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Using Lean Manufacturing Approach for Improvement in Food Manufacturing: Case Study from Egypt

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Abstract

This research focuses on Lean implementation in manufacturing processes. It discusses different tools used to help in implementing this approach in any organization. Lean Six Sigma is now widely used all over the world and its principle is based on balancing between lean methods and six sigma's Define-Measure-Analyse-Improve-Control (DMAIC) methodology. There are some important tools used in Lean Six Sigma, such as 5S, Value Stream Mapping, Single Minute Exchange of die, Systematic Plant Layout, and many other tools. The purpose of the research was to select suitable tools to be applied according to the needs of the company. This study applies Lean Six Sigma for food industry in t. The focus in this case study was on processed meat lines to make improvements on it. Tools like Value Stream Mapping, Single Minute Exchange of die and 5S were used to apply the improvements. After applying Single Minute Exchange of die, it was found that changeover time was reduced from 18 to 11 min, leading to an improvement almost equal to 38% in the total cycle time. For the automated line, a reduction from 10 to 5 min was achieved which represents improvement by 50% in the transportation time. By applying 5S training through kaizen planning, the workers worked faster, easier and in a tidy place. This led to reduce the unpacking cycle time to 8 min instead of 12 min. Also, the lead time was reduced by 0.5% of the total lead time. The originality of this research is the application of lean manufacturing tools and value stream mapping in a complex production line of food industry, and thereby fills the gap between the theory and practice in the optimization of food production lines. This is a relatively new application area in the Middle East.

Keywords
Lean Six Sigma, Value Stream Mapping, Single Minute Exchange of die, DMAIC

1. Introduction

To understand Lean and Six Sigma (LSS) methods we need first to understand each one separately. Lean is a method used to reduce or eliminate useless activities that do not add value to the process; these activities can be defined as wasteful steps in any process. By reducing or eliminating it, the process will have useful and value-added activities. Also, lean can provide high quality and satisfy customer's needs. Moreover, Lean method helps in reducing the time required for the process cycle, product improvement, less delivery time, lower inventory levels, and improving the resources' utilization. Value is defined by customers for certain processes or industries. So, one can categorize activities in three groups:

- non-value-added activities: Activities that do not add any value to the process (wasteful). This affects the product negatively with excess useless steps that may eventually lead to customer dissatisfaction.
- Value-added: Essential activities that add to the product's quality and improve the productivity.
- Enabling value-added activities: This falls under non-value-added activities but that are important for continuity of the process.

It is estimated that 80% to 85% of the activities in an organization are non-value-adding activities (itechgurus.org, 2020). Hence, comes the role of the lean method to distinguish between the activities and use certain lean tools to reduce and remove the waste. According to Deshmukh et al. (2022), Lean obtained its concept from TPS (Toyota Production System), who were using 3M methods which are Muda, Mura, and Muri; Muda is assigned for any non-added value activities or the wastes.

According to lean concepts, anything that adds cost or time without adding value is a waste. The seven wastes are: Over producing, waiting (queue time), transportation, overprocessing, inventory, motion, and defects. Mura is assigned for inconsistencies that lead to production fluctuations that leads to inventory accumulation and undistributed workload, while Muri is assigned when there is huge stress and strain on the machines or the workers due to overutilization of the machines or working for too many hours. Lean can remove DOWNTIME waste. DOWNTIME refers to eight wastes "defects, overproduction, waiting, Non-utilize Talent, Transportation, Inventory, Motion, Extra Processing". Lean method can be applied using different tools, some of these tools are Value Stream Mapping (VSM), Kaizen, Just in Time, Single Minute Exchange of die (SMED), and Poke Yoke. Each one of these tools targets something to improve, VSM defines wastes and their reasons. Kaizen's Continuous Improvement (CI) approach targets small improvement, it focuses on the low-level people in the organization, Just in Time focus on the demands of the customer and meeting these demands, SMED focuses on the changeover time improvements, and Poke Yoke is like an alert for failure or defect in assembly.

