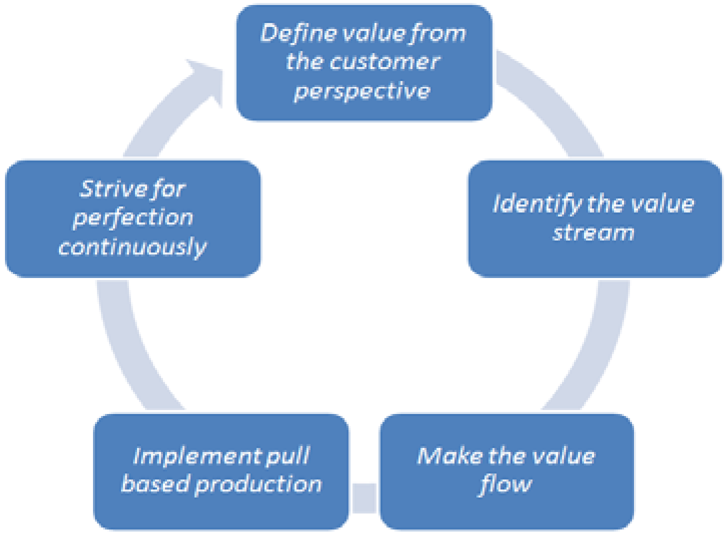

Figure 1. Five Key Principles of Lean Thinking
Source: Thangarajoo and Smith, 2015

a. The first key principle of LT is Define Value from the customer perspective. In Lean Production the value of a product is specified only by the customer. Customers have specific requirements of products at delivery time and price, whereas the numerous processes that products go through during their production have little meaning to them (Emiliani, 1998). To Define Value means to identify the activities that create value, to specify what the customer would actually pay for (Lian and Landeghem, 2002).

b. The second principle is 'Identify the Value Stream'. Value Stream can be defined as all the necessary activities in order to get a product through the critical tasks of an organization: i) Problem Solving, which provides solutions to issues that arise before the launch of a product, ii) Information Management in the whole spectrum of activities, from order acknowledgement to the delivery of the product, and iii) Physical Transformation of raw material to finished products delivered to customers (Womack, Jones and Roos, 1990). The goal is to divide all activities in two categories: Value Adding – the ones that create value for the customer – and wasteful activities. The latter, in turn, can be separated into Non Value Adding but necessary and Non Value Adding unnecessary activities (Maleyeff, 2006). Value Stream Mapping is the tool that reveals such issues in the current state and proposes improvements in future performance (Howell and Ballard, 1998).

c. The third principle of LT is 'Make the Value Flow'. After the identification of the Value Stream and the elimination of wasteful activities, the organization has to introduce flow in the Value Adding activities that remain (Thangarajoo and Smith, 2015). The objective is to make products run through the system fast and in a smooth manner, without stops and interruptions that are present at batch processes where products accumulate at several points (Dettmer, 2001). Lian and Landeghem (2002) defined that the concept of Flow is to produce one item at a time and to transport them through the workstations without any waiting times. The presence of buffers is proof of ineffective Flow. Lean attempts to eliminate buffers and places where Value Adding work – be it material or information – is interrupted (Howell and Ballard, 1998).

d. Implementation of Pull Based Production is the fourth principle of LT. In an organization that has adopted the first three principles, it is Pull that assures the customer will get their products when they anticipate them (Thangarajoo and Smith, 2015). In a Pull Based Production, the customer is initiating the production, not the organization. Everything upstream in the Value Stream will start producing only when a certain demand from the customer is placed. In this manner, the customer receives the products exactly when they want them, neither after nor before their requested delivery date (Vlachos, 2015).

e. Strive for Perfection Continuously is the final key principle of LT. This principle refers to the elimination of wasteful activities so that those remaining are the ones creating value in the Value Stream (Vlachos, 2015). Strive for Perfection means that organizations having implemented the other four principles, have to go through them continuously with one objective: to eliminate waste from the system (Thangarajoo and Smith, 2015). Perfection is achieved when the employees in an organization concentrating on customers' needs, realize that waste elimination is actually possible (Lian and Landeghem, 2002).

2.3 The Eight Types of Waste

The Lean Manufacturers strive for perfection and their efforts towards this end focus on minimizing waste, defects, and unnecessary inventories. Any Non-Value Adding activity – as perceived by the customer – is considered as waste. The idea is simple: if the customer is not willing to pay for an activity, the activity is a waste. Taiichi Ohno, one of the developers of the Toyota Production System identified the following seven types of waste (Heizer, Render and Munson, 2017). These types of waste defined by Ohno, also known by the Japanese word MUDA, are overproduction, waiting, transportation, unnecessary motion, inappropriate processing, unnecessary inventories, and defects.

Later approaches refer to an additional type of waste, the one of people underutilization (Wahab, Mukhtar and Sulaiman, 2013). The eight types of waste (Figure 2), in further detail, are:

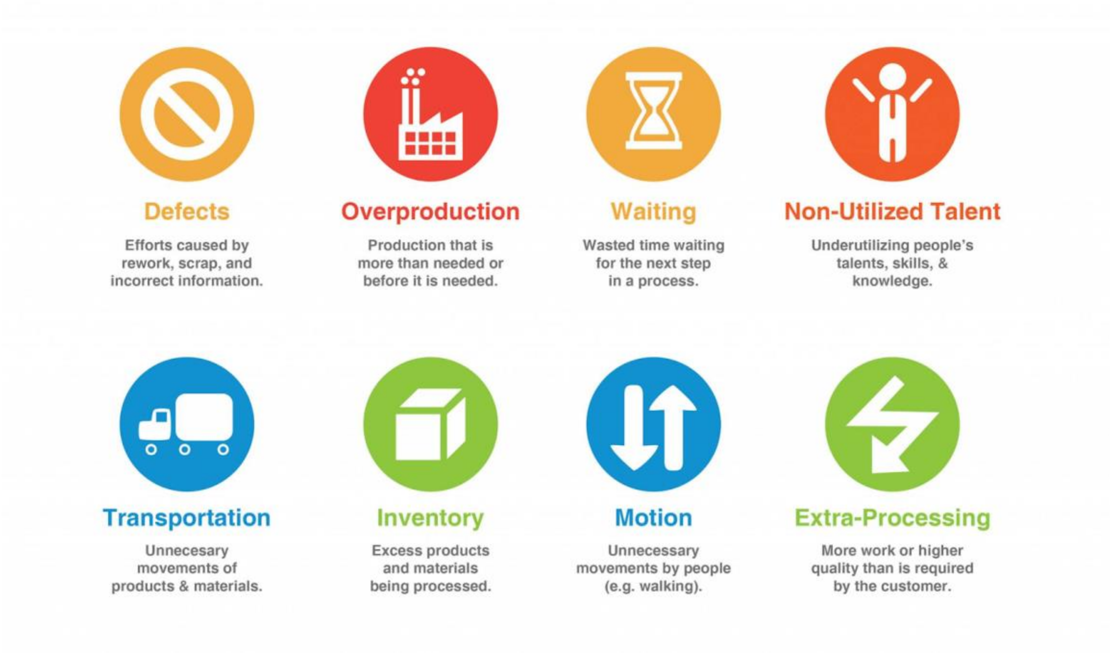

Figure 2. The Eight Wastes of Lean
Source: (Sarhan, 2015)

Overproduction

Overproduction is sometimes what comes natural as a way of operation in corporations: produce more just to be on the safe side. This, however, causes a series of problems such as prolonged lead times, defects that remain hidden for longer periods, unnecessary motions to name but a few (Bicheno and Holweg, 2009). According to Ohno (1988), overproduction is the biggest enemy, the root cause of many problems, as it facilitates other wastes to remain hidden. For example, in an overproduction case, working ahead of schedule hides waiting times and builds up inventory in various points of the production line. The goal is to produce what the customer needs, exactly when they need it, and in perfect quality. As Bicheno and Holweg state (2009, p.22) "The motto 'Sell daily? make daily' is as relevant in an office as it is in a factory".

Waiting

The second Lean waste is Waiting; it refers to the disruption of Flow and the appearance of bottlenecks in the procedure. Ohno identified this type of waste as employees waiting for a machine to finish its operation or for an upstream activity to conclude its work

(Womack and Jones, 1996). Waiting occurs when time is not used efficiently between activities, resulting in idle time for personnel and in inactivity periods regarding information which in turn take their toll on product flow and lead time (Wahab, Mukhtar and Sulaiman, 2013; Jaffar et al., 2015). According to Bicheno and Holweg (2009), anytime a product does not Flow in the procedure, this indicates waste. However hard it might be to eliminate Waiting and the existence of bottlenecks, it still represents the objective that will give the corporation the ability to reduce lead times and increase competitiveness and customer satisfaction.

Transportation

To define this type of waste it is sufficient to say that any movement of raw materials, intermediate or final products is waste. Customers don't want to pay to have their products moved around as this does not create value (Bicheno and Holweg, 2009). Moving materials between facilities or work centers represents waste. Transportation waste includes also double handling which has a negative impact on productivity and overall product quality (Wahab, Mukhtar and Sulaiman, 2013; Heizer, Render and Munson, 2017). Another cause of the Transportation waste is the fact that in the majority of cases products are being manufactured centrally in locations thousands of kilometers away from their final distribution increasing dramatically the supply chain demands (Arunagiri and Gnanavelbabu, 2014). This type of waste is identified all the more in corporations which upon its recognition can take steps to reduce its impact by monitoring non value adding activities (Bicheno and Holweg, 2009).

Unnecessary Motion

Unnecessary motion poses another major Lean waste. It relates to both layout and human factors. Poor employee ergonomics for productivity and quality may cost huge amounts of time wasted due to a poorly arranged workplace. Examples of unnecessary motions are operators wasting time looking for tools in the production hall or having to stretch to complete an activity that should have been designed in a better way (El-Namrouty, 2013). Ostensibly, in every case of a badly designed workplace, the first casualty is the operator, and this can be seen from a health and safety perspective as well, but finally, it all comes down to overall quality and customer satisfaction. When seen from the layout dimension, inadequately designed arrangements result in repetitive micro wastes which in many cases are not noticed by anyone on the production floor. The unnecessary motion waste may be greatly alleviated by Lean tools that attack it such as 5S among others (Bicheno and Holweg, 2009).

Inappropriate Processing

This is a waste that occurs when sophisticated process solutions apply in simple procedures or when the involved equipment is used inefficiently. It is obvious that inappropriate processing can lead to other issues as defects and poor quality (Rawabdeh, 2005). Bicheno and Holweg (2009, p.23) state that "Overprocessing refers to the waste of 'using a hammer to crack a nut", referring to big machines called for simple tasks that discourage employees and take away the feeling of ownership. Furthermore, this type of waste involves machinery that is not capable of quality manufacturing. A smooth process involves the right procedures and training along with the right standards of operation. To tackle this waste, the notion is to employ the smallest possible equipment in order to facilitate the production of goods in the required quality while having everything placed at the right positions upstream and downstream the procedure (Wahab, Mukhtar and Sulaiman, 2013). Smaller machines may also assist in reducing the Waiting Waste, can be serviced and looked after more frequently, and above all are easier to acquire facilitating the organization's cash flow (Bicheno and Holweg, 2009).

Unnecessary Inventories

According to Ohno (1988), businessmen might not feel secure if they don't upkeep and monitor certain inventories of raw materials, final products, or even work in progress (WIP). Keeping inventories seems like the cure for various issues that appear in corporations such as wrong predictions, equipment malfunctions, and defective products. It is the root cause of other issues though, more defective products, increased lead time, and reduced productivity and profitability to name but a few. Masaaki Imai (2012) states that inventories are the outcome of overproduction and that they should be minimized because they are the perfect hideout for other problems. Furthermore, inventories create higher demands in warehouse spaces which in turn increase the overall operating cost of organizations. When goods are stored in warehouses, they do not add value; instead, they are prone to lose value due to deterioration or even worse being exposed to other hazards as fires, to give an example. Only by the attempt to reduce inventories will problems as defects, equipment malfunctions, even absenteeism be identified and addressed accordingly.

Defects

The Defects Waste is probably the most direct and measurable one. Defects mean goods on hold, rework, and in the worst-case scenario items scrapped. This waste does not solely represent the loss of material and human effort; it creates various shortages, idle times and prolongs lead times. Defects affect other wastes such as overproduction and especially transportation due to increased needs of moving items for rework or scrap (Rawabdeh, 2005). Apart from the aforementioned internal failures, there is another category of the Defects waste impact which refers to external failure. External failure includes warranties, repairs and services out of the organization and the possible loss of customers. When the defects remain hidden the associated costs tend to magnify. This demonstrates the need to prevent instead of detect and it is achievable by concentrating the efforts of all departments involved (Bicheno and Holweg, 2009). In Toyota, they believe that the defects should be seen as improvement opportunities instead of being regarded as something to be compromised against badly run operations management (Hines and Rich, 1997).

People Underutilization

This ‘new’ waste refers to the unused talent of people. It appears in cases where people are not utilized to their full potential, being under-employed or allocated to the wrong department. Thus, they are not being able to unfold their creativity towards problem solving and procedure improving, wasting in this way their knowledge and skills (Mostafa, Dumrak and Soltan, 2015). The solution to this type of waste lies on the effort to utilize all employees, not just managers. This requires management support and commitment because uncapping the potential of self-directed teams might appear as a threat to foremen or middle managers. It involves also a change of culture and the involvement in the production floor, the so-called Gemba walks, along with the basic training provision. As Ohno had stated, one of the TPS objectives was to invest in creating thinking people and in this way this type of waste can be also linked to Ohno (Bicheno and Holweg, 2009).

2.4 Identification of Waste – Value Stream Mapping

Over the last decades, various tools have emerged to facilitate the improvement of production systems and to speed up the process of designing Lean materials and information flows in the production field (Matt, 2014). One of the most effective tools employed by Lean Manufacturing to identify waste is Value Stream Mapping (VSM). The implementation of VSM augments value added activities and boosts product quality by revealing errors, losses, and idle times, thus creating positive outcomes in terms of operational risk and cost reduction (Dadashnejad and Valmohammadi, 2018). VSM differentiates from other recording methods in that it visualizes many aspects of the process such as cycle times, intermediate inventories, utilization of employees and equipment as well as information flows. It depicts the overall transformation of raw materials to final products (Seth and Gupta, 2005). VSM, as Rother and Shook state (1999), is referred to at Toyota as Material and Information Flow Mapping and it is utilized to record current and future process states, in their continuous effort to design and incorporate Lean systems. The main idea is to follow the route of goods through the whole process, from the supplier to the customer, and capture every detail regarding material or information flow.

Rother and Shook in their book *'Learning to See: Value Stream Mapping to Add Value and Eliminate Muda'* (1999) refer to VSM as a pen and pencil technique that helps in visualizing the value stream and results in drawing a future state map of how value should flow in the system. VSM is an easy tool to comprehend and apply. It uses boxes to depict production phases and incorporates simple symbols such as trucks, factories and cards for both the actual state (Figure 3) and the future state (Figure 4). Reaching the future state requires short-term improvements towards waste minimization, which can be shown as Kaizen bursts on the map, along with long-term implementation of Lean practices in the field of Layout and Scheduling (Braglia, Carmignani and Zammori, 2006; Bicheno and Holweg, 2009). To apply VSM, the first step is to choose a product or product family. The drawing of the current state follows, capturing a snapshot of how things are being done at the moment and identifying all the weaknesses in the process. The whole procedure, shown in figure 5, indicates the iterative nature of the VSM tool; as the mapping of the current state takes place, future ideas will emerge, whereas in the same manner, while drawing the future state issues overlooked during the current state mapping will be brought to attention. The current and future states are potentially revisited several times before the development of the future state map (Rother and Shook, 1999). Finally, the future state map emerges visualizing how the process should be after all the inefficiencies have been eliminated. This final step acts as the basis for the action plans towards system improvement (Braglia, Carmignani and Zammori, 2006; Abdulmalek and Rajgopal, 2007). To effectively map the future state the following eight questions addressing basic and technical issues as well as improvement actions need to be answered (Mcdonald and Aken, 2002; Rother and Shook, 1999):

- What is the TAKT time?
- Will the company produce directly to shipping or to a finished goods supermarket?
- Where can continuous flow processing be applied?
- Will supermarket-based pull systems be necessary anywhere in the system?
- Which point in the process can serve as the pacemaker?
- How can the production mix be leveled at the pacemaker process?
- What increment of work can be systematically released from the pacemaker process?
- Which will be the necessary improvements in order to reach the desired future state?

