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# The Use of Innovative Mechanical Solutions to Implement Lean Methodologies in a Meat Manufacturing Factory

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## Abstract

The increasing and intense competition between companies in the market has become tremendously aggressive. Manufacturing systems have had many modifications in the past decades to increase profitability. Therefore, manufacturers search for strategies to keep them competitive in the market. The lean manufacturing methodology is one of the most popular techniques/strategies that take the production system ahead. The main idea of lean manufacturing is to help the manufacturers make the best use of available resources with minimum waste. It focuses on increasing the profit by reducing the cost through reducing and eliminating different types of waste. Lean manufacturing has various tools that are used to eliminate waste. This paper includes a step-by-step methodology to implement lean techniques in a meat manufacturing factory in Egypt. This methodology can be implemented anywhere in similar organizations. It focuses on the use of innovative mechanical solutions to minimize production waste. The case study was carried out in one of the leading meat factories in Egypt. The factory seeks to implement a lean manufacturing methodology for the luncheon production line. After several visits to the factory, the different types of waste and the current state of luncheon production were identified by Gemba walk and value stream mapping. Several production improvement cases are suggested/implemented using Kaizen, 5S, and mechanical solutions to minimize production waste. Implementing lean manufacturing in the meat factory results in a 61% increase in productivity, NVA time has decreased by 47%, and the total number of workers is decreased by 20%.

## Keywords
Lean manufacturing, Productivity Enhancement, Value Stream Mapping, Kaizen, and Continuous Improvement.

## 1. Introduction
The manufacturing systems have undergone many changes in the past decades. The reasons behind these changes can be summarized into the developing environment surrounding the customers, like the development of communication technologies and the increase in the world economy. This causes an increase in customers' demand for different

products worldwide. Therefore, the global market competition has intensified, reflecting on the manufacturing plants that must evolve and adapt to withstand the increasing demand. Firms must increase their plants' efficiency by enhancing their production and management systems (Tekin, Arslandere et al. 2018). The manufacturers run after improving the multiple operational performance of their plants, such as reducing lead time and downtime, reducing cost, increasing product quality, increasing process flexibility, etc., to have a competitive advantage in the production technique. Consequently, many studies have been conducted to identify the different resources that make production systems excel in these operational performances (Khanchanapong et al. 2014). Lean manufacturing is one of the most popular techniques that take the production system ahead in a competitive market.

### 1.1 Lean Concept

The main idea of lean manufacturing is to help the manufacturers make the best use of the maximum available resources for the factory with minimum waste. It aims to focus on Value-Added (VA) activities and identify and eliminate the various types of waste and non-value-added (NVA) activities in a production system related to several stages of product processing and human effort. All industries seek high production to fulfill the customer demand and reach the target, but they do not take care of the production cost as far as they get revenue. The lean manufacturing technique catches minds and minimizes production costs by eliminating NVA activities to achieve higher productivity and a high production amount with minimal utilized resources. Lean manufacturing does not add any benefit to the customers' products, and it does not add any extra price to the products. It is just about reducing the production system's waste and, thus, cost. In addition, lean methodology targets the reformation of the manufacturing process towards continuous production flow, reducing lead time and cycle time, increasing quality, cost reduction, maximizing profit, rapid response to customer demand, and maximizing product value (Palange and Dhatrak 2021).

The first introduction of lean manufacturing originated by Toyota, a famous Japanese automotive company, and is referred to as the Toyota Production System (TPS). Toyota is the pioneer of the lean manufacturing concept that aims to eliminate the waste types faced by the company in the late 1940s (Melton 2005). Waste can be defined as any extra cost that the customer does not have to pay. The seven wastes (MUDA) that are related to lean manufacturing and do not bring value to the end customer are as follows (Melton 2005):

1. Overproduction
2. Motion
3. Inventory
4. Overprocessing
5. Defects
6. Waiting
7. Transportation

### 1.2 Lean Manufacturing Tools

The following paragraphs show different lean manufacturing tools and concepts.