Lean follows certain principles to establish its concept in any process to reduce waste, the principles of Lean manufacturing are:

(1) Define the value of the product as defined by the customer,
(2) Map value stream at which the steps of the workflow process steps are shown. Also, this helps in classifying and determining the non-value-Added activities, which lead to reduce delays in the process,
(3) Create a continuous flow system to improve and maximize the efficiency of the process,
(4) Establish a pull system to meet the customers' demand. It meets the Takt time which is "the rate that the product needs to be ready to fulfil customer needs",
(5) Pursue perfection at which consistent work should be done to improve the current process to satisfy customers' needs.

The second term is Six Sigma, which is problem-solving using data-driven methodology. Six Sigma method focuses on the variation that happens on a certain process to reduce the defects on a product (Valles et al., 2009). It aims at making the product almost 99.99996% defect-free. Six Sigma methodology uses "DMAIC (Define-Measure-Analyse-Improve-Control) framework" (Pongboonchai-Empl et al., 2023). This framework consists of five stages. Define, at this stage important components are defined which is same as the project charter in project management. The project charter is a blueprint of the project as it includes important information like the business case, problem statement, goal statement, project scope, resources, timeline, and estimated benefits. The second stage is to Measure the process variables through data collection. Analyse is the third stage at which the data are analysed to recognize and obtain the root causes of the defects. The fourth stage is to Improve the process by applying solutions to it and testing these solutions. The final stage is Control at which the chosen solution performance is recorded to monitor the improvement in the process.

Lean Six Sigma method is a combination of both Lean and Six Sigma approaches. It reaches customer satisfaction by reducing both the variation and wastes of the processes (Figure 1). Lean and Six Sigma are complementary to each other as Lean reduces the waste and Six Sigma improves the quality, it was found that if Lean or Six Sigma is applied separately it will not give the full potential of the improvements (Dora & Gellynck, 2015). Hence, Lean Six Sigma is a CI tool for any process, also, the bottom-line profits improve when using this approach. To start using lean and Six Sigma one needs first to understand its principles. It consists of five principles:

(1) Focusing on the customer,
(2) Define roadblocks to consistent quality,
(3) Eliminate Inefficiencies,
(4) Communicate and align with people,
(5) Adaptability and flexibility.

Figure 1. Integration of Lean and Six Sigma together credits to (Rastogi,2020)

The objective of this study is to test the effect of using LSS on the food industry to reduce waste in this industry and to see the impact of applying this approach on the process.

2. Literature Review

LSS can improve the lead time up to 80% and reduce quality and operation costs by almost 20%, also, it can improve delivery time by up to 99% (George, 2002). One of the effective methods to apply LSS successfully is to identify the Critical Success factors (CSFs). Several research works addressed LSS applications, according to Jeyaraman and Teo (2010), to improve the performance of any company through the implementation of LSS, it is required first to define and analyse the CSFs to see their impact on the performance. In Mathiyazhagan et al. (2022), this case study, the company was a multinational electronic manufacturing service company (EMS). When analysing CSFs for the implementation, the company chose the most ten highly effective CSFs. Data was obtained and gathered using a questionnaire distributed to multi-sites of six EMS industries, the sites were in Malaysia and other global sites. After analysing and collecting data through the questionnaire. Nine CSFs and one moderation factor have been chosen as they highly affect LSS implementation, the top two CSFs are management engagement and commitment, and Reward and recognition system. Also, there was one moderation factor which is organizational belief and culture. Timans et al. (2012) studied the implementation of LSS in SMEs, the study was implemented in a factory in the Netherlands. The main concept used for implementation is to define and rank CSFs that impede the process. Collecting of the data was done through a survey on “Dutch SMEs”. In-depth data and information have been collected from six case studies. After analysing the data and ranking CSFs. It was found that “linking to the customer, vision and plan statement, communication, management involvement, and participation are taking the high CSFs ranks”. In addition to, “internal resistance, the available resources, changing business focus, and lack of leadership are highly ranked impeding factors”. After reviewing cases studies to validate the ranked and analysed CSFs, another three CSFs have been obtained which are supply chain focus, development of project leader’s soft skills, and personal LSS experience of top management. The survey showed that the top ten used tools are 5S with a mean of 3.96, Brainstorming mean of 3.72, PDCA 3.7, Histogram (3.56), VSM (3.53), Pareto chart (3.49), process flow chart /mapping (3.47), SIPOC (3.45), and Cause and effect (3.4). The study showed that out of 106 companies, 63 were using lean tools only to improve productivity and reduce waste, 42 companies used LSS, and only one was using six sigma alone. At the end of the questionnaire, it has been shown that it is expected that the importance of LSS implementation in the SMEs sector is increasing.