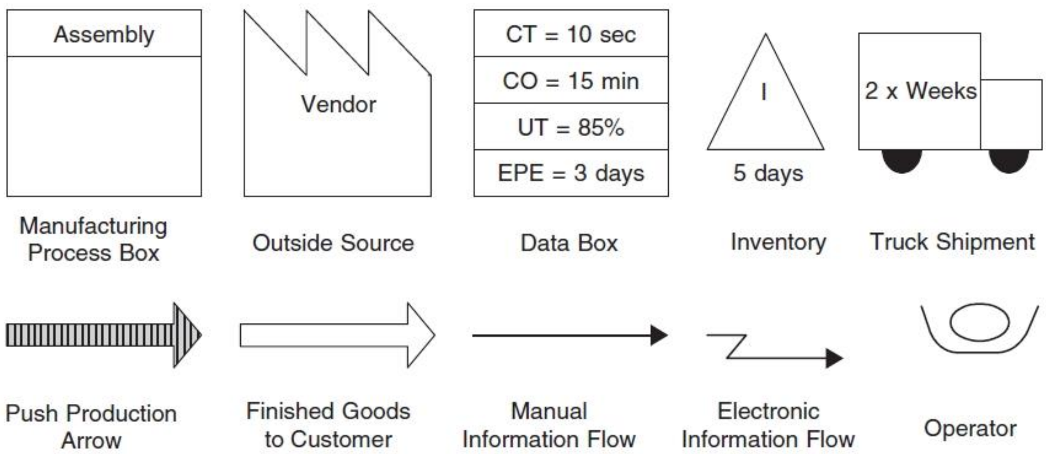

Figure 3. Actual State Map Icons
Source: (Braglia, Carmignani and Zammori, 2006)

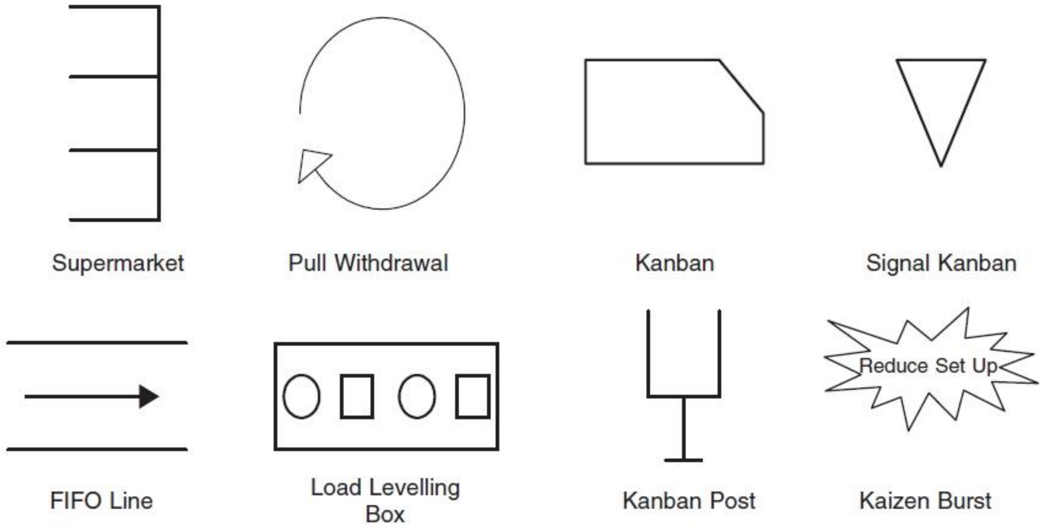

Figure 4. Future State Map Icons
Source: (Braglia, Carmignani and Zammori, 2006)

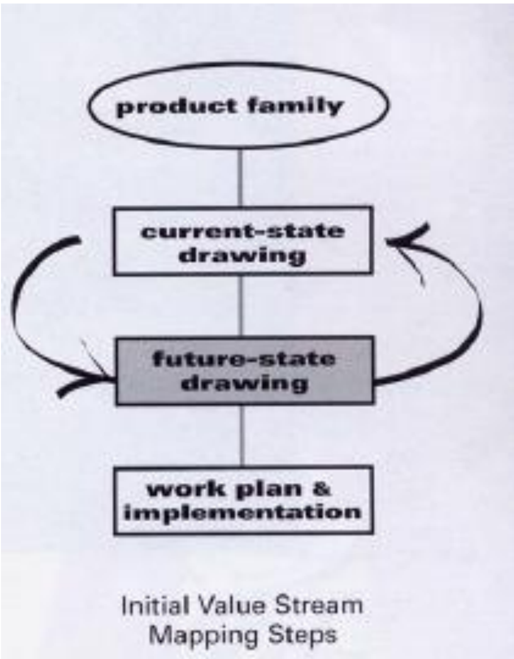

Figure 5. Initial Value Stream Mapping Steps
Source: (Rother and Shook, 1999)

VSM maps are inclusive and easy to read. In the upper part, the information flows determine the communication between the suppliers, manufacturers and producers. In the lower part the material flow is captured, following the production stages and recording information of parameters as (Abdelaal and Elshaer, 2021):

- Cycle time (CT), required for the completion of an operation or activity.

- Switching Time (TT) or changeover time, between different products in a manufacturing line.
- Occupation percentage at which the workstation operates.
- Available Time of employees and equipment.
- Batch Size of the goods produced together.
- Efficiency of the line.
- Value Creating Time as the time from the customer perspective.
- Lead Time, defined as the time required for the goods to flow through the whole value stream from raw material to the customer.

Identifying waste is not an easy task; towards this end various tools in the context of VSM are called for to facilitate the analysis of material and information flows (Hines and Rich, 1997; Lehtinen and Torkko, 2005): a) Process Activity Mapping of all the flows in the system, b) Supply-Chain Response Matrix that uncovers unnecessary inventories and idle times, c) Production Variety Funnel that provides information about buffer stocks holding, d) Quality Filter Mapping that reveals defects, e) Demand Amplification Mapping that assists in scheduling and inventory decision making, f) Value Analysis Time Profile that brings in surface financial resources tied up with inventories and g) Physical Structure Mapping that attempts to eliminate wasteful activities and to simplify and combine value adding ones.

Although VSM is an invaluable tool towards waste identification and Lean Production implementation, it comes with two disadvantages. Being a paper and pencil technique, its accuracy is limited and the number of variations that can be handled is low. Furthermore, in cases of high variety and small volume, the value streams include vast numbers of parts and final goods, inhibiting the application of the standard VSM method. In complex processes the solution to apply VSM is by visualizing solely the key flows and drawing flows that superimpose each other if necessary, thus avoiding to depict every branch at least during the first mapping attempts (Rother and Shook, 1999; Braglia, Carmignani and Zammori, 2006). In a case study of three parallel assembly lines, Mcdonald and Aken (2002) tackled system complexity in terms of differing processing and setup times, by applying VSM with simulation and managed to provide significant information that complemented the future state map. Khaswala and Irani (2001), dealt with the improvement of a fabricating jobshop that produced precision metal products. The unique feature of the firm’s operation was that it incorporated multiple flows that merged into a single path represented by a certain manufacturing stage. An improved VSM method, Value Network Mapping, that integrated into the traditional VSM industrial engineering tools for flow mapping and the computer software package Production Flow Analysis and Simplification Toolkit (PFAST) for flow analysis, was developed and implemented, making the drawing of the current state map and the design of Lean processes feasible in complex flows.

VSM can be applied to both manufacturing and service sectors. Rohac and Januska (2015) in their case study of a plastic bottle manufacturer for the pharmacy and healthcare sector, introduced the VSM tool to analyze and improve the Logistics category Key Performance Indicators. VSM was applied on one of the most demanding production lines and identified certain problems that inhibited the efficient management of Logistics. The mapping of the current state (Figure 6) revealed that the Lead Time was exceeding company performance set-point by three times, thus inflicting substantial financial loss due to unusable resources stored in unnecessary inventories. The study employed the 5-Whys tool to identify the root causes of the problematic issues and concluded to certain improvements, visualized in the future state map (Figure 7), such as people abilities reassessment, special inventory reports, application of strict deadline and Pull systems and construction of own adjacent logistic center. Henrique et al. (2016) in their action research at a Brazilian hospital concluded that VSM concepts in the healthcare sector are highly relevant in the daily operation of hospitals. The VSM model proposed was capable to capture all the flows that affect patient Lead Time and to visualize every interface between patient and support activities, resulting in the identification of bottlenecks in the patient's treatments. The proposed improvements led to a significant reduction of patient treatment time and of the number of transitions between departments, thus increasing the overall service quality. Parthanadee and Buddhakulsomsiri (2014), in their significant case study of a roasted and ground coffee producer in Thailand, applied VSM in combination with computer simulation software. VSM was used to record a snapshot of the current and future states whereas simulation provided an animation for the assessment of the aforementioned states of the system (Donatelli and Harris, 2001). In the study, the implementation of VSM was followed by the application of computer simulation of the proposed improvements that enabled testing of the future state without disruption of the actual process or expensive test-runs. The case study concluded in proposing equipment sharing, a new employee management plan, and a new investment that included replacement of a manual operation with an automatic machine, in order to tackle the production capacity issues that the enterprise faced at that moment.

The food industry, a sub-sector of the processing industry, has been studied by many researchers and was found to have been benefited from Lean practices implementation. VSM has also been the subject of many scientific articles that revealed its contribution to the improvement of production efficiency in the food industry context, especially when applied in combination with other Lean tools (Liu, Yang and Xin, 2020). Liu, Yang and Xin (2020) proposed a feasible Lean implementation in an agricultural plant with an unbalanced capacity and processing time in each step of the process, by applying a modified VSM tool as the main Lean practice. Nonetheless, the food industry is a real challenge for Lean thinking due to its unique characteristics, food perishability being the most important of them (Dora et al., 2012). As concluded in their case study of four food industries, the adoption of Lean proved difficult due to the unique characteristics of the sector and the volatility in demand and supply.

VSM will be utilized in detail in the present thesis, in order to assess the benefits from its implementation in the real context of a food industry, in terms of waste identification and Lead Time and WIP decrease.

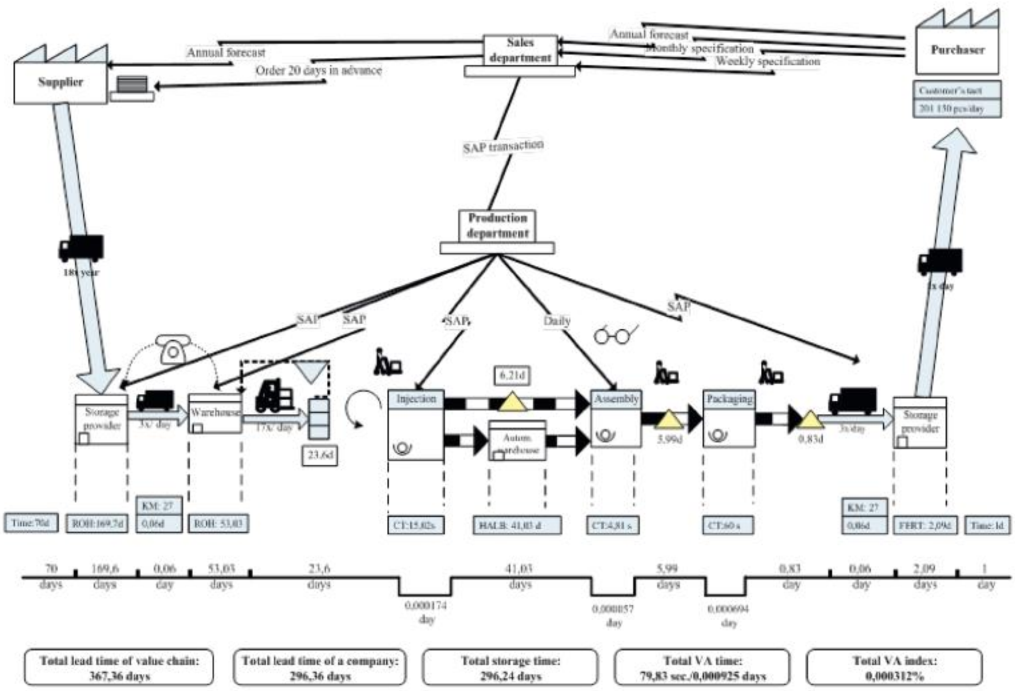

Figure 6. Current State Map
Source: (Rohac and Januska, 2015)

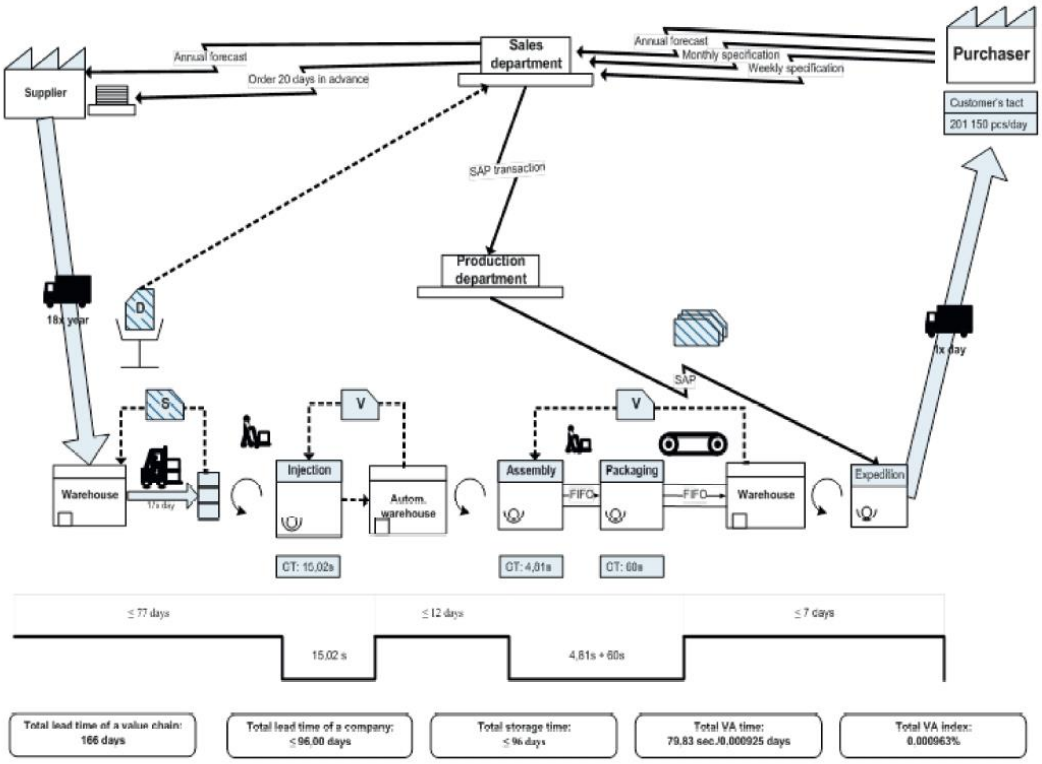

Figure 7. Future State Map
Source: (Rohac and Januska, 2015)

2.5 Waste Elimination – The Lean Tools

Lean Production's main objective is the elimination of waste in the whole spectrum of business activities, from industrial management to supply chains and customer service. It attacks waste in every form trying to utilize less resources, human capital and production floorspace, in order to meet customer demands providing quality goods in the most efficient way (Phillips, 2000). Lean Production and TPS, although having some differences that discern them, have been widely adopted over the past decades by organizations of various sectors in the western industry, and significant outcomes have been recorded after their implementation in terms of enterprise performance and waste reduction (Belekoukias, Garza-Reyes and Kumar, 2014). Initiated by TPS many Lean tools have been developed, 5S, Kanban, Single Minute Exchange of Die (SMED) and Total Productive Maintenance (TPM) to name but a few (Chiarini, Baccarani and Mascherpa, 2018). Figure 8 gives a representation of the TPS two-pillar temple model, where the first pillar is Just-in-Time (JIT) referring to producing the right parts at the correct quantity exactly when needed, and the second is Jidoka which means manufacturing quality parts (Rüttimann and Stöckli, 2016).

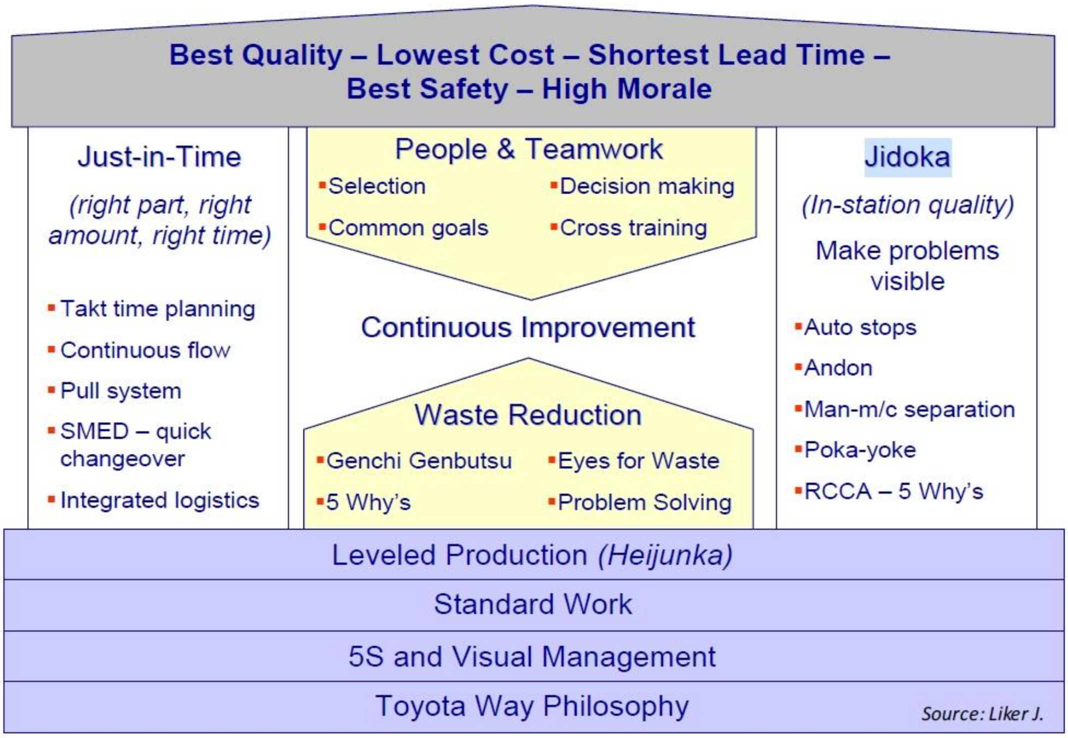

Figure 8. The Classic Representation of the TPS
Source: (Rüttimann and Stöckli, 2016)

Anand and Kodali (2010) reviewed various Lean Manufacturing tools and practices previously listed in research papers and concluded with a list of 69 elements, some of which were defined as tools while others as principles or techniques. In their article, Pavnaskar, Gershenson and Jambekar (2003), identified as many as 101 Lean Production tools and achieved to organize them by developing a classification scheme that acted as a link between production waste issues and the aforementioned tools. Their objective was to systematically put in order all Lean tools based on their level of abstraction, location of implementation in the organization, type of waste they address, and whether they reveal, monitor or reduce waste. By providing a connection between waste/problem and appropriate tool, their work accomplished to assist companies in their Lean journey. Other researchers have attempted to group the Lean Manufacturing tools into bundles, having as a priority to facilitate the comprehension of people in managerial positions. Paez et al. (2004) proposed a simple categorization into two subsystems: the human subsystem that encompasses all the employee competencies required by Lean as Problem-Solving, Creative Thinking and Team Work and the technological subsystem that includes practices as Kanban, Autonomation and Production Smoothening. Shah and Ward (2003), in their work that was based on a vast number of completed surveys, assessed the possibility of Lean practices implementation by examining the effects of other contextual factors as plant size and age, and unionization state. In their article, they suggested the use of four bundles that present self-consistent and interrelated practices; Just-in-time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM) and Human Resource Management (HRM). In another research Shah and Ward (2007), applying an empirical method and information collected from a large number of manufacturers selected to represent a list of 48 Lean tools that could be categorized in 10 components: three components related to supplier involvement, one with customer feedback and six with internal organization issues namely, Pull, Continuous Flow, Setup Time Reduction, TPM, Statistical Process Control and Employee Involvement.

Lean tools can be applied separately or in combination; in such cases, the attempts produce improved outcomes. Certain research findings concluded that there is a synergistic effect when applying different Lean bundles contemporaneously, that conduces to augmented results in operational performance (Shah and Ward, 2003). A brief presentation of basic Lean tools follows hereunder.