1. 5S: Its main idea is to find a place for everything at every time. 5S is a process of housekeeping to reach an organized, safe, and clean working area that creates a quality work environment, allowing the operators to observe any problem and perform the work. 5S stands for sort, set in order, shine, standardize, and sustain (Agustiady and Cudney 2016).
2. Value stream mapping (VSM): It is also known as material-information mapping. It aims to analyze the state of the processes of a particular product from receiving the customer demand when it is a raw material until the final product reaches the customer. VSM is a visual system showing all the VA and NVA activities to make the product (Rohac and Januska 2015).
3. Kanban: aims to visualize and control the workflow where the VA activities take place. It is a technique developed for a pull system where the materials flow from one station to another only when a signal is triggered (Junior and Filho 2010).
4. Judoka: It is a system that makes the machines able to detect any abnormalities or faulty situations in the production, so the machine stops automatically or gives an indicating signal like sound or a text to make the operator pay attention to stop the machine or the whole production immediately.
5. Poka-Yoke: It is used, in essence, to eliminate errors from their sources. This approach manages with fool-proofing and mistake-proofing. Poka-Yoke is an idea developed and applied on the shop floor to prevent the operator from making any mistakes (Kurhade 2015).

6. Gemba walk: It aims to walk around the work area and shop floor to identify visible problems and suggest solutions.
7. Kaizen: It aims for continuous improvement and development by reducing waste, enhancing productivity, and improving the quality of the products. It supports any slight improvement in the manufacturing system from non-stop exerting efforts. This improvement involves all the employees in the organization, from the top management to the workshop workers and, therefore, all the departments (Kiran 2020).
8. SMED: It is used to minimize the setup time that is required for an equipment changeover. It offers an efficient and rapid method to change the current manufacturing process of one product to another manufacturing process for another product.
9. Just-In-Time: It aims to produce only the exact required item, when it is needed, in the required quantity, at the required place. It is used to obtain the best usage of the available resources and to meet customer needs (Taghipour, Hoang and Cao 2020).
10. TPM: It is used to avoid all the problems related to machines, such as machine breaking down, rejected parts, idle machines, long-time maintenance, machines working below the rated speed, start-up losses, and bottlenecks. In addition, the total participation of all employees is a must to create autonomous group activities where operators take care of the equipment without being asked to do so by lubricating, tightening, readjusting, etc (Wakjira and Singh 2012).

### 1.3 Research Objectives
This research aims to increase the productivity and thus, the profitability of a meat manufacturer in Egypt. This increase would result from applying lean manufacturing concepts and tools on the factory work floor. Lean manufacturing would be applied using innovative mechanical solutions to eliminate different types of waste.

## 2. Literature Review
Lean manufacturing and some of its practices have been utilized in many industries. Kundgol et al. (2021) were assigned to identify waste and NVA activities in an aerospace manufacturing industry to reduce the lead time and cycle time of operations 20 (Preparatory operation) and 30 (Face milling, Pocket milling). They used the VSM technique to identify the current state of part XYZ of the FANUC controller machine, which failed in the delivery to the customer. The data collection was done for all the stages of the part, from the raw material to the finished good, in addition to the cycle time, including the setup time. The VSM started with the customer expectations, so takt time was calculated (available time/customer demand). It was observed that 98% of the total delivery time was from waiting or NVA activities. It took nine days in the deburring section (bottleneck) due to the unorganized layout of this section, which did not support the materials flow due to unorganized workers and tables causing WIP. A Kaizen project was conducted to develop a new layout for the deburring section, considering that it would reduce the cycle time.

Romero et al. (2019) have addressed upgrading a CNC machine based on the Judoka principle. The problem with CNC machines is the wear of the cutting tool. Therefore, if the tool is not changed for a relatively long period, the final product will have some quality problems. Also, if the tool is changed early, this implies a loss of money and materials. Therefore, wear is studied based on several sensor readings (vibration sensor or acoustic sensor) and dynamometer readings where a controller, like Arduino or PLC, is used to predict the tool's useful life. In addition to the sensors and controller, a machine learning algorithm is developed to make a model for predicting the tool wear. By doing so, the CNC machine stops when the tool gets worn, and the operator changes the cutting tool.