Thomas et al. (2014) investigated the implementation of LSS in the sector of SMEs in UK. The data was collected through a survey done at two points before and after the 2008 recession. Data was collected from a sample consists of 96 manufacturing SMEs. Data collection was from CEO using questionary, direct observation, and interviews. After analysing the data and observing categories of LSS used by those companies. It was found that the recession has not affected increasing the awareness of LSS implementation in reducing waste and operational costs. Dora & Gellynck (2013) used LSS to improve the processes in a gingerbread factory and to reduce wastes. The case was on a medium-sized confectionary which is a food manufacturing company. The focus was improving the cutting and packaging processes. The company used DMAIC methodology to improve process quality and to reduce variations in the packaging of products sections. The team used Design of Experiments (DOE) to identify the significant factors that affect the company's products. After applying LSS in this company, there was a significant improvement in performance.

Douglas et al. (2015) studied the implementation of LSS in services and manufacturing organizations in East Africa. The paper investigates the CSFs and impeding factors for LSS implementation and identifies the advantages and knowledge of LSS tools for these organizations. Data was collected through questionaries survey for employees who took training courses in yellow, green, or black belt LSS. After the analysis, it was found that management involvement and participation are the most important (CSFs). For problem-solving tools, process mapping and brainstorming are the most used tools. The paper showed that LSS usage is rapidly increasing as the need to improve quality in East Africa increases. The paper emphasized the importance of training that helps employees to choose the right and most useful tools to be used.

Gutierrez-Gutierrez et al. (2016), studied the effect of the combination of LSS on CI in logistics services. The case study illustrated in this paper was on a large electronics consumer company. The analysis was done by applying within-case then performing a cross-case analysis. The paper focused mainly on LSS implementation in internal logistic processes. Moreover, the study investigated the effect of using DMAIC methodology and VSM. The two focused internal processes were the payment process and the process of request-to-ship. At the end of the case study, it was concluded that LSS implementation provided many benefits for this company such as improving the process and reducing the flow time. Also, this shows that the logistics sector has a high potential for applying LSS implementation to improve companies' process quality. A study made by Flor Vallejo et al. (2020) stated that the LSS methodology gives companies highly competitive advantages and put a roadmap for using LSS implementation in Scottish packaging SMEs. This paper showed the high importance of identifying CSFs for LSS implementation, also, the road map designing process can be used as a guide to develop a model for CI initiatives implementation for other SMEs. However, there were some limitations of this study. The limitations were that there is not enough literature with a similar scenario or characteristics for the studied company. Also, LSS implementation does not have a standard framework to ensure sustainability.

Costa et al. (2018) studied the effect of LSS on the food industry to see if this helps in reducing the delivery time of products at low cost. The authors reviewed the evolution of LSS within the food sector through 58 publications. The review showed that only 10% of the papers published on the food sector use LSS and the majority use Lean manufacturing only. The drivers of adoption for LSS were cost, time, value, and defect. The main CSFs in this industry were management commitment, training programs, and skilled workers. As shown in Figure 2, it was found that only 5% of the papers are for cases from Africa, hence a research gap lies in using LSS implementation in the food industry. Another important research direction is the application of Lean philosophy in SMEs (Melander et al., 2023).