2.5.1 The 5S

5S, also known as workplace organization or housekeeping, is a basic tool aiming to remove disorder from the workplace. Stretching farther than just cleaning up, it is a practice that can be applied in every business sector (Liker and Meier, 2006; Rüttimann and Stöckli, 2016). The 5S that originally included the acronyms for the Japanese words seiri, seiton, seiso, seiketsu and shitsuke, is a tool that attempts to incorporate the corresponding principles of organization, neatness, cleaning, standardization and discipline into the workplace (Gapp, Fisher and Kobayashi, 2008). In English, for consistency reasons, the 5S tool uses the acronyms of the words sort, set in order (or straighten), shine, standardize and sustain, as shown in figure 9 (Liker and Meier, 2006; Omogbai and Salonitis, 2017). In a study on small and medium-sized companies (SMEs) the 5S tool was found to be the top-ranked Lean practice applied, indicating a high level of implementation (Zhou, 2016). Another survey on 20 well-established companies of the manufacturing and service sector in Mexico revealed that the 5S tool is the foundation for other quality and improvement methods and that it also supports employee empowerment and continuous improvement (Ablanedo-Rosas et al., 2010). If 5S is not firmly instated in an organization, other Lean techniques as TPM, standardization and pull systems may lack effectiveness and fail to bring positive results (Suárez-Barraza and Ramis-Pujol, 2012). Finally, a survey on 161 UK enterprises of the manufacturing and service industries showed that 5S can act as the cement for the foundation of TQM implementation (Ho, Cicmil and Fung, 1995). A brief analysis of the philosophy deriving from the 5S follows.

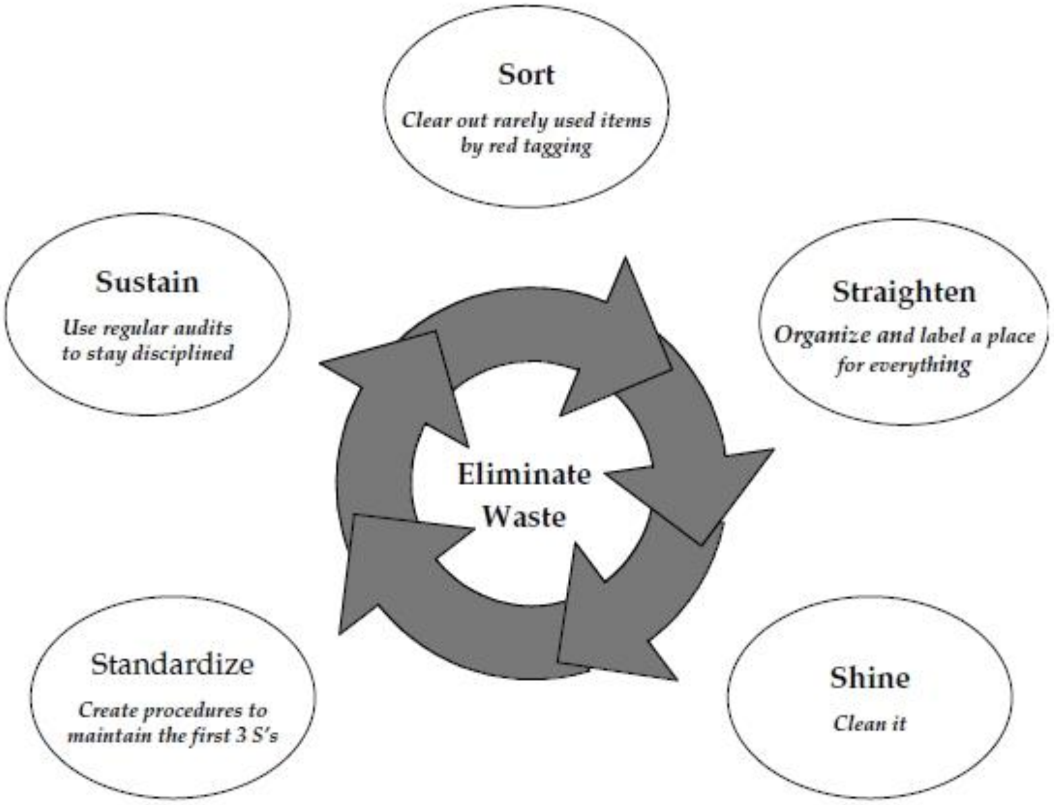

Figure 9. The 5S Process
Source: (Liker and Meier, 2006)

a. Sort (Seiri): The first step refers to organization in general. It is about distinguishing the necessary items from the unnecessary, aiming to the effective operation of the system (Kobayashi, Fisher and Gapp, 2008). According to Breyfogle (2007), tooling, machine parts and other material should be assessed based on their use; if they are not used within a month they should be tagged and moved to a special area. Removing such items from the production floor usually improves Flow (Heizer, Render and Munson, 2017).

b. Set in Order (Seiton): After having removed all unnecessary items whatever remains should be placed at the correct position. Everything should be at a logical location to improve ergonomics and avoid employee stretching and bending. As Bicheno and Holweg (2009, p.79) stated "The standard is The 'Dental Surgery'. Why? Because everyone can relate to that standard of excellence, and know the consequences of failure." Supplies, WIP and tools should be placed at the right position, designated by their address or dedicated markings that would indicate the location in times when they are being utilized (Imai, 2012).

c. Shine (Seiso): Shine relates to the physical cleaning of the workplace, an activity that includes floors, walls, equipment and tools. Correct implementation of Shine involves cleaning instructions and a cleaning schedule (Breyfogle, 2007). Shine can provide a useful service by discovering possible malfunctions during the cleaning procedure. Imai (2012) refers to a case where during removing debris, a possible fire hazard was revealed in the form of naked cables that had deteriorated through time losing their insulation properties. Cleaning includes checking and this can be stretched out to involve calibrating, monitoring and routine servicing (Bicheno and Holweg, 2009).

d. Standardize (Seiketsu): The fourth step depends upon the level of implementation of Sort, Set in Order and Shine. It relies on both personal and workplace cleanliness to ameliorate the effects of Kaizen (Kobayashi, Fisher and Gapp, 2008). Organizations must put in place procedures and standards to assure that the first 3 Ss are maintained. Such procedures have to be implemented based on an annual schedule by well-trained personnel (Imai, 2012). Variability in the production procedure can be checked by removing non-conforming practices or by altering them to incorporate modifications (Becker, 2001). This step also encompasses measurements, employee training and work balancing (Bicheno and Holweg, 2009).

e. Sustain (Shitsuke): Sustain relates to the participation of all stakeholders in the attempt to strengthen the implementation of the other 5Ss. It also involves internal audits on housekeeping (Bicheno and Holweg, 2009). This step is about augmenting employee morale through proper training in order to improve the quality of work life and of operational procedures (Gapp, Fisher and Kobayashi, 2008). As Hirano states (1995, p.38), "While managers can organize as many 5S campaigns and 5S contests as they want, without discipline the 5Ss will not last long". Not implementing this step will make the other 5Ss fail and the workplace will return to a bad status. Thus, managers must have in place procedures to assess the progress for each of the 5S and assure these procedures are followed correctly (Imai, 2012).

2.5.2 Total Productive Maintenance (TPM)

The main goal of TPM is to maximize the overall effectiveness of equipment during its total operational life by the motivation and engagement of all the employees in an organization. It moves in three axes: minimization of the number of defects, machinery failures and accidents. In order to accomplish the above, TPM involves activities as autonomous maintenance, organization of employee training courses, and establishing of a maintenance schedule within the framework of a well-designed management system (Ahmed et al., 2010). TPM is a scientific tool that spans the whole organization, involving all personnel with their equipment in terms of quality, maintenance and efficiency. Its foundation lies on the top management support towards the increase of employee morale and it requires effective communication between production lines' operators, technicians and engineers. TPM boasts great results in minimizing machinery breakdowns and improving equipment performance (Ahmad, Hossen and Ali, 2018). TPM brings positive results when applied in combination with 5S. It effectively increases equipment availability, enhances quality and minimizes rework (Rivera and Manotas, 2013). TPM was first introduced in 1971 when the Japanese company Nippon Denso Co. implemented a program called Total Productive Maintenance that granted them an Excellence Plan Award. TPM after its debut in Japan expanded rapidly in other countries as the USA (Sun, Yam and Ng, 2003). Ireland and Dale (2001) in their article referred to seven TPM pillars considered as crucial to its successful implementation: focused improvements, autonomous and scheduled maintenance, quality maintenance, employee education and training, equipment maintenance, and safety and environment. In their study of three global manufacturing companies that have incorporated TPM in their practices, the authors found that five of the pillars were common between them and that there were minor differences in how TPM was implemented. Additionally, all three companies demonstrated a substantial effort in employee education and training. TPM requires a synergistic relationship between every department of an organization. Cooperation of production and maintenance departments is of grave importance though; it provides the means to assure improvement in terms of quality, operational performance, capacity and safety (Park and Han, 2001). Among the various benefits of TPM, the most easily identifiable are the planning of maintenance costs and the decrease of maintenance workforce due to the fact that many maintenance activities pass over to the production department. Other benefits of TPM are the improvement of employee relations, the upgrade of operators to knowledge workers, enhanced problem solving, higher customer satisfaction and easier production scheduling. Park and Han (2001) state that the prerequisites to a successful TPM application are a well-established organization strategy as regards competition and investment in human resource management. The same study also concluded that TPM positively affects competitiveness: TPM increases Overall Equipment Efficiency and availability, which in turn tend to decrease stock inventories and finally decrease Lead Time.

2.5.3 Single Minute Exchange of Die (SMED)

SMED is a Lean tool that was first introduced by Shigeo Shingo and attempts to minimize the changeover times of production equipment. It is obvious that the implementation of SMED is a prerequisite for an organization to operate with small batches (De la Vega-Rodríguez et al., 2018). As Shingo (1985) mentions in his book 'A Revolution in Manufacturing: The SMED System', the setup activities can be discerned in two types: The internal setup which refers to exchanging machine formats, and the external setup such as moving formats from and to the production floor. It is obvious that only the internal setup activities require that the relevant production equipment be out of operation when they take place. It is a systematic procedure that leads the way to the reduction of production lot sizes which in turn decreases the WIP in the production facility and the lead time of finished goods. In figure 10, where external activities are colored orange and internal are colored green, it is clearly demonstrated that SMED is able to reduce changeover time by having external activities executed while the line is in operation (Lopes, Freitas and Sousa, 2015). The financial resources invested in material and storage space demands can also be decreased as a positive result of the SMED implementation procedure (Rivera and Manotas, 2013). Deros et al. (2011), in their case study of a battery assembling company, found that applying SMED techniques apart from reducing setup times revealed other benefits, as quicker response to customer demands, enhanced employee motivation due to the simplification of changeover activities, improved health and safety in the working environment and increased production flexibility. Maalouf and Zaduminska (2019) conducted a case study on a fish processing company applying VSM to identify waste and SMED to effectively reduce changeover time by 34% and improve the capacity of a production line by 11%. They addressed all the issues that arose from the unique nature of the processing sector and the food industry context in particular, proving the usefulness of the tool.

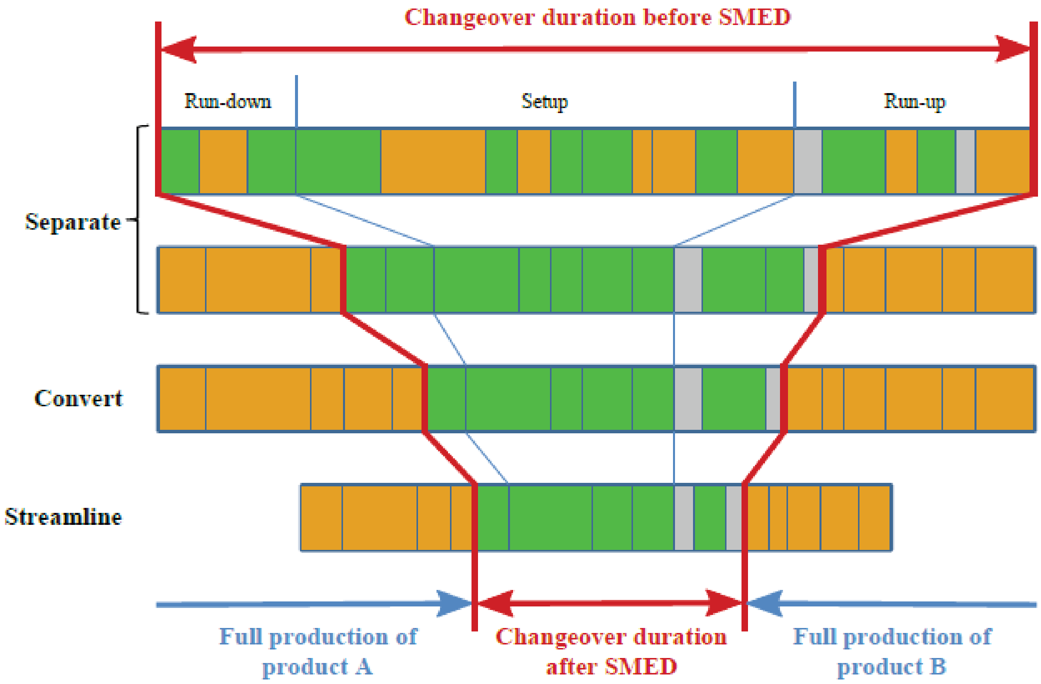

Figure 10. Main Stages of the SMED Methodology and Its Impact on Changeover Times
Source: (Lopes, Freitas and Sousa, 2015)

2.5.4 Kaizen

Kaizen as a term comes from Japan and it can be translated as continuous improvement. It became widely known by Masaaki Imai's famous book *'Kaizen, The Key to Japan's Competitive Success'* which assisted in the spreading of Kaizen philosophy in different business sectors (Suárez-Barraza and Ramis-Pujol, 2010). Kaizen's main objective is the mobilization and engagement of all employees in an organization in order to contribute positively to the organization's performance. As noted by Brunet and New (2003, p.2) "with every pair of hands, I get a free brain". The Lean teams can be divided in two categories: daily work teams that perform daily activities aiming to improve or standardize and Kaizen teams that assemble when demands for process improvement arise (De la Vega-Rodríguez et al., 2018). Kaizen has three discrete key features: a) it is continuous as its embedded nature represents an iterative journey towards efficiency and quality, b) it is incremental, differing from technology breakthroughs or reengineering projects of top management and c) participative, in terms of involving employee engagement and intelligence (Brunet and New, 2003). It includes other practical methods as Total Quality Control (TQC), JIT, 5S, Kanban system, TPM, Autonomation and Six Sigma (Shang, 2017). Shang (2017), attempting to relate Kaizen with innovation, supported the viewpoint that Kaizen processes can be viewed as continuous innovation; an enterprise can achieve innovation by applying Kaizen methods. Kaizen means improvement and the aspects addressed first are quality, cost and delivery. Quality, apart from finished goods, applies also to the internal processes that goods go through during their transformation, cost refers to all expenses involved from design and marketing to servicing the final products and delivery relates to the delivery of the right quantity when needed by the customer. The above, being the main goal of Kaizen strategy, require management support and cross-department cooperation (Imai, 2012). Kaizen events propose improvements in combination with VSM and are depicted in the future state map. In a case study of an Indian automotive parts manufacturer, a Kaizen event identified the root cause of defects and proposed a measurement that significantly reduced rejects costs (Dhingra, Kumar and Singh, 2019).

2.5.5 Just in Time (JIT) - Kanban

Toyoda Kiichiro, who set the foundation of the Japanese automotive industry was the first to conceive the JIT concept that later transformed into a production system. According to Ohno (1988), JIT is one of the main pillars of TPS and it can be described as waste elimination and efficiency improvement made possible through the procurement of goods at the desired quantity and at the time needed. Rivera and Manotas (2013) refer to JIT as applying the Pull discipline on information and material flows, producing only the required quantity at the time needed. JIT means smaller lot sizes and simple production procedures in order to reduce WIP and other unnecessary inventories. Initially, JIT referred solely to material flow but over time it evolved and related directly with the competitiveness of enterprises. When JIT is implemented in the manufacturing field, it takes into consideration resources apart from material flow, namely, workforce competencies and machining time, thus targeting all inventories from raw material to WIP and final product (Alcaraz et al., 2014). Ten practices underlie the JIT concept: focused factory, reduced set-up times, group technology, TPM, multifunctional employees, uniform workloads, Kanban system, total quality control, quality circles, and JIT purchasing (Davy et al., 1992). White, Ojha and Kuo (2010) suggested a sequential implementation of the practices mentioned above, that would augment the operational outcome: Quality circles and total quality control, associated with employee involvement, should be applied at the beginning thus providing a foundation for other practices, whereas Kanban and JIT purchasing near the end of the process. White, Pearson and Wilson (1999) in their interesting article on JIT implementation in Small and Large U.S. companies in the manufacturing sector, found that reducing setup times, multifunctional employees and Kanban practices create a similar outcome regarding organization performance irrespective of the company size. Many benefits have been reported to impute to JIT implementation, quality improvement, raise in productivity, the reduction of production cost and of waste and reworks being the most significant ones (Alcaraz et al., 2014).

Manufacturing Just in Time demands Pull techniques, Kanban being the most popular of such systems. It is a card-based system that allows the release of materials in the production when they are actually needed (De la Vega-Rodríguez et al., 2018). As defined by Worley and Doolen (2006, p.230), Kanban can be "Defined as a system that uses a card to signal a need to produce or transport a container of raw materials or partially finished products to the next stage in the manufacturing process". The Kanban system creates a need for manufacturing parts when a shipment demands withdrawing ready parts from the Kanban signal location (Motwani, 2003). Kanban is a visual management system that utilizes observable signals in various forms as cards, pictures, beacons, colored containers, or lines on walls that aims to reduce transactions, WIP and bureaucracy (De la Vega-Rodríguez et al., 2018). The most used Kanban cards are the production Kanban and the withdrawal Kanban. The production Kanban card follows the route of the containers during their production. Upon the production completion, this card is returned to the beginning of the procedure, whereas a withdrawal card replaces it and accompanies the container (Figure 11). All in all, Kanban is creating Pull within the JIT context so that the demands at each stage are met and the WIP inventories are minimized (Singh, Shek and Meloche, 1990).