Zhang (2014) has studied many cases of applying the Poka-Yoke concept in manufacturing. First, a production line that assembles hard disks from raw drives had problems with the number of work order drivers due to human counting. The company used an information system for driver counting. Therefore, the machine stopped counting when the work order driver's number reached the required number. The second case concerns a warehouse that ships many orders daily. The problem was shipping wrong orders and causing customer complaints. After analyzing the root causes, it was found that there was a lack of integration with the enterprise resource planning (ERP) system and the actual shipments by the operators. The Poka-Yoke method used was wireless devices that scan the products before shipment. If the scanned product was not the same in the ERP system, a buzzer gave a sound and stopped the shipment. A project for kaizen concept implementation is conducted in a wheat factory by a technical team and production managers. They took notes from shop floor workers about the conveyor carrying the wheat. The problem with the conveyor was that the wheat caused corrosion to the conveyor metallic sheet as time passed, resulting in wheat spillage. The spilled wheat accumulated in the conveyor and caused a stoppage of the system. After investigation, the team used abrasive-resistant fiber instead of a conveyor sheet. After market research, the new material was supplied and applied to the conveyor. In addition to the fiber, small gaps were made in the chain of the conveyor to prevent clogging and stop the system if the wheat spilled. Also, small reservoirs were added to the chain to collect wasted wheat. Therefore, the project reached its targets by eliminating system stoppage, reducing the waste in wheat and time, and increasing productivity (Tekin, Etlioglu et al. 2019).

Moreira and Pais (2010) implemented the SMED system in a mold-making factory in Portugal by forming an SMED team. First, they observed the production during changeover operations by interviewing the workers individually at hierarchical levels and collecting information regarding the changeover operations using videotaping. The team separated the activities into internal and external activities, where the internal activities are those done during the changeover, and the external activities are done before the production stops. Finally, the team converted some internal activities into external ones, saving 5 to 7 minutes of setup time.

In the U.S., in the mid-1980s, Hewlett Packard Inc. suffered from many problems in its manufacturing systems, especially the long lead time in its computer systems division. The time required to make printed circuit boards (PCBs) was from 11 to 15 days, which is relatively long, and from 10 to 45 days for the assemblies. Also, testing schedules of the memory circuits took too much time as they were not linked with the material requirement planning system. Therefore, JIT was implemented in the company by using small lots, Kanban cards to control the material flow and continuous manufacturing. The results were positive as the set-up time was reduced by 30 to 45%, eliminating $2 million in inventory cost, space was reduced by 3750 $ft^2$, and the lead time was decreased from 15 to 1.5 days. Through this implementation, Hewlett Packard Inc. became one of the first companies that implemented the JIT philosophy in Western countries(Mukwakungu et al. 2019).

## 3. Methodology

This paper aims to implement lean manufacturing tools in the Egyptian meat industry. Lean principles are used to carry out this project. The first step is to define the factory system, taking into consideration the product type, variability, and production volume. Then, manufacturing variables, such as productivity, are measured and evaluated. The next step is to state the current processing of the factory with a time study and labor force. The factory processes are mapped using VSM to show all VA and NVA activities and reveal the different types of wastes in the processes. After that, the most important step in the project is to identify and remove the different types of waste in the manufacturing process by implementing different lean tools within the factory's capability. This must lead to an improvement in the manufacturing performance variables. Finally, the performance variables like processing time, labor force, and productivity are evaluated after implementing lean tools.

The data collection from the shop floor was done through various methods. After several visits to the factory, each process's cycle time was measured using a stopwatch and eye observation. Also, the Gemba walk was used to observe the process, measure the number of operators in each station, and identify any problems on the shop floor. Moreover, the production manager was interviewed to understand how the information and materials move inside the factory. Furthermore, some operators were interviewed to acquire information about each station and machine. In addition, historical data on factory productivity was acquired from the planning department manager.

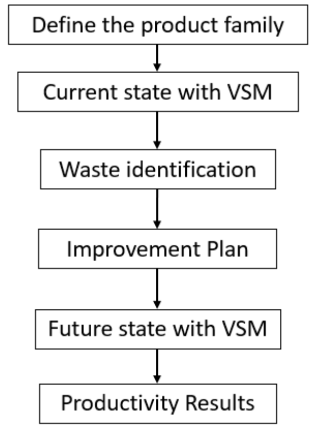


Figure 1. Methodology Flow Chart

## Data Collection and Case Studies

### 3.1. Factory Background

The case study for this research was carried out in one of Egypt's giant meat factories, contributing to a vast market share in the Egyptian meat industry. It seeks to increase its productivity by conducting some projects like implementing lean manufacturing methodology. The factory under study is named X according to the confidentiality agreement. The factory produces beef and chicken meat processed products in various types. It has three leading families of final products: chilled, frozen, and ready meat. Each family has different processing and storage methods. The chilled meat category has many final products divided into different types of beef and chicken luncheon products. Frozen meat is diverse, with different final beef, chicken burgers, and sausage products. The ready meat category has more than one final product. Each final product has a different setup and processing according to its family and specifications.