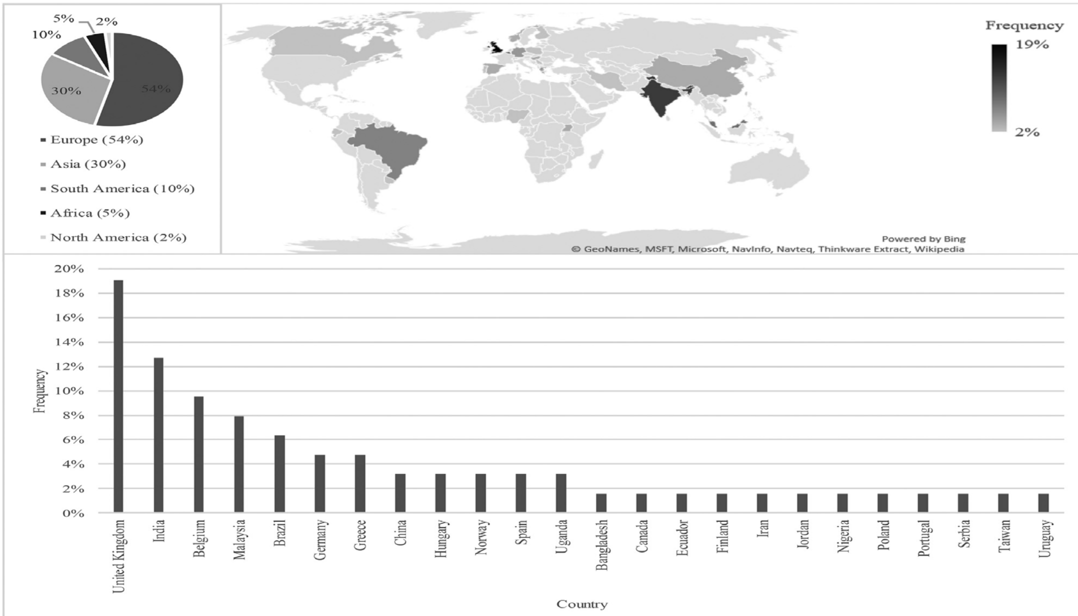

Figure 2. Geographical distribution of the reviewed papers in the food industry sector (Costa et al., 2018)

3. Methodology and Case Study

This study was performed in a food factory in the Middle East. Data was collected through audits, visual recording, and stopwatch. This factory has a large product variety as it produces 60 different products. The processed meat production line was selected for the study as it has the largest market share. Figure 3 shows the product and process flow.

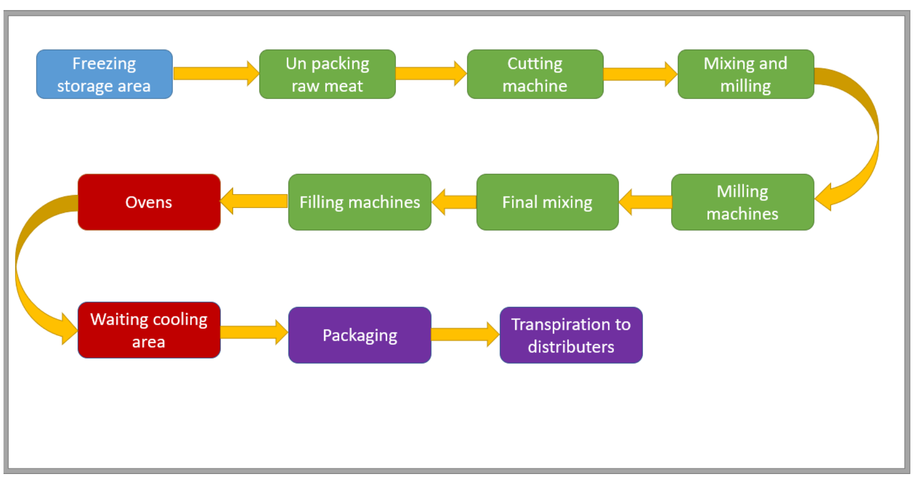

Figure 3. Process flow of food factory

LSS concepts will be used to help in improving factory the production line and solving its problems, this will happen by applying the concept of DMAIC. In the first stage, Define, the problems of the production line were defined through brainstorming, visual recording, and interviews. Second and third stages will be covered through data collection (Measure) and the current VSM mapping (Analyse). Fourth and fifth stage which are Improvement, at which suggestions will be provided, and Monitoring to observe the impact on the process. Based on the data collection and the observations on the studied food factory, three tools were identified to be used: VSM, SMED and 5S.

3.1 Value Stream Mapping

According to Tapping & Shuker (2003), VSM ensures that the process flow is smooth as possible through visualizing the full process of certain organization. However, VSM is not just a visualization tool, it also plans the improvement that will help the organization to become lean. VSM involves workers (people) in it as an essential part for development, as they are critical in implementing the improvements and eliminating waste time. The flow of information and material to produce a product has a value to the customers, this is called value steam. Value stream includes communication between workers, value-adding activities, and the processes (with times and resources) involved to convert raw material into final product. Another view of VSM is the order-to-cash cycle which starts from customer order received by sales department and ends with payment receipt. Around 60 to 80% of product cost is associated with a non-production process. This non-production process makes sure that the orders are delivered, shipped, and released. This play crucial role in the issues and needs to be focused to make the process more efficient. The purpose of LSS is not to put more load and effort on the workers but rather to handle the flow and optimize it to make the work as fast as possible through value streamlining. Work unit routing is used to identify the target value stream by using a certain sequence:

(1) List work units or customers families which are involved in the targeted area to be improved,
(2) List the average work volume for each family within a pre-determined period,
(3) List the process and activities performed in each family,
(4) Visualize the families that have the same process routes according to the value rank.