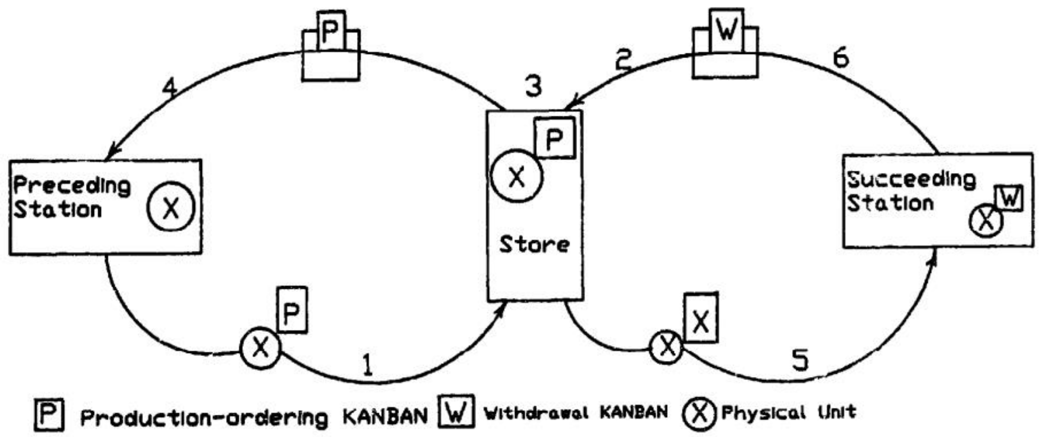

Figure 11. Mechanics of a Simple Kanban Cycle
Source: (Reda, 1987)

He and Hayya (2002) conducted a survey on 48 U.S. food industries which, based on descriptive statistics, regression, canonical correlation and factor analysis, concluded to the existence of a positive relationship between JIT application and food quality. However, another survey on 35 food SMEs showed that pull techniques are not frequently used (Dora et al., 2014), while in a large scale food production in a hospital environment, JIT and pull practices failed to produce positive results in terms of efficiency improvement (Engelund, Breum and Friis, 2009).

3 Research Framework

3.1 Lean Production in the Greek Food Industry

Industries in the Food & Beverage sector are in a continuous struggle to remain competitive irrespectively of their size. Customers' increasing pressure for high food quality and lower costs on the one hand and strict regulations for low food waste and environmental impact on the other, force industries to develop new approaches in terms of efficiency and quality management in order to retain profitability. A solution to these issues can be found in the adoption of Lean principles; however, the nature of the process of the food industries producing in large batches, makes it difficult for a straightforward implementation (Kennedy, Plunkett and Haider, 2013). Indeed, relevant academic research supports that organizations in the food sector face many obstacles in their attempt to implement Lean. Dora et al. (2014), concluded that Lean adoption in European Food SMEs progresses at a low pace and in any case it is not fully implemented by organizations due to barriers that derive from the unique features of the sector. The special characteristics of the Food sector will be presented later in the present thesis.

In Greece, there is lack of a substantial number of articles regarding Lean adoption. The case study that Psomas, Antony and Bouranta (2018) conducted on 9 Food SMEs was – to their knowledge – the first attempt to focus on Lean application in Greece. Contrary to the above findings from European Food SMEs they concluded that Greek Food SMEs apply Lean to a higher extent. These findings can be justified by the micro, macro and internal business environment. The unprecedented financial crisis forced Greek SMEs to find ways to reduce costs. Furthermore, their cooperation with larger companies from above through export might have been the leverage that tilted their existing systems towards Lean.

3.2 The Unique Features of the Food Industry

Nowadays, globalization and competition that rise all the more in every business field force enterprises to experiment with ways that might potentially lead to enhanced productivity. Organizations try constantly to improve their processes and their operation efficiencies. Being on the same page, food industries strive to minimize waste and to reduce delivery times due to the limited shelf-life of their products. Furthermore, food manufacturers have to comply with strict regulations in order to reduce their impact on the environment and to assure the safety of their products in terms of consumer health (Mahalik and Nambiar, 2010). According to Dudbridge (2011), there are three reasons for the uniqueness of the food industry: i) Political, referring to food safety, abundance and low pricing, ii) Food Business, emphasizing the critical character of supply chain and iii) Food fashion, relating with the complexity of food due to the constantly rising numbers of new launches. Furthermore, Dora et al. (2013b) in their study on lean implementation in European food processing SMEs refer to the unique factors of the industry namely, limited shelf life, multiple and diverse raw materials, seasonality and differences in harvesting. According to their article that reviewed literature on quality management in SMEs, the majority of studies in non-food SMEs focus on Lean, TQM and Six sigma, while findings in food SMEs indicate a focus on quality assurance systems as ISO, BRC (British Retail Consortium) and HACCP. Moreover, Gellynck and Molnár (2009) who conducted qualitative research on 54 companies of the traditional food sector in Italy, Hungary and Belgium, concluded with the identification of factors that determine the chain governance structure, such as various complexity chains, chain level, product and country differences and retailer size. King et al. (2008), in their article '*Making Cereal – Not Cars'* emphasize the differences between assembly manufacturers and process industries. The main difference is that while in an assembly plant the raw materials are of a tremendous variety and the procedure ends up in few final products, in a process industry few raw materials transform to create a vast product variety. Furthermore, King et al. (2008) point out another unique feature of the food industry: in many cases product families may include products that contain allergens, peanuts being the most common of them. In such cases having dedicated lines isn't always feasible, leaving companies with the only option of having to clean thoroughly and decontaminate their production lines every time they need to switch from a product containing allergens to other products.

Quality assurance plays a significant role in food industries. The main systems included in the quality assurance context are HACCP that controls the critical production steps aiming to the production of safe products, ISO which refers to the establishment of procedures that ensure the assignment of responsibilities, BRC that aims to assure food safety with a focus on retail products and IFS (International Food Standard) that is similar to ISO9001 with a focus on food safety (Van Der Spiegel et al., 2003; Dora et al., 2013a). However, QA systems represent only a part of a holistic quality system.

3.3 The Degree of Lean Implementation in the Food Industry

Industries in the Food Sector have implemented many Lean practices, VSM, 5S, SMED, TPM, Kaizen, work standardization to name but a few. There are many benefits from their application in production efficiency and finished goods quality, in employee involvement, in waste reduction and in lead time improvement (Kennedy, Plunkett and Haider, 2013). Dora et al. (2014), through their case study on Hungarian, German and Belgian food SMEs that adopted lean, showed that the most frequent Lean practices are TPM and the ones that have a customer or supplier orientation. On the other hand, Pull, Flow, Setup and Employee Involvement related Lean Tools had a low degree of implementation, while Statistical Process Control was almost not used. Another study on a Large food processing company in the UK identified the Lean tools involved to be related to waste elimination, continuous improvement and employee autonomy, and participation in problem solving. Furthermore, the study revealed that full Lean implementation isn't always the best option; a piecemeal approach in certain cases might bring better results (Bamford et al., 2015). Khusaini, Jaffar and Yusoff (2014), carried out an extended survey on Malaysian food industries of all sizes that revealed that Lean in this sector is still at its infancy. The tools applied more frequently were Kaizen and 5S, followed by Standardized Work and TPM while two of the most important tools, VSM and JIT, are not practiced at any degree. Psomas, Antony and Bouranta (2018), concluded that Food SMEs in Greece apply the majority of Lean tools such as Flow, Continuous Improvement, TPM, Standardization, Quality Management, Multifunctional Employees and Customer and Supplier Involvement (Figure 12). However, Pull – JIT is not adopted by many organizations, a conclusion indicating that the degree of Lean implementation can be improved. This study is not in accordance with the study of Dora et al. (2014) in terms of Lean adoption level, whereas – on the other hand - they present similarities in the Lean practices applied.

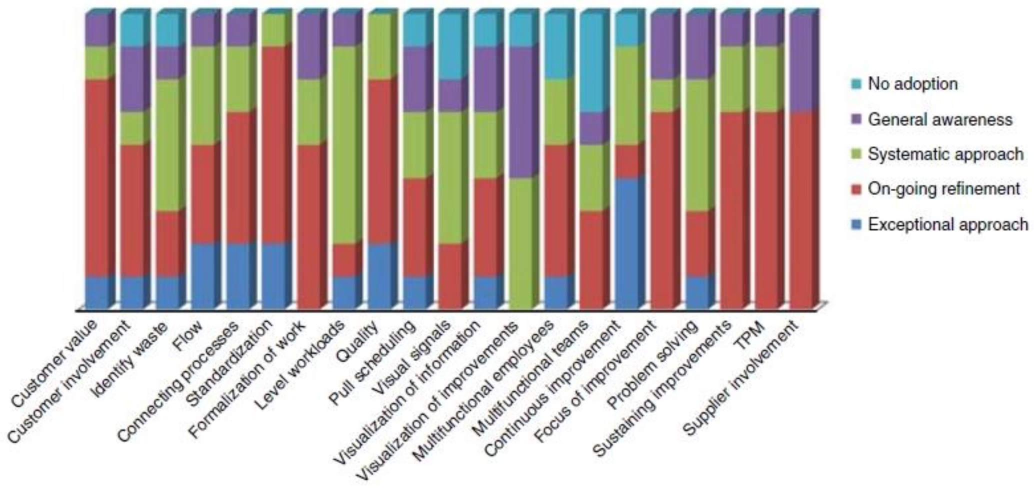

Figure 12. Level of Lean Principles Adoption in Greek Food SMEs
Source: (Psomas, Antony and Bouranta, 2018)

3.4 Barriers to Lean Implementation in the Food Industry

The success of Lean Manufacturing at Toyota inspired many companies of different industries, sizes and geographic positions around the world, to adopt Lean towards efficiency and productivity improvement. Nonetheless, Lean applications are far less in the process sector than in discrete plants due to some barriers that make companies reluctant to take the Lean journey (Abdulmalek and Rajgopal, 2007). According to Abdulmalek and Rajgopal (2007), the special characteristics that span the continuous process sector such as the utilization of large pieces of equipment, the long changeover times and the seemingly inevitable production in big batches, make managers hesitant towards Lean implementation. Melton (2005), referring to the forces resisting Lean in process industries mentioned resistance to change as the most important one; it is frequently met as questioning the validity of Lean thinking and little time availability. Other forces acting against Lean derive from production culture such as limited changeovers and big batches and from functional culture (Melton, 2005). Barriers to Lean implementation are also the lack of leadership, organization vision and workforce engagement. Moreover, food industries producing in large batches are not an easy field for Lean implementation (Lopes, Freitas and Sousa, 2015). There is limited research on the food industry regarding Lean implementation due to recent developments in the sector. The important research conducted by Dora et al. (2014), revealed the major barriers to Lean application by food SMEs: extended cleaning times, long product changeover time, product perishability, low resources availability and employees' lack of education and low engagement. Last but not least, the quality assurance demand that the production floor should be separated from the packaging area to avoid cross-contamination. A research by Jain and Lyons (2009) showed that the Lean model applied to the discrete manufacturing can not be adopted by food and drink industries. In their case study of six industries of the food and drink sector in the UK, they found that food manufacturers face difficulties to align production with demand due to fluctuations in demand, limited product shelf life, variability in process yield and raw materials, food quality regulations and the fact that prices are the main criteria affecting orders. These inhibitors force food industries to create and maintain buffers. However, food industries that are discrete in terms of their mode of operation are more likely to achieve production-demand alignment. The findings of a research on 68 organizations in the UK bear significant importance. Bhasin (2012) investigated the variation of barriers to Lean implementation with regard to the size of the companies participating in the research: for small enterprises, the cost of Lean application is the most important barrier, while for medium and large organizations the greatest inhibitor is the inadequate supervisory competencies. Insufficient management time and employee resistance to change are other significant barriers irrespective of the size of the organization.

3.5 Recapitulation of Literature Review - Formulation of Research Questions

In conclusion of the literature review, this study initially referred to the basic terms of Lean Production in order to facilitate the reader's understanding. After that, the VSM tool was presented as the main Lean practice for waste identification. Academic research on VSM application to companies of various sectors including the food industry was reviewed and the findings of relevant articles about how VSM was utilized to reveal waste and consequently minimize it in conjunction with other Lean tools were discussed. The study referred also to the innate disadvantages of the VSM tool, especially when applied to processes of high complexity, that inhibit the implementation of the standard VSM method. Then, the major Lean tools were presented along with the results of academic studies about their implementation in the processing sector and their impact on organization performance. Finally, the Lean adoption in the food industry with its unique characteristics was reviewed through significant articles and contradictory results have emerged in terms of the degree of implementation and of the Lean tools' application. The present thesis also attempts to investigate the applicability of Lean tools in the food industry. In order to fulfill the purpose of this research the following three research questions will be investigated:

1. Can Lean Production be applied to minimize waste in the food industry?

2. Can the VSM tool be utilized to improve Lead Time and Work in Progress in the food industry?

3. Which are the most applicable Lean Tools in the food industry?

4 Methodology

4.1 Research Strategy

Psomas, Antony and Bouranta (2018) that assessed Lean adoption in Greek food SMEs conducted a multi-case study gathering data from interviews. Concluding, they suggested that future research be based on objective evidence such as company archives as well as on direct observations. In this study that also attempts to examine the applicability of Lean in the food industry, in order to answer the research questions, a qualitative approach is followed by studying a certain case of a Greek food industry. In this case though, the author gets involved in the process and takes action attempting to address practical issues and to propose solutions. Hence, an action research methodology is selected over the classic case-study approach. According to Coughlan and Coghlan (2002), AR is research in action and it is literally concurrent with action. AR operates through an iterative process of planning, acting, assessing the action, and then planning based on the feedback of assessment; a cycle that is repeated. Furthermore, AR is participative as the members of the system are not mere objects of the study; they actually participate in the process described earlier. Finally, AR is an approach to problem solving because the researcher cooperates with members of the organization providing solutions to practical issues. In sum, AR may result in problem solving as well as in contribution to science (Coughlan and Coghlan, 2002). However, there are certain disadvantages when attempting an AR methodology: first, the researcher may become biased due to their high involvement in action (Halila and Tell, 2013) and second, the individuals participating in the research may feel embarrassed or get harmed in some way as a negative result of the research (Saunders, Lewis and Thornhill, 2009). Furthermore, AR is – compared to other research methods – not as precise, as Coughlan and Coghlan (2002) mention in their article. To tackle the ethical issue described above, the author of the present study works closely with managers and employees of the case company creating a trusting relationship (Halila and Tell, 2013). As regards the precision problem, similar to the approach followed by Karlsson and Åhlström (1996) and Vlachos (2015) that aimed to increase the validity of the research, data collection in this study involves direct observation, interviews and archival records.

Thus, the author adopts an action research approach, as depicted in figure 13, in order to address the research questions:

1. Can Lean Production be applied to minimize waste in the food industry?

2. Can the VSM tool be utilized to improve Lead Time and Work in Progress in the food industry?
3. Which are the most applicable Lean Tools in the food industry?

The research initiates with the data gathering step. The main data collecting method is direct observation complemented by interviews and archival records. Thus, the author literally walks the production process and obtains data from every production step and inventory accumulation point, while interviews of managers and employees provide relevant information to corroborate direct observation or other details related to the customer and the suppliers. Archival records are used to gather historical information. The data collection is further analyzed in the next chapter. After the relevant data is collected, VSM is applied to create the current state map. The next step is the analysis of data provided by the current state map which enables the identification of wastes. To enable the visualization of the future state map a second phase of interviews takes place providing data about possible improvements in the process. Finally, upon completion of the future state map, the actions required to reach it are planned and proposed to the company. Due to the restricted timeframe, the present thesis terminates at the action planning step, while the actual project will continue and be finalized in the next months.

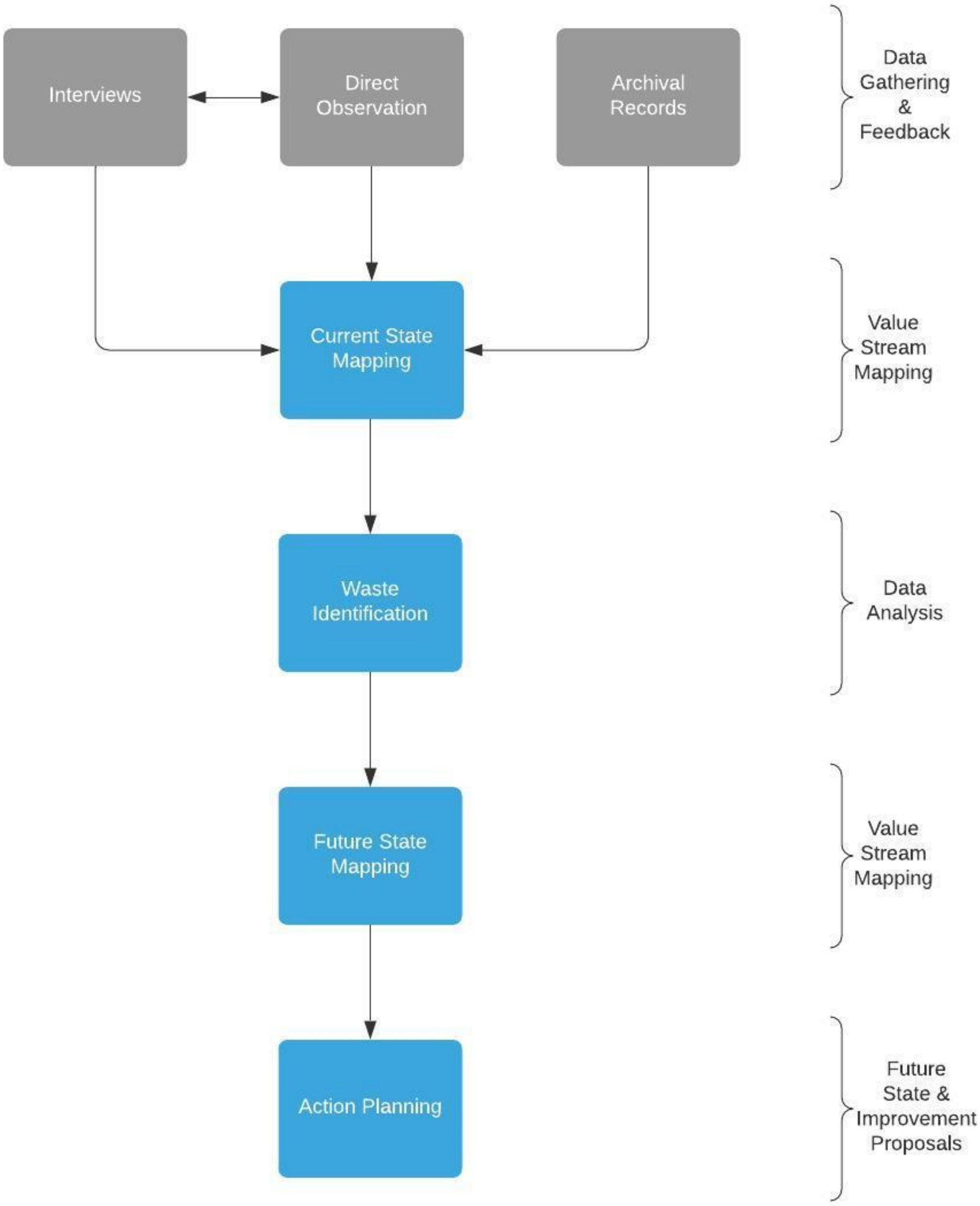

Figure 13. Research Strategy Flowchart
Source: Own compilation

4.2 The Case Company

The case company is a family-owned food industry in Greece, with a history of around one hundred years. For confidentiality reasons, the name of the company will not be revealed in the present thesis. The company is situated in Northern Greece, employs approximately 350 people, and has an annual turnover of about €80 million. The firm specializes in seed pastes, nut butters, wafers and confectionery, and holds a strong position in the domestic market. The product portfolio is extended; around 800 products (commercial codes) in more than 20 product families are produced in state-of-the-art facilities and then distributed to more than 50 countries all over the world. The company also boasts a significant number of own-label products well established in the market, along with long-lasting cooperation with multinational organizations in Europe and the USA. In terms of production processes, the company utilizes advanced technology equipment, high working standards and applies quality management systems such as HACCP, ISO9001, ISO14001 and IFS. In addition, the organization during the last years has put in place a continuous improvement system, in its attempt to continually optimize all procedures. As regards Lean Production, it is not adopted by the organization except for 5S and SMED. These tools are applied on the production floor for reasons of housekeeping and performance; however, they are not implemented as part of a Lean Production plan but as proven industrial practices. On the production floor, batch and continuous processes cooperate succeeding one another according to the unique features of the products.