### 3.2. Define the Product

The project is conducted on the chilled family product, the 5 kg beef luncheon. The chilled product family, especially luncheon, is the main product for the factory because it contributes to the most significant amount of total production and profit. The final product has some specifications that the customer defines. The weight of the luncheon pieces is 5 Kg. Also, the customers demand the luncheon taste to be homogenous. In other words, the luncheon ingredients must be distributed thoroughly in each piece. This project aims to maximize customer satisfaction and reduce the waste associated with production. The lean manufacturing project is done for one production batch as a unit reference of improvement. The one batch consists of 1200 kg of raw meat and 1000 kg of additional ingredients for the recipe.

### 3.3. Current State of Luncheon Production

As previously mentioned, the processed luncheon is a batch process containing 1200 Kg of beef and 1000 Kg of secret recipe additions. The factory has two sections: one for meat processing and the other for cooking, cooling, and packaging. The processing section works for one shift of 8 hours and one break hour, but the other works 24 hours. The VSM of the current state is shown below in Figure (2). The Figure shows the Value Added (VA) and the Non-Value Added (NVA) activities to produce 2200 Kg of beef luncheon batch as follows:

The processes to produce 2200 Kg of beef luncheon batch are as follows:

1. Raw beef inventory in the fridge (NVA).
2. Transporting the beef to unpacking tables (NVA).
3. Unpacking the beef from the boxes (NVA).
4. Transporting the beef metallic container to the crusher (NVA).
5. Frozen beef crusher (VA).
6. Addition and mixing of the recipe (VA).
7. Beef softening (VA).
8. Second mixer (VA).

9. Transport the beef mixture batch to the fillers (NVA).
10. Luncheon filling (VA): The beef mixture is filled with the required shape and amount of the final product.
11. Transporting the luncheon trollies to the ovens (NVA).
12. Cooking the luncheon in the ovens (VA).
13. Transporting the luncheon trollies of luncheon to the cooling area (NVA).
14. Packaging of the luncheon (NVA).
15. Transport the final product boxes to the final inventory (NVA).