There are three phases of lean application in VSM (demand understanding, continuous flow, and levelling). Customer demand is the first phase at which the customers and their requirements are determined, after that some tools are used to determine and meet the demand including Takt time, pitch, buffer, and 5S. The second phase is the continuous flow that must be established to make sure that the right work is done at the right time in the required amount. Tools and events used in this phase include in-process supermarkets, Kanban, and Line balancing. The last phase is levelling which is done to make sure that work is evenly and effectively distributed using visible pitch board, load levelling box, and runner system).

3.1.1 Current state mapping

After gaining some knowledge and information about lean, the current state is mapped. The first step is to prepare the map. This step consists of observing the main process, observing the number of workers at each process, and determining the total cycle time and changeover time. The second step is to draw the current state after gathering information about the process and the flow of information. After drawing each process, the time of each process and the transportation time between the processes are added to the map.

3.1.2 Selection of lean tools for improvements

After mapping the current state, data is analyzed, and the lead and cycle times are calculated; this will help to select the suitable lean tools to help in improving the process and to reduce the total cycle time. This will lead to faster delivery time and henceforth higher customer satisfaction. The seven wastes discussed previously are called lean measurables because they can be measured and eliminated through lean tools. Time standards are used while analyzing and collecting data such as cycle time, queue time, and lead time. Cycle time is the time required for a certain process to start and finish usually measured in seconds or minutes. Total cycle time is a summation of all processes cycle times. Queue time is the time that process will wait for a downstream process to be completed. Total lead time is the summation of all process cycle times in addition to the queue time found between these processes. Figure 4 shows some of the symbols used in VSM.

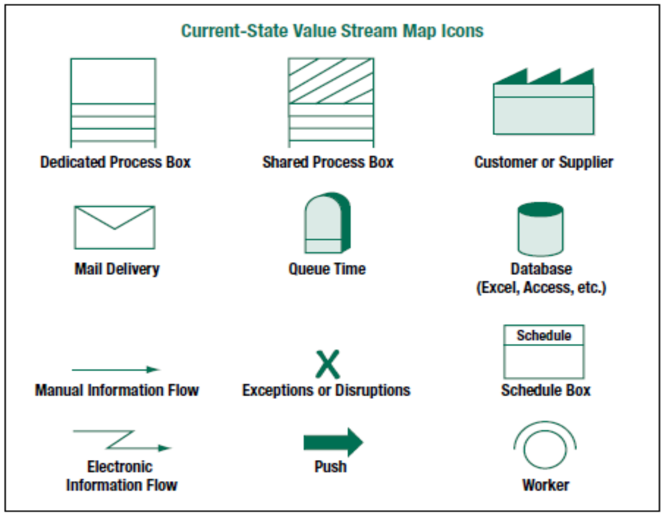

Figure 4. VSM symbols (Tapping & Shuker, 2003)

3.1.3 Future state mapping

After calculating times from the collected data and analyzing the flow of information and material within the processes, improvements are suggested, and their effect is measured through future state VSM. Future state has three phases; the first phase is 'customer demand' which is concerned with determining customer demand for the product or service. In this phase, it is necessary to calculate the 'takt time' which is the rate or time per order received from the customer. Then, 'pitch time' is calculated which is a multiple takt times required to establish a sustainable and consistent workflow. Another terminology which needs to be explained is 'buffer resources'. Buffer Resources aims to meet the demand while ordering or takt times changes.

$$\text{Takt time} = \text{operating net available time} / \text{daily total required quantity} \qquad \text{(Eq. 1)}$$

$$\text{Pitch time} = \text{takt time} * \text{number of work units} \qquad \text{(Eq. 2)}$$