This thesis will deal with products within the nut butters family, a rather new yet dynamic product family that has been increasing its market share all the more during the last years. The production process and layout had been determined since the launch of the products and their early steps in the organization. Today, the company needs to i) increase the capacity of this specific production line in order to meet customer demands in the future and ii) to optimize the whole process. The aim of this study is to investigate if Lean Manufacturing can be applied to minimize waste in the production procedure and which Lean practices are the most applicable towards this end. Furthermore, to show how important KPIs as Lead Time and Work in Progress (WIP) can be improved by the implementation of the VSM tool.

4.3 Data Collection Methods

4.3.1 Direct Observation

According to Voss, Tsikriktsis and Frohlich (2002), one of the most important methods in collecting case-based data is direct observation. It includes observation of processes and meetings and it can be either systematic in nature or more casual. In action research, evidence derives from the researcher's involvement in the production process. The researcher observes and takes part in the client system in problem solving and decision making. Such observations take place in formal or informal settings generating data.

Central to the action research is how to obtain data through observation and at the same time be of assistance to the organization (Coughlan and Coghlan, 2002). Vlachos (2015) mentions that the main issue of direct observation is reliability; on the other hand, Karlsson and Åhlström (1996) argue that direct observation can provide an insight to organization procedures revealing differences between how things are declared to take place and how they are actually performed. In the present research, VSM is the main Lean tool applied and according to Rother and Shook (1999) when applying VSM direct observation plays the most significant role in data gathering. Thus, the author of the present thesis obtains data by walking the whole process; evidence emerges from casual observation of inventory accumulation points or even from precise measurements regarding cycle times or changeover times where the author literally uses a stopwatch to collect production details.

4.3.2 Interviews

Interviews are significant sources of data used in both surveys and case studies. They can be very helpful by providing answers to "how" or "why" questions, attempting to explain key events or the way people act in various situations (Yin, 2018). In the present action research, interviews are conducted with the company's managers in sales, production and procurement in order to provide an insight into how specific procedures are established and run in the organization. In order to obtain more focused evidence, operators in every discrete production step and technicians are interviewed as well. According to Voss, Tsikriktsis and Frohlich (2002), interviews can be unstructured, focused, or structured like a questionnaire. As Vlachos (2015, p.1356) states "In action research, interviews take the form of informal and formal discussions". Thus, in his article, he conducted semi-structured open-ended interviews. Similar to his approach, the present thesis adopts data gathering by semi-structured open-ended interviews. The interviews are conducted in two phases. The first phase regards interviews aiming to collect data about the production process and how the process is run at the initial state. The interviewees are the production manager, three operators and a technician. Furthermore, the procurement and sales manager are interviewed to provide evidence about raw material deliveries and customers' orders quantity and frequency. After the application of VSM and the mapping of the current state, a second phase of interviews takes place. During this phase, the interviews are more focused and aim to identify areas of improvement that are depicted finally in the future state map of VSM. In Appendix I the interview questions are listed.

4.3.3 Archival Records

Researching archival records is another data collecting method used to increase reliability and for fulfilling triangulation criteria. Furthermore, when the research regards current cases, gathering historical archival evidence is almost mandatory (Voss, Tsikriktsis and Frohlich, 2002). In their action research, Karlsson and Åhlström (Karlsson and Åhlström, 1996) analyzed archival documents aiming to obtain significant data having also in mind the possibility of selective survival of such documents. Vlachos (2015) in his action research of a Tea industry recognized the significance of archival records in increasing the reliability of his research. Thus, he utilized archival documents such as reports to gather information about the organization's performance and create the current state map, being in accordance with Rother and Shook (1999) who mentioned that in applying VSM company archives can be used to retrieve data on machine uptime, defects and changeover times. In the same manner, for the present research analyzing archival records is a secondary data collection method. However, data obtained from company archives are restricted solely to equipment uptime and changeover times. The records utilized are reports from the company's continuous improvement system. An example of such reports in the Greek language, partially blurred for confidentiality reasons, is at the end of the present thesis in Appendix II. This document is a weekly report regarding the relevant products, where the performance of the packaging process is recorded on a daily basis. Line 24 of the document corresponds to equipment uptime.

4.4 Description of the Production Process

The selected production line produces two products in terms of the kind of nuts processed. However, this study will deal with the production process of one of them because it holds by far the biggest sales percentage of the two. Furthermore, there are two variations/flavors of this product which from now on will be referred to as Nut Butter A and Nut Butter B. The most common packaging is a tray that contains both products at an equal percentage. The production process is shown in figure 14 and a detailed description of the whole procedure follows hereafter:

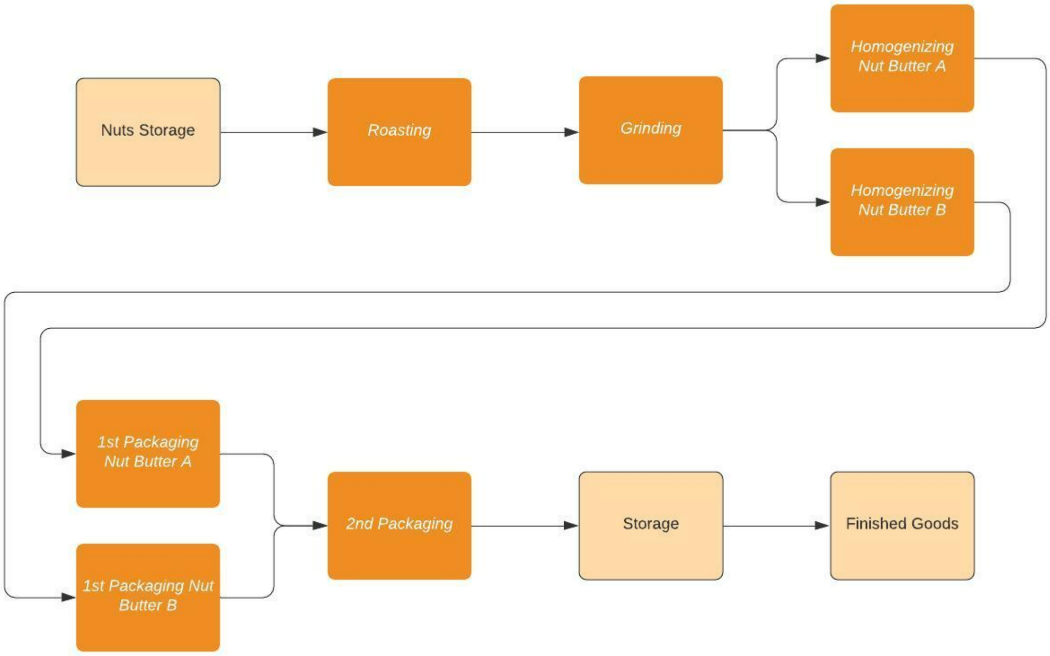

Figure 14. Flow Diagram of the Production Process
Source: Own compilation

Roasting

The company uses a semiautomatic batch roaster that has a capacity of 165kg/batch and a batch time of 34 minutes. The equipment is installed in a building that houses also the storage facility for the nuts. The sole operator of the equipment is responsible for the feeding of the raw material, which arrive in big bags of 1.250kg, to the roaster's hopper. From there, the nuts are forwarded to the relevant chamber, where the roasting procedure takes place at the appropriate temperatures. After this step, the operator opens the outlet and the roasted nuts are forwarded to the cooling stage of the roaster. When the roasting chamber is completely empty the operator allows the next batch in. At the outlet of the cooling stage, the nuts are packed manually in plastic containers that hold approximately 11kgs. The plastic containers are placed on pallets that are weighed and signified by adhesive stickers. This production step operates at three shifts, on weekdays, to be able to meet the demand. During the first shift, the pallets of roasted nuts are transported by forklift to the next production step, whereas during the other two shifts the roasted nuts pallets are stored temporarily in the roasting area until the following morning. It is a time-consuming operation with a total daily capacity of 7.000kg and since it is the only one that runs on a three-shift basis, it clearly is the bottleneck in the process. Furthermore, an average of 1.800kg of nuts per day is roasted in order to be ground and sold to another customer.

Grinding – Homogenizing

The main equipment in this step is a grinder and two homogenizers, one for each of the Nut Butter products. The equipment is installed in another building where the rest of the production process takes place. The grinder operates in a continuous mode at a capacity of 1.100kg/hr while the homogenizers are batch-wise equipment that can process up to 3.000kg of finished product per batch. There are two operators assigned to this step. The first operator manually feeds nuts to the grinder. From there, the nut paste that is produced is pumped in continuous motion into the homogenizer of Nut Butter B at a quantity defined by the recipe followed. The rest of the ingredients have been added earlier in the homogenizer by the second operator. After filling the homogenizer of Nut Butter B, the operator pumps the nut paste produced by the grinder into the homogenizer of Nut Butter A. After the two homogenizers have been fed with the nut paste from the grinder, the latter is used to grind roasted nuts to be sold to the customer mentioned earlier, at an average quantity of 1.800kg per day. The homogenization procedure starts as soon as the filling begins. With the end of the filling, the Nut Butters A and B are pumped into dedicated storage tanks of 6.000kg capacity, which act as a buffer prior to packaging. The emptying of the homogenizers takes about 2 hours to complete. The second operator prepares and feeds all the minor ingredients and performs other secondary activities. This production step operates in one shift. The average grinding time is 3,27sec per kg of nut paste and the average homogenizing time is 2,4sec per kg of Nut Butter for each of the homogenizers. At this point, it has to be mentioned that each kilogram of nut paste is used to produce approximately 1.08 kilograms of Nut Butter.

1st Packaging

The products under consideration are packed in glass jars of 0,45kg capacity. The packaging line which is placed in a different hall of the same building which houses the grinding and homogenizing step consists of a glass cleaning machine, a filling machine, a capper, a foreign body detector (Xray) and an automatic labeler. The machines are connected upstream and downstream with conveyors and Flow is assured in the packaging line. Three operators are assigned in this step. The first operator is at the beginning of the process feeding empty glass jars to the cleaning machine. The second operator is at the end of the procedure placing the filled, capped and labeled jars on wheeled shelves. A third operator takes care of the replenishment of caps and label rolls and of the smooth operation of the line. Every day the line packages the Nut Butter A during the first half and the Nut Butter B during the second. The second operator, during the packaging of Nut Butter B, places jars on the trays, as will be described in the next paragraph. This production step operates in one shift.

2nd Packaging

The glass jars are packed in carton trays that contain four jars of Nut Butter A and an equal quantity of Nut Butter B jars. As mentioned before, during the first half of the shift the line packages the Nut Butter A and the jars are temporarily stored on wheeled shelves. When Nut Butter B starts to flow through the packaging line, the secondary packaging procedure is initiated. Four additional operators are involved in this step while the second operator from the previous step places jars of both products in the carton trays. During the first half of the shift, these operators prepare the best part of the quantity of carton trays and carton covers that will be used when the 2nd Packaging is initiated. After that, the first operator forms the trays from blanks, the second retrieves the jars of Nut Butter A from the wheeled shelves and the third one places a carton cover on the filled tray and forwards it to the case sealer. At the end of the procedure, a fourth operator loads the ready trays on pallets. Then the pallets are stored for 24 hours in a dedicated chamber at a controlled temperature. Finally, the pallets with the finished goods are wrapped with stretch film and are ready for delivery to the customer.

4.5 Data Gathering and Feedback

As explained earlier the data collection methods followed in this research are direct observation, interviews and archival records. The author obtains data by as many sources as possible in order to increase the validity of this study. The main data gathering method is direct observation which in combination with semi-structured interviews provides the majority of information necessary for the VSM application. Archival records are utilized to obtain historical data; however, they are used in certain cases only. Data gathering from interviews takes place in two phases. During the first phase, data is collected by interviewing company's managers in sales and procurement so that the author gets all the complementary information such as the frequency and quantities regarding orders from the customer or to the suppliers of raw materials. Furthermore, interviewing the production manager, three operators and a technician provides data concerning cycle times, changeover times, available times, inventories and production scheduling. After the current state mapping, feedback is given to the personnel of the case company aiming to familiarize them with the results of the VSM application. Then the second phase of interviews follows, aiming to help the author conclude to the action plan which, encompassing the appropriate Lean tools, will lead the company to the improved future state. Recapitulating, figure 15 shows how each type of data is retrieved.

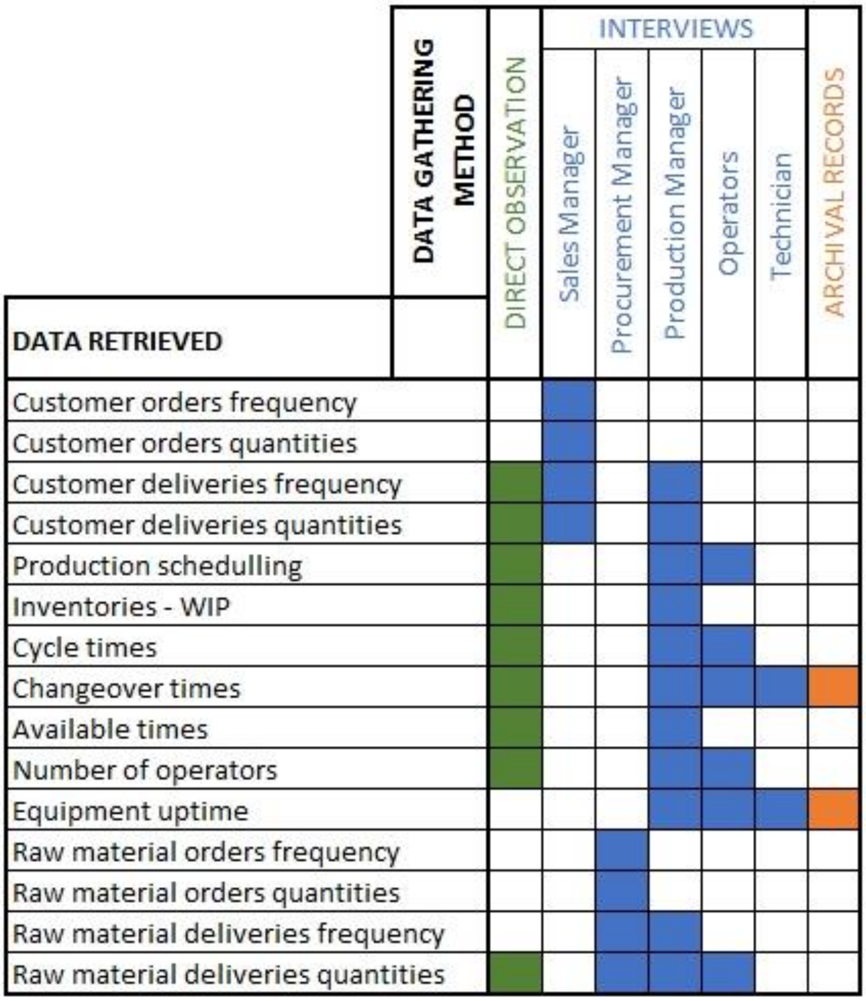

Figure 15. Data Gathering
Source: Own compilation

4.6 Current State Mapping

In order to create the current state of the Value Stream, the procedure described in *Learning to See* (Rother and Shook, 1999) was followed. Data collection begins at the side of the customer and then, working backward through each production step, ends at the raw materials. For the purposes of the present thesis, data regarding production processes was obtained by field observation and interviews, whereas data about sales and procurement mostly by interviews. Organization’s archives were used for pieces of information regarding equipment uptime and changeover time.