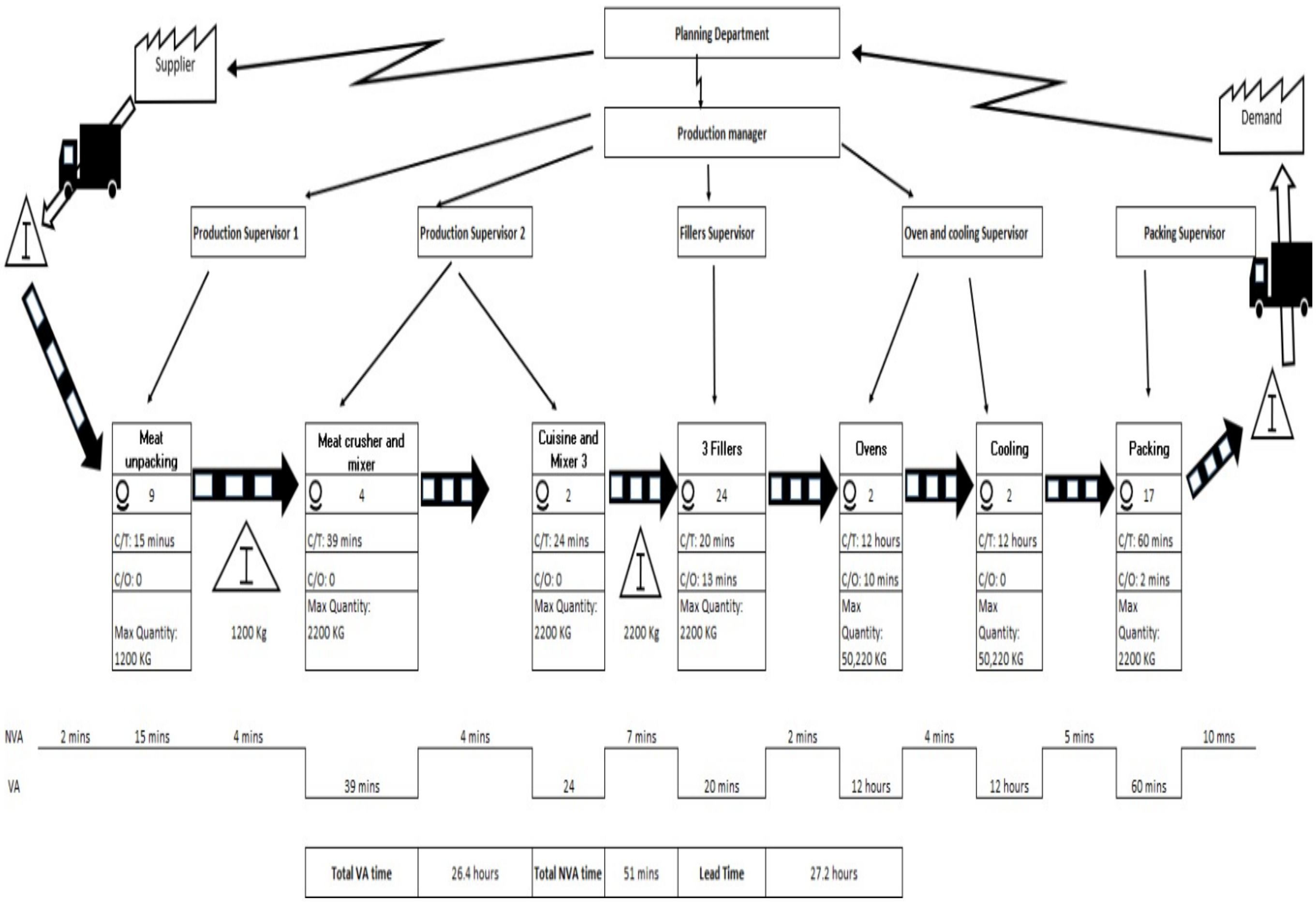


Figure 2. VSM of the Current State

### 3.4. Waste Identification and Improvement Plans

The factory suffers from several types of waste identified by Gemba Walk and VSM of the current state. The study and observations were done in the luncheon preparing area, which is the process before the ovens. Some of the observed types of waste in the factory are excess motion, overprocessing, waiting, transportation, and untidy places. The following 4 cases of waste are tackled, and some improvements are developed.

**Case one (Beef Unpacking process):** NVA activity with 9 workers. Also, a forklift moves unsafely on the work floor to carry the beef container to the scale to weigh it. The container takes about 15 minutes to get full, then 4 minutes weighing it on the scale.

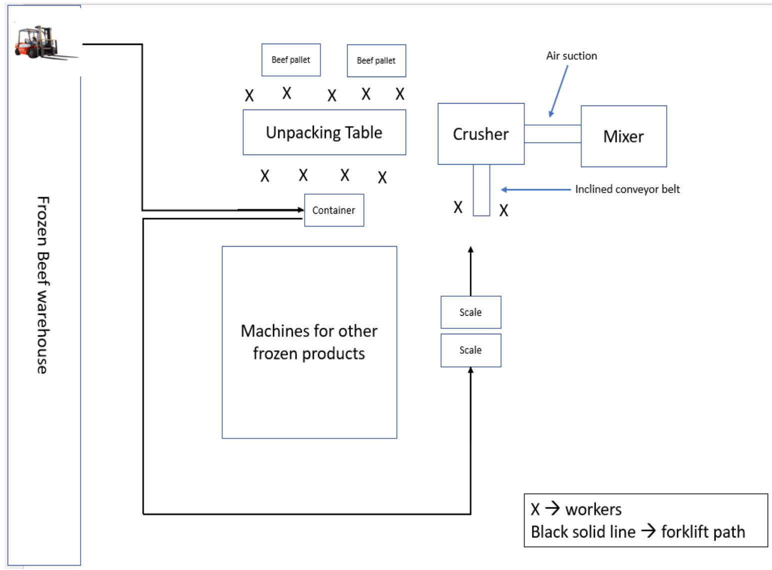


Figure 3. Case One Current State

To improve in this case, the Kanban signal technique is used. A small scale is provided with a microcontroller on the table to link the unpacking process with the crusher directly. The scale has a space capacity of one beef piece per time. This small scale must save the data of the weighed beef pieces accumulatively by a simple program uploaded on the microcontroller. Also, the orientation of the inclined conveyor belt of the crusher is turned 90 degrees clockwise to align the conveyor with the unpacking table. By doing so, the process becomes as follows:

•Three workers open the cardboard boxes.
•Three workers remove the nylon cover.
•Three workers carry the beef pieces, weigh them on the tiny new scale, and place them directly on the crusher conveyor belt. The new scale can save data. Therefore, when the accumulative data reaches 1200 Kg, representing the batch quantity, the scale gives a sound indication like a buzz to make the workers stop feeding the conveyor belt.
This improvement removes an NVA activity, reduces the number of workers in the whole process by three including the forklift worker inside the work floor.

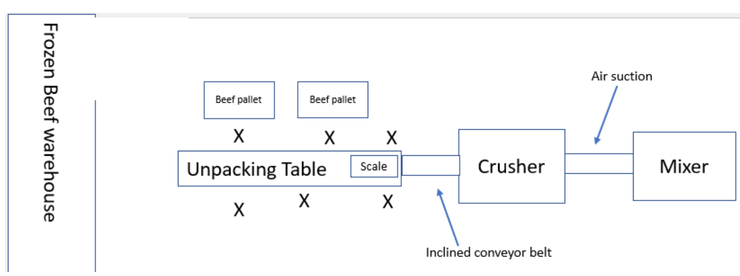


Figure 4. Case One Improvement

**Case Two (Idling Time for the first mixer Process):** After the crusher finishes one batch, it must wait 25 minutes for the first mixer to finish its operation. At these 25 minutes, the crusher stops and has an idling time of 25 minutes. Also, when the first mixer finishes its operation, it idles for about 12 minutes, waiting for the crusher to finish, as the crusher can operate only when the mixer is empty. Therefore, the mixer and crusher are considered as bottleneck continuous process. The average current utilization of the mixer is 68%, and for the crusher, it is 32%.

A kaizen methodology is carried out to reduce the idling time for the crusher and the mixer, remove the bottleneck, or reduce its cycle time. A new external container is placed just beside the first mixer. Also, screw duct would be modified to be moved with an angle of 30 degrees anticlockwise to make the output side of the crusher directed to the new external container. By doing so, the crusher fills the external container, not the mixer directly. Then, the external container is discharged in the mixer directly for about 6 minutes. Therefore, when the mixer operates for about 25 minutes, the crusher can fill the external container for about 12 minutes. The mixer idles for about 6 minutes to discharge the crushed beef from the external container to the mixer. Therefore, mixer utilization increases from 68% to 80%. Therefore, this leads to a reduction in the maximum cycle time by 36%.

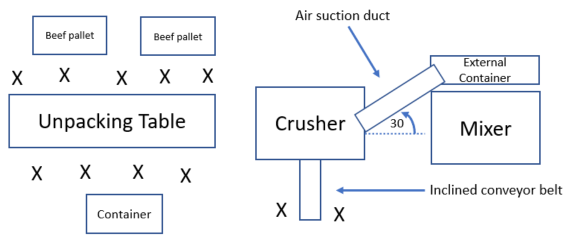


Figure 5. Case Two Improvement

**Case Three (Unorganized Meat Carts):** The carts' parking area is beside the second mixer but is highly unorganized. On some visits to the factory, there were a few numbers of carts. On other visits, many unorganized carts blocked the movement of the workers and supervisors. This happened because no guides specified the area for the carts. These carts come from the laundry after washing them with pumped water. Moreover, the just-cleaned carts have no dedicated area for waiting, so they are left in front of the laundry, waiting for the workers to take them. This causes crowdedness in the laundry between the clean and the used carts.