The second phase is to make a continuous flow to make sure that the customer receives the right product at the right time and in the right quantity. Line balancing process is needed in this phase to make sure that the process variables, such as workers are evenly distributed within the VSM to meet the takt time. The number of workers is the process cycle total time divided by the takt time. The last phase is levelling, in this phase the focus is to reduce queue time and to allow the movement of small work units by evenly distributing the work. This can be done through the takt time and pitch after reviewing customer demand. Also, levelling can be done by converting the system to 'Pull system' by using Kanban that establishes visual control form that can be understood by anyone in the working place. This form includes important information such as what is produced, when, how much and by whom. Kaizen plans need to be set to ensure establishing a sustainable VSM and to help in the CI of the factory or organization.

3.2 Single Minute Exchange of Die

According to Shingō (2019), many factories encounter huge difficulties regarding production volume and diversity, in that case, setup operations, such as tool change and calibration become a real challenge. SMED is a technique used to break down the setup operation time to make it under ten minutes (a single digit). Setup time can be categorized in two categories: internal setup and external setup. Internal setup includes die changing or removing, it is concerned with any activity that can be done when the machine is stopped. The second category is the external setup in which activities can be performed while the machine is running, such as transporting the changed dies to the storing area. There are important 3 steps to apply SMED:

(1) Separating internal and external setups,
(2) Converting internal setup to external setup whenever possible,
(3) Streamlining the internal elements.

In a recent study made by Vieira et al. (2020) on automotive industry, SMED lean tool was able to achieve reduction up to 38% of the total setup time, 53% of the internal time and a 7.7% increase in the *Overall Equipment Effectiveness* (OEE). This gives indication on the potential of using such Lean tool in factories.

4. Results and Discussion

4.1 Current state VSM

After collecting and analyzing the time for each process and the flow of material and information, a current state VSM was mapped as shown in Figure 5. The current VSM starts with the information received by the production team in the factory from the sales department. Then, based on the required demand, the production process starts. The VSM depicts each process with its cycle time, changeover time, and number of workers. The current state VSM helps to see which process is causing problems like bottlenecks or delays due to changeovers. Also, it will help to establish a standard process flow and resources requirements. After plotting the current VSM, the total cycle time and the lead time were calculated. The total processing time was 1619 minutes, the total waiting time was 53 minutes, and the total lead time was 1672 minutes.

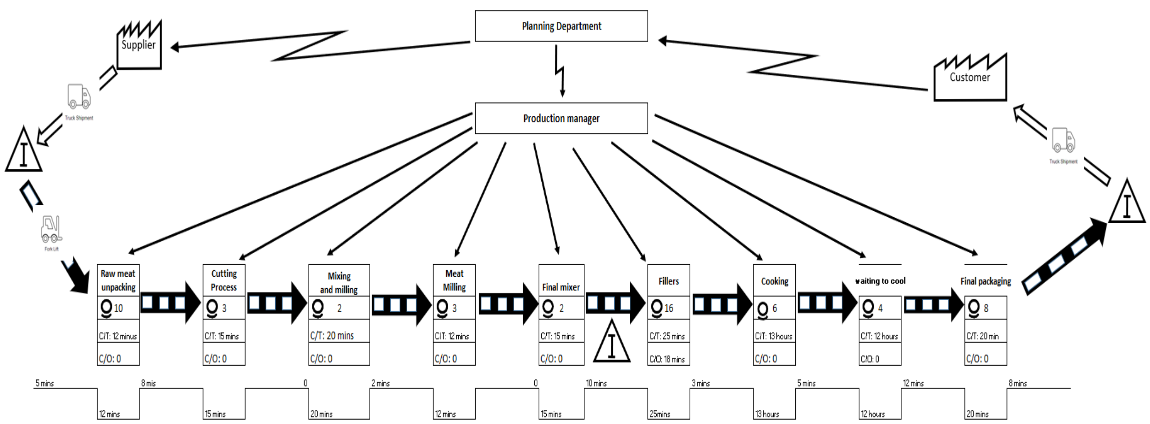

Figure 5. Current state VSM

4.2 Insights on the Current VSM

After analyzing the current VSM and the performed audits. One of the suggested improvements is to reduce the changeover time using SMED methodology. Another improvement is to add more automation in the process. The last recommendation is to improve the material handling through using fully automated systems to reduce the number of workers, transportation time, and waiting time.