In the current state map, the customer requirements are shown at the upper right corner as a factory icon with a data box underneath it. Each production step is depicted as a process box and the associated data box records information as number of operators, cycle time, changeover time, available working time and equipment uptime. Inventories are shown as warning triangles and are placed in every location where product accumulates. At the supplier's end a factory icon represents the supplier and the relevant data box records the raw material deliveries. A truck icon and a wide arrow depict movement of raw material and finished goods, while striped arrows represent Push movement of intermediate or finished products. For the visualization of the information flow, narrow lined or lightning-like arrows are used to indicate information delivered by paper or transmitted electronically accordingly. The mapping of the information flow takes place from the right side of the map to the left and at the top half of the map. Information about production lead time and processing time is recorded at the bottom of the map; right below the process boxes and inventory triangles, a timeline is drawn to depict this data. Each individual lead time deriving from inventories or processing time of each production step is recorded on this timeline, providing the total time for the nuts to go through the whole process in their transformation into the finished product. The total processing time is also depicted underneath the production lead time at the right bottom corner of the map. The lead time calculation is obtained by dividing the inventory quantity by the daily demand of the customer. The data gathered in this way can be recapitulated as follows:

Every order from the customer is exactly a full truckload that contains 33 pallets of 952 jars each; a total of 31.416 jars divided in equal quantities of Nut Butter A and Nut Butter B. The customer usually places two orders that have to be delivered in a week's time. Hence, the daily demand can be calculated as 12.566 jars. Each delivery takes place upon completion of the associated order quantity. As regards the information flow, the sales department receives the orders and enters them to the ERP system. From there the information is available to the procurement and production departments in order to organize their consequent actions. The procurement manager, based on the current customer orders and on the annual forecast, places two or three orders annually to the suppliers of the nuts. The relevant deliveries are executed in full containers of 20 big bags and scheduled at a frequency of six containers monthly, delivered in pairs. The production manager schedules the production weekly and communicates with the people responsible for each production step by handing them daily job orders. All process information is given hereinafter in the order of material flow; lead time information is converted so that it is based on the finished product packaging (the jar):

- Observed inventory of raw material: 50 big bags corresponding to about 150.700 jars. The lead time is 12 days.
- Roasting: Three shift operation with one operator. Since a 600kg/shift quantity of nuts follows another path after grinding, the available time is calculated as 21.400sec/shift. Additionally, the batch cycle time is 34min, the uptime is 100% and there are no changeovers. The inventories accumulate at two places with a total of 26 pallets of roasted nuts containers corresponding to 31.824 jars. Thus, the lead time is 2,5 days.
- Grinding – Homogenizing: Due to the continuous flow of the grinder and the absence of intermediate inventories, this step is represented on the current state map by a single process box. It is a single shift operation with two operators. The total cycle time is 7 hours, the uptime 100% and there are no changeovers. The available time of the grinder is restricted due to capacity reserved for the other customer and it is calculated as 22.900sec; however, the available time of the homogenizers is 28.800sec. The amount of product accumulating in the two storage tanks was observed to be approximately 3.000kgs of Nut Butter which corresponds to 6.667jars. The lead time deriving from this point of WIP is 0,5 days.
- 1st Packaging: One shift operation with three operators and available time of 28.800sec. The total cycle time is 1,9sec, the uptime is 89% and the changeover time is 31min. The wheeled shelves loaded with Nut Butter A jars hold in total 6.283 jars which results in a lead time of 0,5 days.
- 2nd Packaging: One shift operation with four operators and available time of 28.800sec. The total cycle time is calculated at an average of 1,5sec and the uptime is 100%. There are no changeovers. Inventory accumulates at two places: a day's production of 12.566 jars after the 2nd packaging is transferred in a storage area for the cooling stage that takes 24 hours, while another amount of 18.850 jars awaits shipping. In total, the associated lead time of this step is 2,5 days.

The mapping of the current state, which is depicted in figure 16, was developed with the use of the Lucidchart software. The timeline at the bottom half of the map reveals that the total production lead time is 18 days, whereas the total processing time is 454min (approximately 1 day).

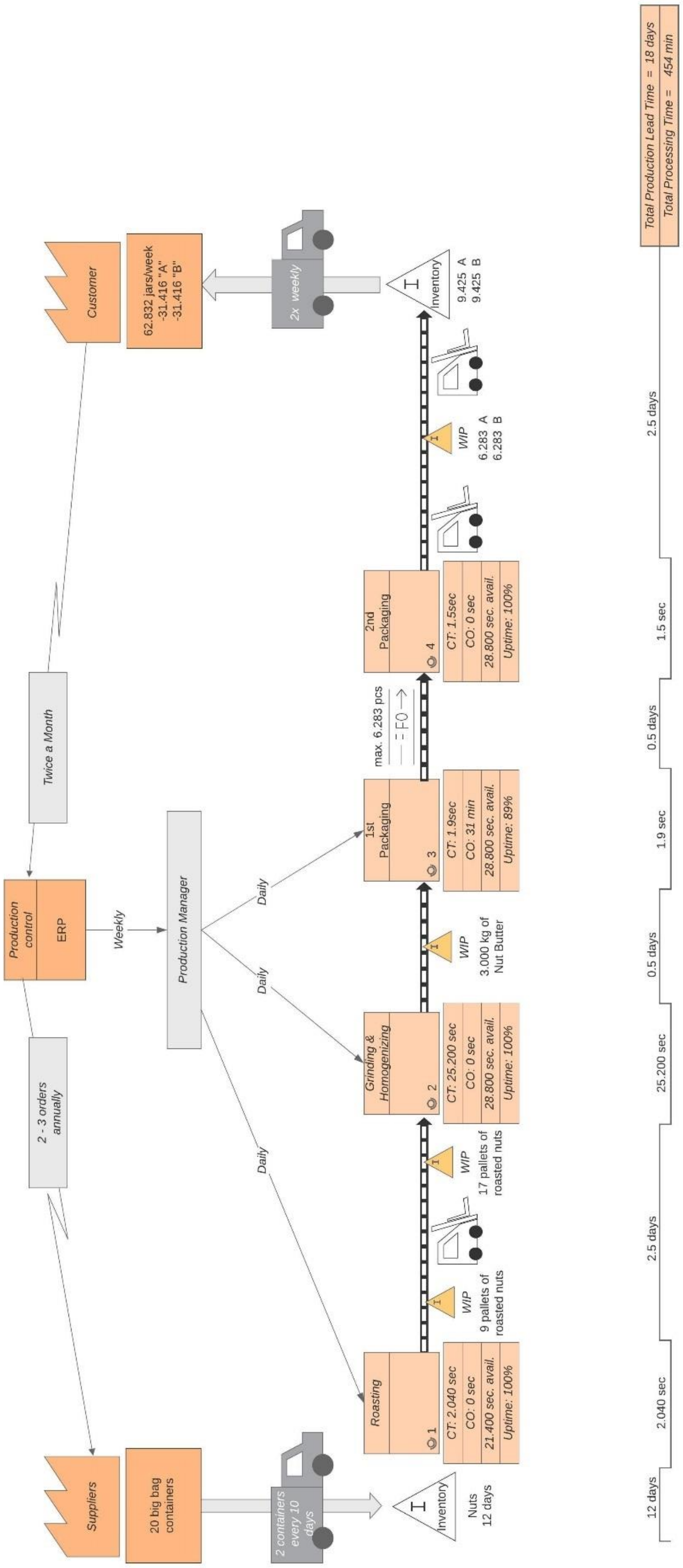

Figure 16. Current State Map of Nut Butter Products A & B
Source: Own compilation

4.7 Waste Identification

Similar to the case study conducted by Abdulmalek and Rajgopal (2007) the current state map of the case company reveals various issues. Large inventories exist at several places, from raw material and finished goods storage areas to WIP between processes. Additionally, the total processing time of 454 minutes is only a fraction of the total lead time which is 18 days. In other words, the value-added time represents only 5,3% of the total time needed for the transformation of raw material to finished goods ready for shipping. Of course, extended lead time is anticipated in cases where large inventories exist because the parts have to wait longer before the next production step. Furthermore, almost each process receives a dedicated production schedule daily. This means that the production process is based on Push systems which in turn tend to enlarge inventories. According to Rother and Shook (1999), the batch and push systems where every process receiving its own schedule operates as an isolated island, conceal overproduction which is the most significant waste as mentioned earlier. Seen from Ohno's perspective the identifiable wastes in the current state of the given process are unnecessary inventories, waiting and transportation; however, a closer look reveals also the waste of overproduction which in turn affects all other types of wastes.

Another observation deriving from the current state map is that the Roasting step is the bottleneck in the whole process; it must operate in three shifts in order to cope with the demand. To analyze this further, if the capacity of the four production steps is converted into jars per minute, the chart of figure 17 results. Clearly, the bottleneck is the Roasting step, something already known to the company, but figure 17 also reveals that the next bottleneck is the 1st Packaging with the Grinding/Homogenization step falling very near, at 31.5 jars/minute and 31,7 jars/minute respectively.

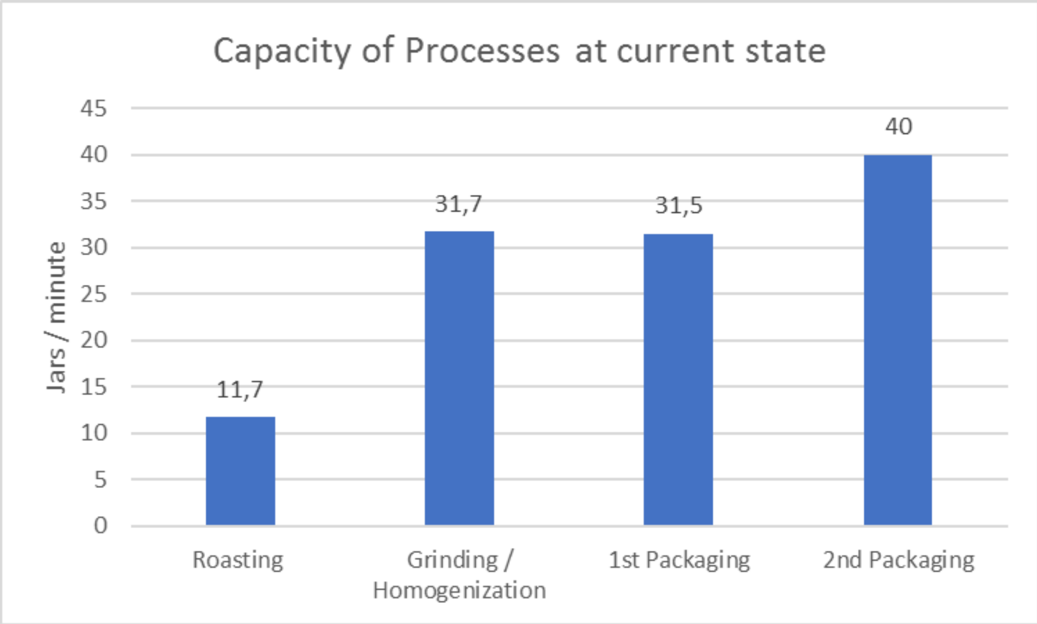

Figure 17. Capacity for All Production Steps at Current State
Source: Own compilation

Further to the production times mentioned up to this point, another of great significance is the TAKT time. It can be calculated as the available production time divided by the production units required by the customer, and it indicates how well a specific production line performs in relation to customer demand (Chowdhury et al., 2016). The TAKT time of the case company is 28.800sec / 12.566jars = 2,3 sec/jar. Following the procedure of Rother and Shook (1999), with the conversion of all cycle times to represent process time per unit of finished goods - in this case seconds per jar - the chart of the company's cycle times compared to the TAKT time results in figure 18. The first observation is that the cycle time of the roasting procedure is much higher than the Takt time. This means that the roasting step doesn't meet the customer demand in a single shift operation and in order to do so, the management operates this process in three shifts. The other three procedures have cycle times lower than the takt time, meaning that their production capacity has the ability to meet the demand. Rother and Shook (1999) emphasize the significance of avoiding big differences between cycle times and takt time mentioning that if one cycle time is a lot lower than the takt time then production problems surely exist in the given process. However, these problems might remain hidden by the high capacity of the process or might not be tackled appropriately due to the lack of incentive.

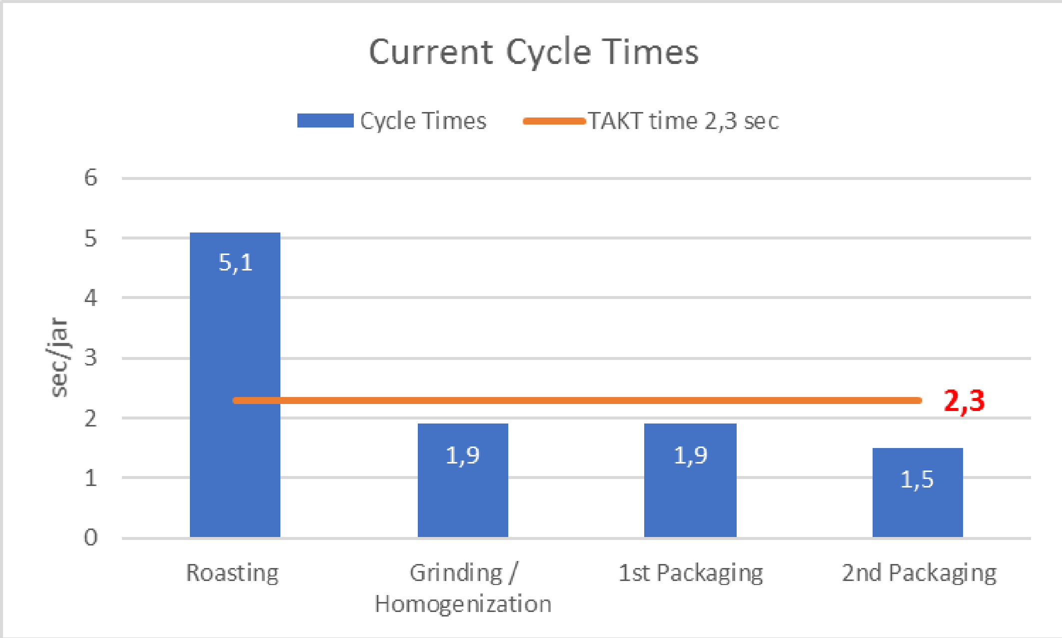

Figure 18. Current Cycle Times
Source: Own compilation

5 Results

5.1 Future State Mapping

The case company, as mentioned earlier, has acknowledged the existence of a bottleneck process – the roasting step – and is determined to take action to improve the capacity of the production line. Thus, the mapping of the future state must take into consideration that new equipment will replace the batch roaster. The company, after conducting a market search, has opted for a new continuous nut roaster that fulfills all criteria in terms of food quality and safety and is well within the predefined budget. This piece of equipment will still be able to handle raw material in big bags and will run at a roasting capacity of 1.000 kilograms per hour, reducing the shifts required for this process to one. As a next step that will minimize the waste of transportation, a change in the layout is called for. Hence, it is proposed that the roasting procedure equipment be installed at the hall adjacent to the grinding and homogenizing. This way, the nuts from the new continuous roaster's outlet will be transported pneumatically in two new intermediate silos and from there with another pneumatic transport to the feeding screw conveyor of the grinder. It is obvious that the need for the temporary packaging of roasted nuts in plastic containers along with the transportation activity of the relevant pallets to the grinding step will cease to exist. The process details of this updated process step are: after deducting the 1.800kg/day quantity of nuts that follows a different path after the grinding procedure, the available time is calculated as 22.320sec/shift. Furthermore, the new cycle time will be 3,6sec/kg or equally 1,5sec/jar of finished product. Finally, the uptime is anticipated to be 100% and there will still be no changeovers.

To be able to create the future state map and to identify the lean tools that will minimize the wastes revealed by the current state map, the procedure by Rother and Shook (1999) that involves answering the eight future state questions was followed :

The Takt time as calculated earlier is 2,3sec/jar. This means that the customer demand will be met only if the case company produces one Nut Butter jar every 2,3 seconds. It is a number that emerges from the customer side and it declares the rhythm the process must follow to deliver the finished goods on time.

The case company already produces directly to shipping. The customer requirements are quite stable allowing for a high readiness level as regards raw and packaging material. Furthermore, since the type of packaging is a custom selection by the customer, building to a finished goods supermarket would only prolong the lead time. The production currently takes place through a pull system initiated by the customer fulfilling the Lean principles.

The next question refers to the introduction of continuous flow processing wherever possible. A close look at the current state map reveals that almost every process is isolated downstream as well as upstream. For example, the grinding and homogenizing step is connected through buffer tanks with the 1st packaging, whereas the roasting procedure is completely isolated in another building. The first attempt to consider Flow introduction in the system concludes that such a Lean tool cannot be easily implemented. Processes that run in continuous motion and at high capacities cannot be bound together without WIP inventories because several micro stops that are likely to occur will result in stoppages of bigger parts of the production line.

One of the most important questions towards the development of the future state map is whether pull-based supermarket systems will be incorporated in the line or not. Starting from the customer's side the first inventory observed is the one related to the 24hr storage of finished goods at the desired temperature. As there isn't any other process downstream and since the production line produces directly to shipping, no changes can be implemented at this point. Moving upstream, the next WIP accumulation point between processes are the two buffer tanks for the storage of Nut Butter A & B before the packaging procedure. At the current state, the grinding and homogenizing step produces Nut Butter based on its own production schedule applying a push-based production system. At the future state, this can be replaced by a pull system controlled by the level of the storage tanks. Thus, the storage tanks will give an electronic Kanban signal, visible to the operators of the grinding and homogenizing, whenever their level falls below the desired point. Only then the operators of this step will initiate production. The filling quantity at the homogenizers will also be altered using production leveling. If it is reduced to 2.000kg then the cycle time of the step will be dramatically reduced as well, without any compromise on the capacity. Hence, the storage tanks will act as an intermediate supermarket system between the 1st packaging and the homogenizing. The next WIP accumulation point will be the storage silos of roasted nuts. Just as the Nut Butter storage tanks, these silos will act as a pull-based supermarket system between the new roaster and the grinder. Whenever a homogenizer starts producing it will "pull" nuts from the silos and when the roasted nuts level falls below a predefined level a Kanban signal will prompt the operator to start the roasting procedure. The new continuous roaster though, is a piece of equipment that needs several adjustments during start-up, hence, each Kanban must refer to a quantity equivalent to the batch of a homogenizer. In the future state, with the installation of the intermediate silos, the WIP inventories between roasting and grinding will be minimized. Of course, these silos will act as buffers in the procedure, but their capacity will be limited; a total of 9.000 kilograms will suffice to provide storage for a safety stock of a day's operation of the next production step. On the other hand, however, their presence will not affect dramatically the lead time. During the first period of implementation, the buffer stock will be around 6.000kgs. A few weeks after the installation of the roaster though, attempts will take place to reduce the roasted nuts stock down to 3.000kgs. The final point of inventory is at the storage of the raw material in big bags of 1.250kg. A third supermarket must be introduced at this point aiming to reduce the stored quantity of nuts. There are certain difficulties though: First, the deliveries take place in full containers that carry 20 big bags. Second, they have a long lead time from the supplier that approximately reaches six weeks. These facts make it impossible to send Kanban to the supplier and to receive raw material according to them. So, the proposal is that the supermarket aim to facilitate the production control in managing deliveries according to the actual usage of raw materials. A Kanban should be placed at the storage area indicating the expected day of the arrival of raw material. The deliveries will still take place at the same frequency of six per month, but the containers will not arrive in pairs but one by one every five days approximately. This way the relevant inventory will be reduced to 30 big bags resulting in a significant improvement in the total lead time.

The case company must schedule only one point in the production line in order to avoid overproduction. This point – called the pacemaker – is the one farthest downstream in the value stream so that every preceding process is pulled by it and there is no supermarket after it (Mcdonald and Aken, 2002; Abdulmalek and Rajgopal, 2007). Based on the above the process that should be the pacemaker is the 1st packaging. Downstream of it there is only the 2nd packaging process connected to it with a FIFO lane while right before it there is the supermarket of the two Nut Butter storage tanks.