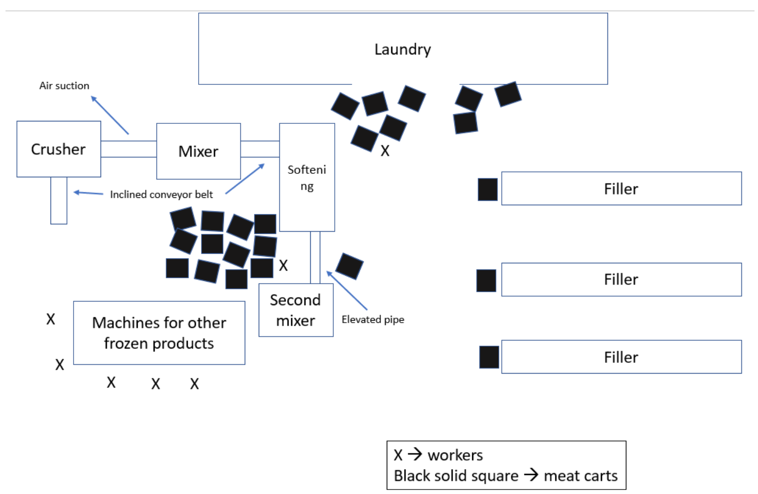


Figure 6. Case Three Current State

The 5S method is implemented to organize the carts. The main idea for this case is to force the worker to move the exact number of carts to their exact place. This improvement occurs in the laundry and second mixer areas. Metallic barrier rails can be constructed beside the empty area of the laundry and at the second mixer. Due to the frozen meat processing, these metallic barrier rails can have space for only 12 carts for the one batch at the second mixer and more than 12 carts beside the laundry. 5S is implemented as follows:

1. Sort the required number of carts only and remove the extra.
2. Set the carts in their exact palaces in the barrier rails.
3. The carts in the barrier rails must be clean.
4. This process must be documented to be followed by everyone.
5. This process must continue and be observed by production supervisors.

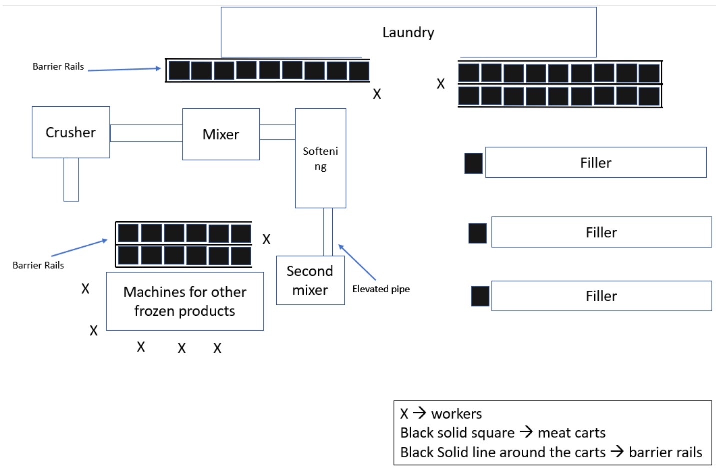


Figure 7. Case Three Improvement

In unpacking, the workers open the boxes and throw the empty boxes on the work floor. Then, two cleaning workers collect the cardboard boxes from the ground and flatten them to put them on a metallic pallet. The pallet is moved from the work area using a forklift. The two cleaning workers work relatively slowly compared to the rate of thrown boxes as the boxes flattening takes more time than opening the boxes. Therefore, the thrown boxes on the work floor cause severe congestion, resulting in the forklift not taking the container filled with beef to the scale, so it takes more time (about an additional 4 minutes) to deliver the beef to the crusher. Also, the boxes on the floor block the workers' paths and limit their movement. Moreover, the work floor is untidy and unsuitable for a productive environment.