Table 1. Changeover tasks' categories before SMED application

Task	Time	Accumulated time	Task type
Search for new die	2 min	2 min	External
Transport die to the machine	2 min	4 min	External
Change machine die	6 min	10 min	Internal
Program the machine	5 min	15 min	Internal
Install new plastic packages	2 min	17 min	Internal
Check on first piece	0.5 min	17.5 min	External
Documentation	0.5 min	18 min	External

4.2.1 Using SMED to reduce change over time: (solution 1)

To apply SMED on this production line, a pilot zone was selected. Based on the analysis of the current VSM, a high changeover time was observed on the filler machine. Hence, it was selected as the pilot zone. The changeover steps were categorized into internal and external tasks. Table 1 shows the tasks done during filler changeover and Figure 6 shows the time breakdown of the changeover tasks.

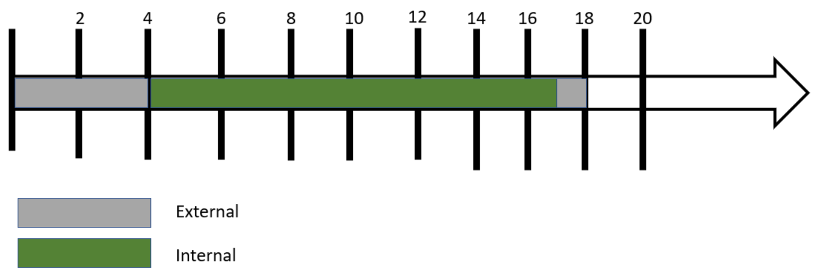

Figure 6. Time scale show the duration of internal and external

From Table 1, it was observed that that filling machine has four external changeover tasks and three internal changeover tasks. According to SMED principles, the goal is to minimize or transform the internal task into external ones. Also, it was observed that changing die and programming the machine take most of the time and they are the most significant internal tasks. The total changeover time is 18 min and changing the die takes almost 33% of this time while programming the machine takes 27%. Hence, both the two tasks altogether consume 60% of the total changeover time. A recommended solution was to use universal die that can be used for more than one product; this solution will require only to change the direction of the die to the desired die shape. Also, For the programming machine, a standardized control panel can be used to enable fast selection of a standard program. After using universal die and a standardized control panel. The estimated reduction in internal time is as illustrated in Table 2.

Table 2. tasks and durations after Appling improvement

Task	Time	Accumulated time	Task type
Search for new die	2 min	2 min	External
Transport die to the machine	2 min	4 min	External
Change machine die	2 min	6 min	Internal
Programming machine	1 min	8 min	Internal
Install new plastic packages	2 min	10 min	Internal
Check on first piece	0.5 min	10.5 min	External
Documentation papers	0.5 min	11 min	External

As shown from using these two solutions will lead to 38% improvement and a reduction or improvement in internal task time by 72% (Table 3).

Table 3. comparison between initial and final state

	Total time of setup	Internal tasks time
Initial	18	11
Final	11	3
Improvement	38%	72%

4.2.2 Adding more automation to the production line (Solution 2)

Another recommendation was to automate the material handling between the final mixing process and the filling process by using pipes with valves and pumps to distribute meat quantity as required to the filler machines. This solution will reduce the transportation time through eliminating the usage of manual filling carts. In addition, this will enable a smother flow with no aisle blocking due to the carts' congestion. Figure 7 shows the pipeline system structure.

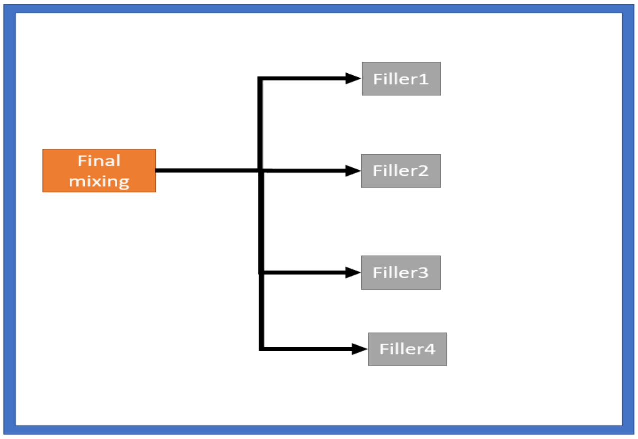

Figure 7. Automated mixer and fillers

4.2.3 Using automated conveyor belts to move products (Solution 3)

Another solution is to establish an automated conveyor belt line between the final production stage and the packaging stage. However, this will require some changes in the factory layout but can save transportation time.