As regards the leveling of the production mix at the pacemaker process the current situation will be considered. Both products are produced in every shift; Nut Butter A is produced during the first half of the shift whereas Nut Butter B during the second. Furthermore, shipping to the customer refers to a full truck which makes any attempt of leveling of low significance since there will be no improvement at the lead time. Considering also that every changeover at the 1st packaging process takes 31 minutes and that the available time for changeovers is 32,9 minutes (this results by deducting from the available time of the step the time required for the production to meet the demand divided by the uptime percentage), it is understood that there is no available time for more changeovers. Thus, the production mix will remain as in the current state.

To determine the increment of work that the production line should release at the pacemaker process the two products will be considered independently. The Nut Butter A jars are manually loaded on wheeled shelves that can hold a quantity of 898 jars. The required number of Kanbans (shelves) to meet the daily demand is 7 and the work increment is 898 jars corresponding to 28 minutes approximately. As for Nut Butter B, when it flows through the 1st packaging it is directly connected with a FIFO lane to the 2nd packaging. Every day the demand is for 13,2 pallets of combined products trays each one holding 476 jars of Nut Butter B. Thus, 13 Kanbans will be required and the work increment for Nut Butter B will be 484 jars corresponding to 15 minutes approximately.

The improvements needed to reach the future state are numerous: given that the new roaster is a major investment decided by the company in the short term, redesigning the production flow is called for. Having this as a starting point many lean tools will be applied namely, Pull-based production system, supplier involvement, SMED, TPM and 5S, production leveling and layout change. The lean tools proposed to reach the future state will be analyzed in the next section of this thesis.

To sum up, the future state map visualizes many changes such as the introduction of three pull-based supermarket systems, the reduction of the raw material inventory that will correspond to 7,2 days, and of the WIP quantity after the roaster that will add only 1,1 days to the lead time. Furthermore, the new production data of the roasting step that will operate in one shift with one operator and will have a cycle time of 3,6sec/kg or equally 1,5sec/jar of finished product, an uptime of 100% and no changeovers. Additionally, the Kaizen bursts at the 1st packaging aiming to reduce the changeover time and to improve the uptime and at the grinding and homogenizing attempting to level the product mix. Moreover, the scheduling at a single process step, the 1st packaging. Finally, the higher frequency of raw material deliveries. The future state map is shown in figure 21. In addition, the capacity of processes and the cycle times at the future state are shown in the charts in figures 19 & 20. Figure 19 shows that the capacities of the production steps, expressed as jars per minute, are much more balanced at the future state and in figure 20 where the cycle times are depicted and compared to the TAKT time, it is understood that all the processes operate well within the range dictated by the TAKT time.

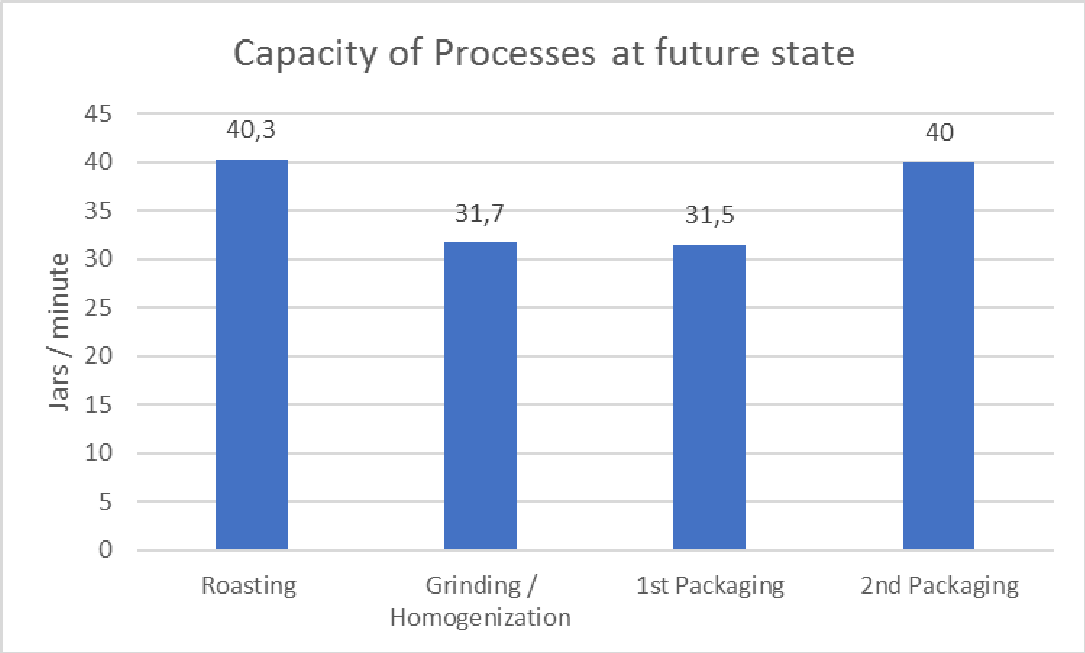

Figure 19. Capacity for all Production Steps at Future State
Source: Own compilation

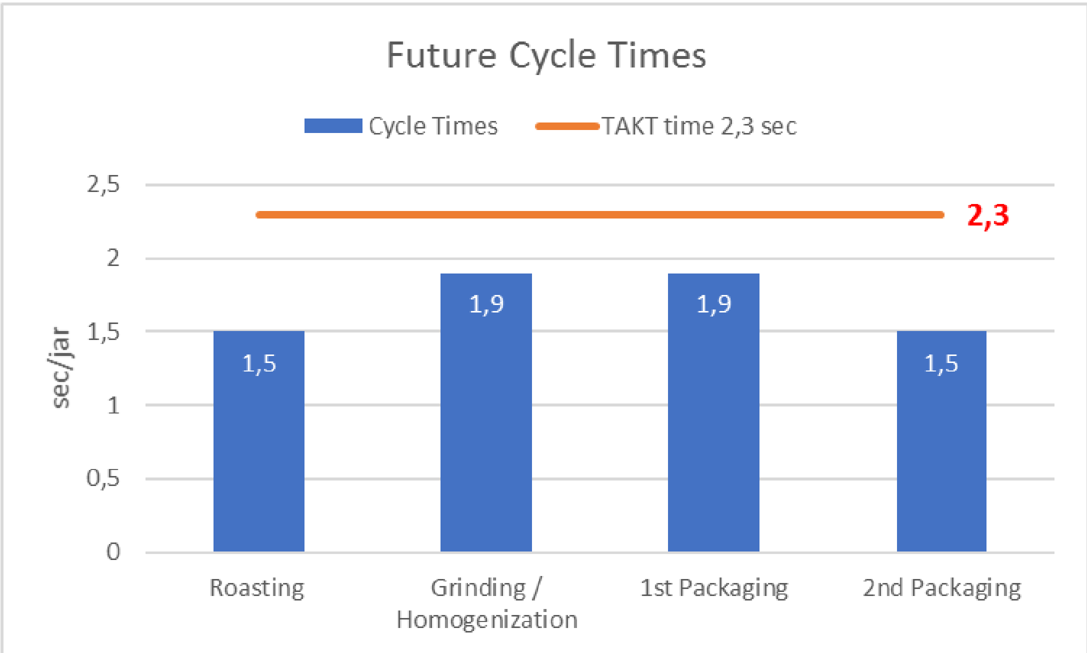

Figure 20. Future Cycle Times
Source: Own compilation

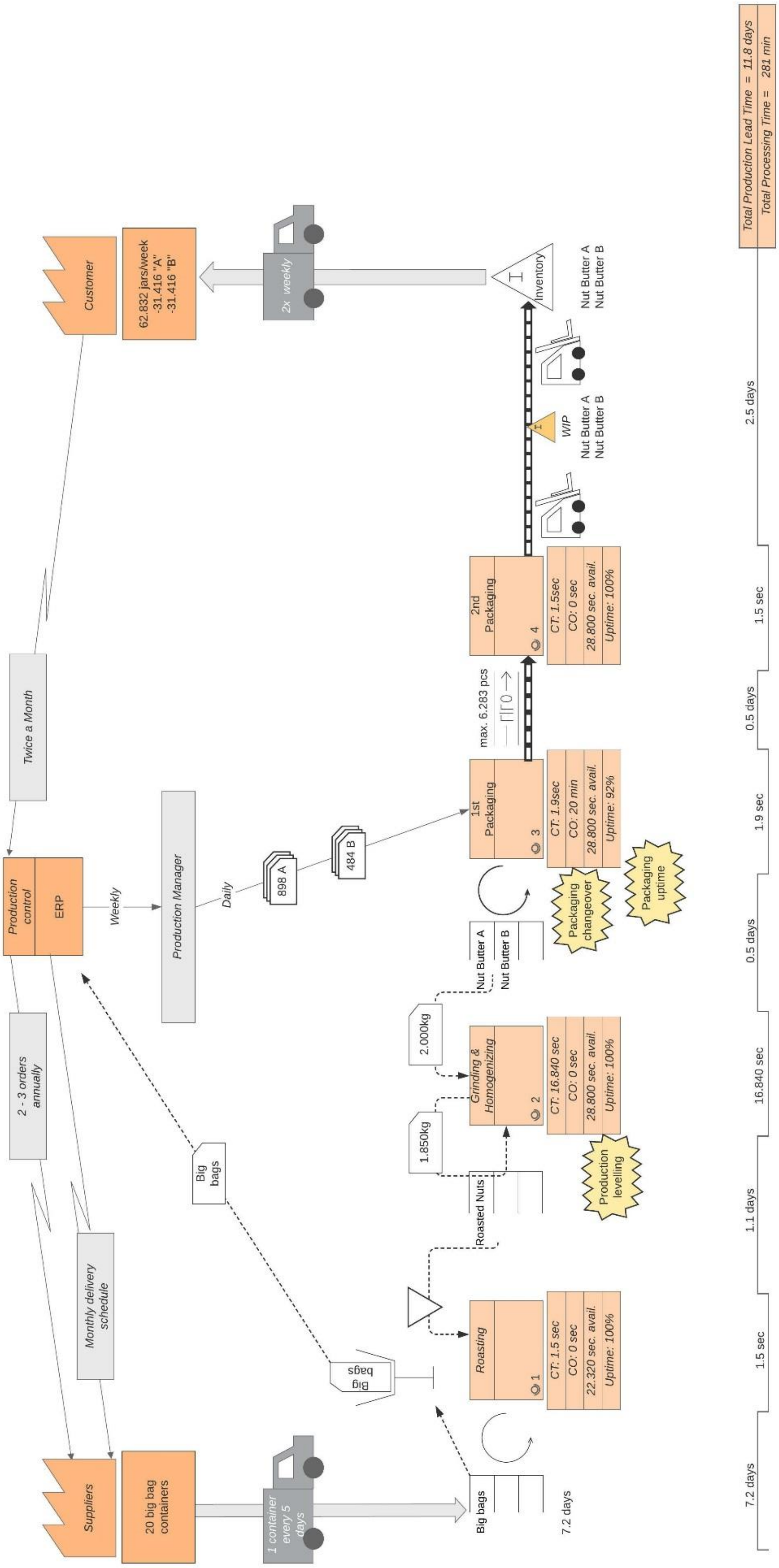

Figure 21. Future State Map of Nut Butter Products A & B
Source: Own compilation

The important KPIs, Lead Time and WIP, are greatly benefitted in the future state. The total Lead time is reduced from 18 days at the current state to 11.8 days at the future state, an improvement of 34,5%. Figure 22 indicates the Lead Time improvement at each point. The WIP inventories at the current state are 26 pallets of roasted nuts corresponding to 31.824 jars of finished product, 3.000 kg of Nut Butter in the storage tanks which equal to 6.667 jars of finished product, 6.283 jars at the packaging step and 12.566 jars at the cooling stage; a total quantity corresponding to 57.340 jars. The updated WIP inventory at the future state refers to 6.000 kg of roasted nuts corresponding to 14.493 jars of finished product while the other WIP inventories remain unchanged as 3.000 kg of Nut Butter in the storage tanks which equal to 6.667 jars of finished product, 6.283 jars at the packaging step and 12.566 jars at the cooling stage; a total WIP quantity that equals to 40.009 jars. Therefore, the reduction of WIP is 30,2%. The above details regarding the WIP improvement are recapitulated in figure 23.

Lead Time Improvement

	Raw Material	Roasted Nuts	Nut Butter in Storage Tanks	Nut Butter in Jars	Cooling Stage & Finished Goods	Total Lead Time
Current State	12	2,5	0,5	0,5	2,5	18
Future State	7,2	1,1	0,5	0,5	2,5	11,8

Figure 22. Lead Time Improvement (in days)
Source: Own compilation

WIP Reduction

	Roasted Nuts	Nut Butter in Storage Tanks	Nut Butter in Jars	Cooling Stage	Total WIP
Current State	31.824	6.667	6.283	12.566	57.340
Future State	14.493	6.667	6.283	12.566	40.009

Figure 23. WIP Inventories Reduction (in jars)
Source: Own compilation

5.2 Action Planning

After the analysis of data and the use of VSM to create the current and future state maps, action planning follows. This procedure in action research is a joint activity (Coughlan and Coghlan, 2002), therefore, in this research the author plans implementation actions utilizing also data gathered by the second phase of interviewing key personnel of the organization. Following the approach of Rother and Shook (1999), the future state map is divided into loops as shown in figure 24: the pacemaker loop, the grinding and homogenizing loop, the roasting loop, and the raw material suppliers loop.

The Pacemaker Loop

The objectives regarding the packaging step are the production scheduling at this point, the reduction of changeover time down to 20 minutes, and the improvement of equipment uptime to 92% aiming to increase the capacity of the packaging process. The action plan is discussed with the production manager and it is due to be implemented through the application of SMED, multi-functional employees, 5S and TPM tools. SMED is already applied to a degree by the company but in combination with multi-functional employees and standardization (5S) can potentially decrease the changeover time. Thus, more operators will handle changeover tasks that take place at the same time reducing the changeover time down to 20 minutes. As regards the equipment uptime, although the relevant figure (89%) is quite high in terms of industrial standards, evidence of production performance documents indicates that there is still room for improvement. Although minor stoppages of the packaging process usually take place due to issues related to the quality of jars and caps, there are also malfunctions the appearance of which is quite repetitive at times. These malfunctions that relate to mechanical problems at the filling and the capping machine could be tackled through the TPM bundle. Thus, it is suggested that autonomous maintenance be applied in order to pass simple maintenance activities from the technical to the production department. In this way, the operators will be able to solve quickly minor problems and furthermore, through this procedure they will become more empowered in problem solving. Hence, the anticipated equipment uptime is 92%. The Pacemaker Loop activities are proposed to be implemented in the next four months.

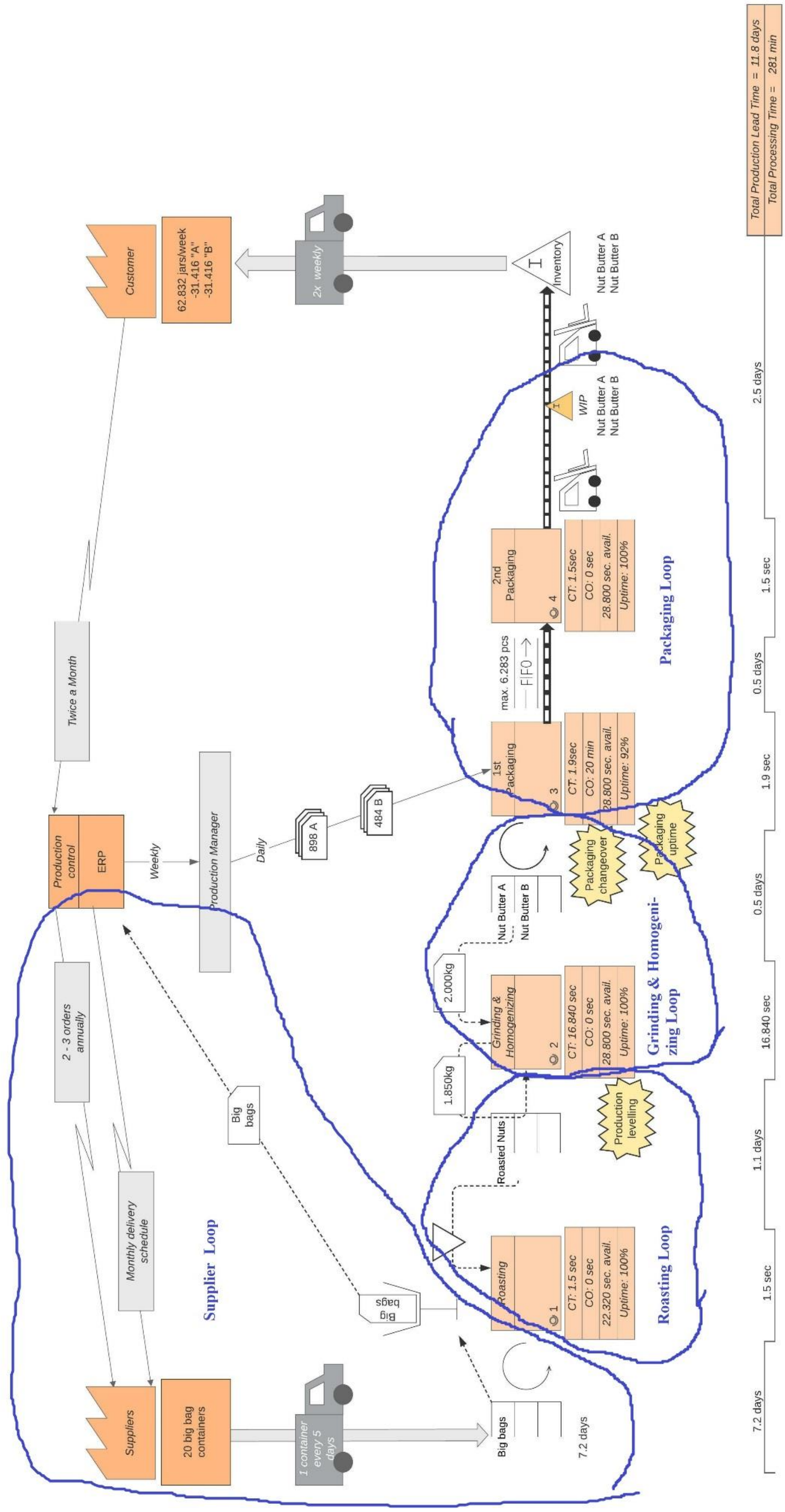

Figure 24. Value Stream Loops
Source: Own compilation

The Grinding and Homogenizing Loop

This action plan refers to the elimination of production scheduling by establishing a pull-based supermarket with Nut Butters A and B in the relevant storage tanks. It is proposed that electronic Kanban signals controlled by level instruments in the storage tanks be installed at the grinding and homogenizing area, prompting the operators to initiate production. Another improvement proposed relates to product leveling; the reduction of the filling quantity in the homogenizers from 3.000kg to 2.000kg. This means that the batch size is reduced equally, aiming to bring down the cycle time from 25.200 seconds to 16.840 seconds. An additional improvement is the possibility to process 4.000 kg of each product per shift whereas in the current state one of the products is always produced at a maximum of 3.000 kg in every shift. This action could be implemented within a three-month period.

The Roasting Loop

This implementation step is a long-term one. As mentioned earlier it is known in the company that the roasting step is the bottleneck process and the management has already decided to invest in a new continuous roaster. This equipment will solve the bottleneck issue and balance this production step with the other line processes by operating in one shift. It is suggested that the new roaster be installed near the grinding and homogenizing procedure, thus introducing a change in the layout. New minor equipment is proposed for procurement and installation: two new intermediate silos that will act as a pull-based supermarket from where, by the means of pneumatic transport, the grinder will pull the nuts. During operation, level instruments will monitor the level of nuts in the silos, and whenever it reaches a predefined point an electronic Kanban referring in terms of quantity to the filling quantity of a homogenizer will prompt the operator to start the roasting procedure. The objectives of this action plan are the reduction of cycle time from 2.040 seconds to 1.5 seconds and the increase of the available time from 21.400 seconds to 22.320 seconds. In sum, this action plan aims at one shift operation and at the reduction of roasted nuts inventory to correspond to 1,1 days. This improvement step has the longest implementation period; eight months are necessary for the procurement and installation of the new roaster and auxiliary equipment.

The Raw Material Suppliers Loop

This action plan refers to the introduction of Kanban at the storage area and to the raw material delivery scheduling. As mentioned in a previous section, due to the fact that deliveries take place in containers carrying 25.000 kg of nuts each and that the transportation time from the supplier to the case company is six weeks, it is impossible to involve the supplier with a Kanban system. However, it is suggested to introduce a raw material supermarket to help the production control manage deliveries based on the actual usage. Furthermore, a Kanban system should be installed to indicate the scheduled date of raw material arrival. This way the operator will control the inventory and inform directly the production control about any deviation in the program. The objective is to schedule the raw material deliveries so that each delivery will correspond to a single container while maintaining the initial frequency of six containers monthly. To achieve it, closer control of the inventory and closer cooperation between the production and procurement departments is called for. This action aims to reduce the nuts inventory in the supermarket to 7.2 days. As regards the implementation, three months are adequate for this step.

Concluding, the Lean tools proposed to the case company in order to further minimize waste are:

- Wider use of VSM to identify wastes. This tool is the basis for the identification of appropriate Lean practices in order to reduce waste.
- Pull-based techniques (Kanban system) to minimize overproduction. In production points where inventories are necessary, pull-based supermarkets will control the processes upstream of them.
- SMED, multi-functional employees and standardization (5S) tools combined, to tackle the waiting waste by further reducing the changeover time at the packaging step.
- Autonomous maintenance (TPM bundle) to improve the equipment uptime at the packaging step, decreasing the waiting waste.
- Product leveling, to reduce cycle time and give the possibility of evenly processed products at the grinding and homogenizing step.
- Layout change, to minimize the transportation waste between the roasting and grinding & homogenizing steps.
- Supplier involvement, to decrease the inventory at the raw material supply step.

6 Discussion and Conclusions

The objective of this thesis is to show how the food industry can minimize waste by applying Lean Production practices. Extensive literature review provided a presentation of basic terms such as those of Lean Thinking and Lean Principles, the types of waste and how they are identified utilizing the Value Stream Mapping tool, and the major Lean tools. Furthermore, studies on the VSM tool were reviewed and their results were presented. Finally, the unique framework of the food industry was introduced along with findings of relevant research on the degree of Lean adoption and the barriers to its implementation in the food industry. This thesis attempts to examine the applicability of Lean by studying a certain case of a Greek food industry. An actual project regarding a certain product family was studied in detail in order to reveal the most appropriate Lean tools for this specific case. The VSM tool was selected as the most appropriate to identify the wastes in the production processes and the analysis of the resulting maps was the basis of the Lean tools proposal. Considering the nature of the project in which the author is literally involved and proposes solutions, action research was chosen as the most appropriate methodology to effectively answer the research questions.

6.1 Basic Findings

The purpose of this study is to reveal the wastes that exist in the production process of a food industry and then propose the appropriate Lean practices in order to minimize their impact. Through an Action Research approach, the case of a product family at a Greek food industry was studied in detail, the wastes in the process were revealed and the appropriate Lean practices were identified and proposed to the case company. Therefore, the objective of this thesis is considered to be achieved. The answers to the research questions follow hereinafter:

Can Lean Production be applied to minimize waste in the food industry?

As described in detail earlier, VSM was the first Lean tool to be applied to the product family under examination. VSM, with the visualization of the current state, identified the existence of unnecessary inventories and the waiting, transportation, and overproduction waste in the system. Then, the consequent analysis led to the future state map and to the action plan proposed to the company that encompassed Lean practices able to tackle these types of waste. In conclusion, as proved in the present case, Lean Production can be applied to minimize waste in the food industry.

Can the VSM tool be utilized to improve Lead Time and Work in Progress in the food industry?

The implementation of VSM at the product family in consideration revealed the wastes in the process namely, unnecessary inventories, waiting, transportation and overproduction, thus proving its applicability in the food industry context. The analysis of the current state map and the visualization of the future state with the relevant proposed improvements can bring a reduction on the Lead Time and WIP of 34,5% and 30,2% respectively. The fact that these KPIs are greatly benefitted by the utilization of VSM effectively answers the second research question.

Which are the most applicable Lean tools in the food industry?

The VSM tool led to the future state map but to reach the future state an action plan encompassing specific Lean tools is called for. This research concluded, through the action plan proposed to the case company, that the most appropriate Lean tools to tackle the wastes in the process and bring the case company to the future state are pull-based production system (Kanban), SMED, multi-functional employees, standardization (5S bundle), autonomous maintenance (TPM bundle), product leveling, layout change, and supplier involvement. Of course, VSM must be added as it was utilized as the basis for Lean implementation.

A comparison of this thesis' findings with the results of significant studies follows hereinafter. The fact that the raw material inventory cannot be decreased further in the future state because of the suppliers' remote location and the long transport time is in accordance with the article of Dora et al. (2014) which mentions low resources availability as one of the most significant barriers to Lean implementation. This research being in accordance with the case study by Dora et al. (2014) on Hungarian, German and Belgian food SMEs, found that TPM and supplier involvement can be applied to the food industry; however, disagreeing with them showed that in the Greek food industry Pull techniques, SMED and employee involvement are easily applicable. The Lead Time improvement and waste reduction, as results of this research, agree with the article of Kennedy, Plunkett and Haider (2013) and with the findings of the case study by Bamford et al. (2015) on a large UK food processing company. Both articles mention the results concluded above among the benefits from Lean tools application; Bamford et al. (2015) also revealed that a piecemeal approach in certain cases is the best option when applying Lean. Contrary to the findings of the survey by Khusaini, Jaffar and Yusoff (2014) on Malaysian food industries, VSM not only is applicable to Greek food industries but it can act as the starting point for Lean adoption. Finally, this research agrees with the article by Psomas, Antony and Bouranta (2018) that concluded that Greek food SMEs apply the majority of Lean tools with the exception of Pull-JIT, in that in the case company a number of Lean tools such as standardization, multifunctional employees, supplier involvement and TPM are applicable. However, Psomas, Antony and Bouranta (2018) mentioned that food SMEs in Greece do not apply Pull techniques to a high extent, while this study anticipates that the Kanban tool will be successfully implemented to the case company in order to tackle the unnecessary inventories and overproduction waste.

6.2 Limitation of research

There are some limitations to this research. The first limitation concerns the research methodology; action research as Coughlan and Coghlan (2002, p.238) state "..compared with other approaches to research it is an imprecise, uncertain and sometimes unstable activity, as life is". Truthfully, the present approach's drawback is the data collection methods and that the data gathering takes place by only one observer, a problem that this study attempts to alleviate by the method of triangulation. Second, the objective of this thesis, which is how the food industry can minimize waste by applying Lean practices, is addressed by using VSM as a starting point. This means that the results are not comparable to the results that would emerge from other similar food industries that follow different paths in implementing Lean. Third, a generalization attempt of the conclusions to food industries that differ in their operation from the case company would possibly have a poor outcome. Finally, the proposed improvements potential is not verified, since the implementation action plan which could validate those improvements is scheduled in a timeframe out of the one of the present thesis.

6.3 Future Research

This thesis deals with the elimination of waste in the food industry, by applying VSM in order to identify the appropriate Lean tools towards achieving this goal. Since the verification of the proposed improvements cannot be included in this study due to its limited timeframe, future research could follow the implementation of the action plan's activities and attempt to validate the proposed Lean practices. In the same context of the food industry, further research is proposed in additional areas. Thus, the first suggestion for future research is that researchers conduct a multiple case study at food industries to assess the applicability of VSM as a basis for Lean adoption. Should such research take place at food industries in different countries would bring interesting results in terms of generalization and validity. Another proposal for research is that Lean implementation could have a starting point different from the VSM tool. Thus, a case study or action research in a food industry, similar in operation to the one of this thesis, that would start out their Lean Journey by beginning with other Lean tools could bring significant results about which tool if applied first can lead to the optimum Lean implementation and organization performance. Finally, a survey could take place aiming to compare the types of waste that exist in food industries of different sub-sectors and in different countries.

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Appendix I: Interview Questions

1st Phase of Interviews

Sales Department

1. How does the customer place orders? (via email, telephone, etc.)
2. Do they place orders at a constant frequency?
3. Which is usually the quantity of each order?
4. What is the customer’s desired lead time?
5. What is the usual quantity of the deliveries?
6. What is the usual frequency of the deliveries?

Production Department (Manager)

1. What is the combination of the two products in the selling unit?
2. What is the frequency of the deliveries to the customer?
3. What is the quantity of each delivery?
4. Which is the main ingredient / raw material?
5. What are the main production steps?
6. How do you schedule production at each step?
7. How many shifts does every step operate in?
8. How many operators are there at each production step?
9. Are there points in the process where inventory accumulates?
10. Which is the cycle time at each production step?
11. Which is the changeover time at each production step?
12. What is the available time at each production step?
13. What is the equipment uptime at each production step?
14. What is the raw materials’ delivery frequency?
15. Is there a constant quantity of raw material at each delivery?
16. What is the packaging of the raw material?

Production Department (Operators)

1. How many shifts does every step operate in?
2. How is production scheduled at the production step you are allocated?
3. How many operators are there at the production step you are allocated?
4. Which is the cycle time at the production step you are allocated?
5. Which is the changeover time at the production step you are allocated?
6. How many changeovers take place during each shift at the production step you are allocated?
7. What is the equipment uptime at the production step you are allocated?
8. What is the quantity of raw material at each delivery?

Technical Department (Technician)

1. Which is the changeover time at each production step?
2. What is the equipment uptime at each production step?
3. Are there any issues affecting the equipment uptime?

Procurement Department

1. How many suppliers do you have for this raw material?
2. Where are they located?
3. How do you place orders (via email, fax, telephone)?
4. How often do you place an order?
5. What is the minimum order quantity?
6. What is the usual order quantity?
7. What is the delivery time of each order (shipping time)?
8. Are your suppliers reliable in terms of quality and delivery time?
9. How are deliveries scheduled and at which frequency?

2nd Phase of Interviews

Production Department (Manager)

1. How would the overall process be benefitted if the new roaster was installed at the hall adjacent to the grinding and homogenizing area?
2. Would it be possible to initiate production at the grinding and homogenizing step based on a signal from the packaging step?
3. Would it be possible to initiate production at the roasting step based on a signal from the step downstream?
4. Could the homogenizers filling quantity be modified to improve the production mix at this step?
5. Would it be possible to control the raw material inventory with a Kanban system and give feedback to the Production Control and procurement department?
6. Could you schedule the production only at the packaging step?
7. Could the packaging step release fixed increments of work in order to control production in a more efficient way?
8. Could more operators be involved during the changeover activities to reduce changeover time?
9. Could the operators undertake minor maintenance activities in order to increase the equipment uptime?

Production Department (Operators)

1. Would it be possible to initiate production at the grinding and homogenizing step based on a signal from the packaging step?
2. Would it be possible to initiate production at the roasting step based on a signal from the step downstream?
3. Could more operators be involved during the changeover activities to reduce changeover time?

4. Could you undertake minor maintenance activities in order to increase the equipment uptime?

Technical Department (Technician)

1. Could more operators be involved during the changeover activities to reduce changeover time?
2. Could the operators undertake minor maintenance activities in order to increase the equipment uptime?

Procurement Department

1. Could you organize the raw material deliveries in a different way in order to minimize the inventory?
2. Would it be of assistance to get feedback from a Kanban system regarding the raw material inventory in order to schedule the raw material deliveries more efficiently?

Appendix II: Weekly Report of Nut Butter Packaging

ΗΜΕΡΗΣΙΑ ΑΝΑΦΟΡΑ ΤΜΗΜΑΤΟΣ

Δευτέρα	Τρίτη	Τετάρτη	Πέμπτη	Παρασκευή	Σάββατο	Κυριακή
7/6/2021	8/6/2021	9/6/2021	10/6/2021	11/6/2021	12/6/2021	13/6/2021

#	Κατηγ. Δείκτη	Δείκτης	μ.μ.	Δευ	Τρι	Τετ	Πεμ	Παρ	Σαβ	Κυρ	Συν.
1	Πρόγραμμα	Όγκος Παραγωγής (Προγρ.)	Κιβ.	1.600,00	1.600,00	1.600,00	1.600,00	1.600,00	1.100,00	0,00	9.100,00
2	Πρόγραμμα	Ωρες Παραγωγής (Προγρ.)	Μ.Ω.	7,32	7,32	7,32	7,32	7,32	7,58	0,00	44,21
3	Πρόγραμμα	Ωρες Setup/Clean (Προγρ.)	Μ.Ω.	0,49	0,49	0,49	0,49	0,49	0,54	0,00	2,97
4	Πρόγραμμα	Ωρες Αλλαγών (Προγρ.)	Μ.Ω.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5	Πρόγραμμα	Ανθρ.Ωρες (Προγρ.)	Α.Ω.	35,82	35,82	35,82	35,82	32,49	32,12	0,00	207,90
6	Πρόγραμμα	Ανθρ.Ώρες Λοιπές (Προγρ.)	Α.Ω.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7	Απαιτ.Πόροι	Όγκος Παραγωγής (Πραγμ.)	Κιβ.	540,00	1.904,00	1.785,00	1.715,00	1.913,00	1.149,00	0,00	9.006,00
8	Απαιτ.Πόροι	Ώρες Παραγωγής	Μ.Ω.	1,80	6,97	6,54	6,19	6,92	6,34	0,00	34,76
9	Απαιτ.Πόροι	Ώρες Setup/Clean	Μ.Ω.	0,50	0,71	0,49	0,49	0,49	0,54	0,00	3,21
10	Απαιτ.Πόροι	Ώρες Αλλαγών	Μ.Ω.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
11	Απαιτ.Πόροι	Ανθρ.Ώρες Παραγ.	Α.Ω.	7,15	31,73	28,62	26,13	29,30	27,13	0,00	150,06
12	Απαιτ.Πόροι	Ανθρ.Ώρες Λοιπές	Α.Ω.	24,00	14,00	12,00	14,00	12,00	0,00	0,00	76,00
13	Απαιτ.Πόροι	Επίτευξη Πλάνου	%	33,75%	119,00%	111,56%	107,19%	119,56%	104,45%	0,00%	98,97%
14	Διαθ.Πόροι	Διάρκεια Παραγωγής	Μ.Ω.	3,22	7,57	7,45	7,47	8,93	7,50	0,00	42,13
15	Διαθ.Πόροι	Διάρκεια Setup/Clean	Μ.Ω.	0,28	0,37	0,42	0,42	0,42	0,33	0,00	2,23
16	Διαθ.Πόροι	Διάρκεια Αλλαγών	Μ.Ω.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
17	Διαθ.Πόροι	Διαθ. Ώρες Παραγωγής	Μ.Ω.	3,00	8,00	8,00	8,00	8,00	8,00	0,00	43,00
18	Διαθ.Πόροι	Διαθ. Ανθρ.Ώρες	Α.Ω.	32,00	48,00	48,00	48,00	48,00	32,00	0,00	256,00
19	Προβλήματα	Καθυστερήσεις	Μ.Ω.	2,32	0,77	1,02	1,32	1,03	0,70	0,00	7,15
20	Προβλήματα	Αδικαιολ.Ώρες	Μ.Ω.	-1,62	-0,45	-0,04	0,01	-0,44	0,42	0,00	-2,12
21	Προβλήματα	Απωλ.Ανθρ.Ωρών	Α.Ω.	0,85	2,27	7,38	7,87	6,70	4,87	0,00	29,94
22	Παραγωγικότητα	Απόδοση (Efficiency) Γραμμών	%	55,96%	92,16%	87,75%	82,86%	77,52%	84,47%	0,00%	82,49%
23	Παραγωγικότητα	Παραγωγικότητα Setup	%	176,47%	193,18%	116,67%	116,67%	116,67%	162,50%	0,00%	143,66%
24	Παραγωγικότητα	Παραγωγικότητα Γραμμής	%	76,67%	96,02%	87,80%	83,41%	92,64%	85,96%	0,00%	88,29%
25	Παραγωγικότητα	Παραγωγικότητα Προσωπικού	%	97,34%	95,27%	84,62%	83,61%	86,04%	84,79%	0,00%	88,31%
26	Παραγωγικότητα	% Αλλαγών & Setup/Clean	%	8,10%	4,62%	5,30%	5,29%	4,46%	4,26%	0,00%	5,03%
27	Παραγωγικότητα	% Καθυστερήσεων	%	77,22%	9,58%	12,71%	16,46%	12,92%	8,75%	0,00%	16,63%
28	Παραγωγικότητα	% Αδικαιολ. Ωρών	%	-53,89%	-5,60%	-0,51%	0,13%	-5,55%	5,29%	0,00%	-4,92%
29	Παραγωγικότητα	% Απώλειας Ανθρ.Ωρών	%	2,66%	4,73%	15,38%	16,39%	13,96%	15,21%	0,00%	11,69%