4.2.4 Improve labor's knowledge (Solution 4)

Training is a key pillar in Lean manufacturing, kaizen and 5S audits are used to establish training programs that increase workers' knowledge about lean. This will improve labor efficiency and productivity. Audits help to assess the labor's knowledge about lean and will help in finding new ways for continuous improvement. This solution can be applied to all the working areas in the factory, especially the first process which is unpacking raw meat from cartons. As the workers need to learn more about 5S to keep the working place tidy and clean as possible.

4.3 Mapping Future State

After providing solutions to the current state, the effects are measured by developing future state VSM as shown in Figure 8. The new total processing time is 1615 minutes, the new total waiting time is 48 minutes, and the new total lead time was 1663 minutes. From the future VSM, it was shown that lean tools can reduce waste and time which will lead to faster delivery time. As shown SMED can reduce changeover time from 18 min to 11 min with an improvement up to 38% in the total cycle time. For the automated line it can reduce the transportation time by 50%. For Appling 5S trainings through kaizen planning to the raw meat unpacking area. Raw meat unpacking workers work faster, easier and in tidy places. This led to reducing the unpacking cycle time to 8 min instead of 12 min. Also, lead time was reduced from 1672 min to 1663 which represents improvement by 0.5% of the total lead time.

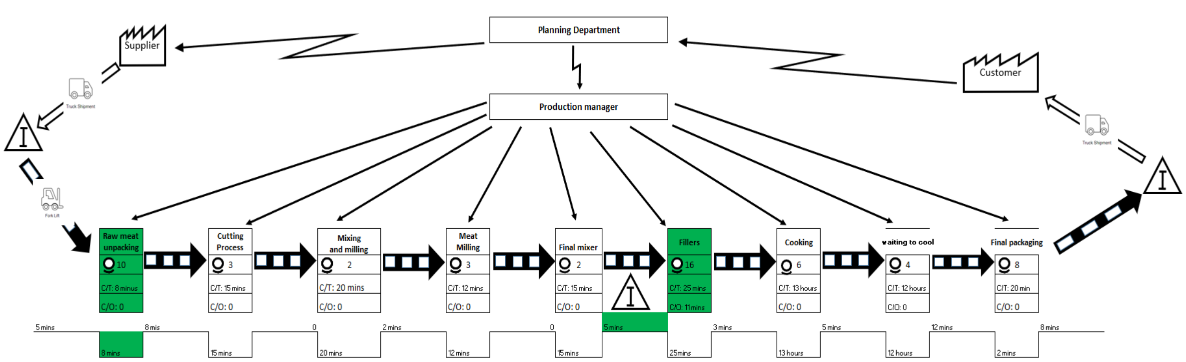

Figure 8. Future State VSM

5. Conclusions and Future Work

In this study, Lean tools, such as VSM,5S and SMED and the implementation of Lean with six sigma are addressed. Many industries use LSS implementation to improve their processes and efficiency. This study focuses on using LSS in a food factory located in the Middle East to solve its problems and reduce total time. After understanding the main process responsible of transforming raw meat into final product, VSM has been developed. Then time and flow of information and material is placed after collecting them through audits, stop watches, and visual observations. After drawing current state VSM. several problems were detected and investigated; filling process and unpacking of raw meat were chosen as a pilot zones. Lean tools, such as SMED ,5S and plant layout, were used to apply some improvements.

After Appling these tools, the changeover time of the filling machine was reduced by 38% with improvement in internal task time by 72%, the automated line it makes a reduction of 50% in the transportation time, and the unpacking cycle time was reduced by 33%. So, here LSS is used through DMAIC principle as in the start of the case study brainstorming done with production manager to discuss the problems faced. Then measuring and analyzing data was done in the focused area through data analysis, Collection and Current VSM. Finally, improvement is done through some lean tools to improve the process and reduce cycle time. These improvements effect was observed through future state VSM.

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Biography

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