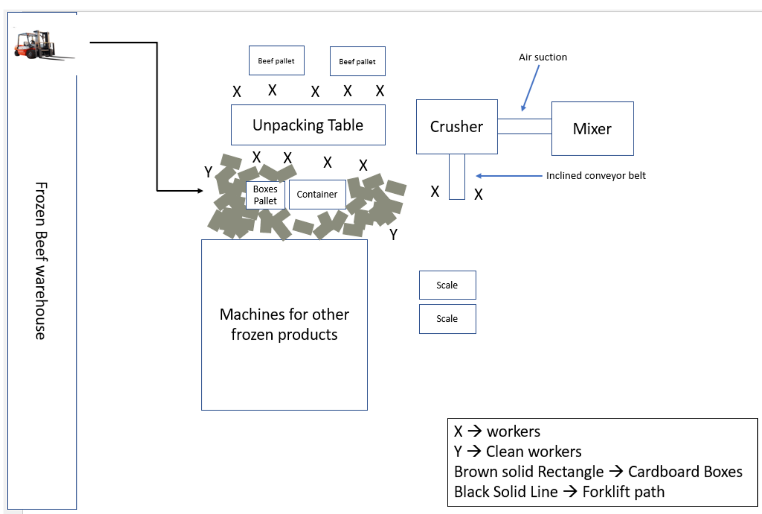


Figure 8. Case Four Current State

To organize the empty boxes, the 5S method is implemented. When the workers unpack the beef pieces, they use a knife to open the cardboard boxes, causing a hole or an opening in the cardboard boxes. Then, the idea arose to use these holes to collect the boxes from production workers. As shown below, two industrial carts are used on the work floor to collect the boxes. The boxes would be inserted in the two poles through the already-made holes so that the boxes would be collected above each other in the cart. The height of these two poles is 2 meters, and the box's height is 10 cm. Therefore, each cart can collect 40 boxes. Moreover, the batch takes between 70 to 60 boxes. Therefore, two carts for box collection are required to make one batch. After one cart gets filled with boxes, the worker takes it to dispose of the boxes and leaves the other one to be filled until he returns. As a result, one cleaning worker is reduced. 5S is implemented as follows:

1. Sort the only required number of industrial carts, which is two.
2. Set the empty boxes in the poles of the industrial carts.

3. The work floor must be clean, as well as the carts.
4. This process must be documented to be followed by everyone.
5. This process must continue and be observed by production supervisors.

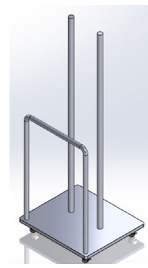

Figure 9. Industrial Cart Designed by SolidWorks

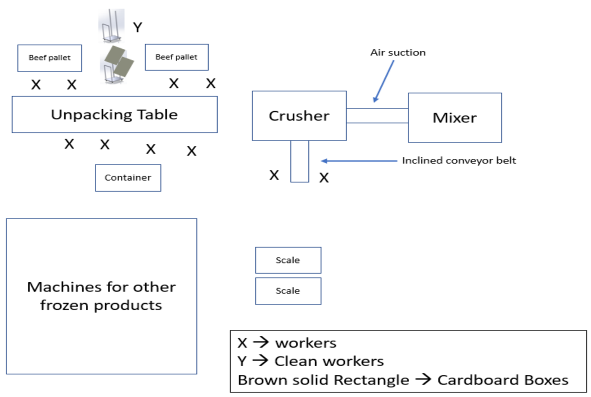


Figure 10. Case Four Improvement

## 5. Results and Discussion

The results and calculations were done for the luncheon preparing processes only (before the ovens process). The main idea of productivity increase is reducing the bottleneck cycle time. The following tables contain the production and productivity calculations before and after implementing the improvement plan to investigate the impact of the plan. The equations used are as follows:

No. of batches = available time per shift/bottleneck cycle time.
Production quantity (Kg) = No. of batches * 2200 Kg of luncheon
Productivity = Production quantity (Kg) / SUM (No. of workers * corresponding cycle time)
Productivity Impact = (new productivity – old productivity) / old productivity

Table 1. Current State KPI

| | |
|---|---|
| Available time for the factory | 420 minutes |
| Number of workers | 39 |
| Maximum cycle time (crusher+mixers) | 14+25=39 minutes |
| Production quantity | 420/39= 11 batches/shift |
| Production quantity | 11*2200=24200 kg/shift |
| Productivity | 24200/(9*15+2*14+2*25+2*29+24*20)= 32.22 Kg/(labor*min) |

Table 2. Future State Expected KPI

| | |
|---|---|
| Available time for the factory | 420 minutes |
| Number of workers | 31 |
| Maximum cycle time (mixers) | 25 minutes |
| Production quantity | 420/25= 17 batches/shift |
| Production quantity | 17*2200= 37400 Kg/shift |
| Productivity | 37400/(9*15+2*25+2*29+18*20) =62 Kg/(labor*min) |
| Impact of the improvement Plan (Productivity increase) | (62-32.22)/32.22= 61% |

From the previous tables, it can be shown that the improvement plan increases the total productivity by 61% for the factory processes before the ovens (luncheon preparing processing). In addition, the VSM of the future state (Figure 11) shows that the total NVA time has decreased by 47%. Also, the total number of workers is decreased by 20%.

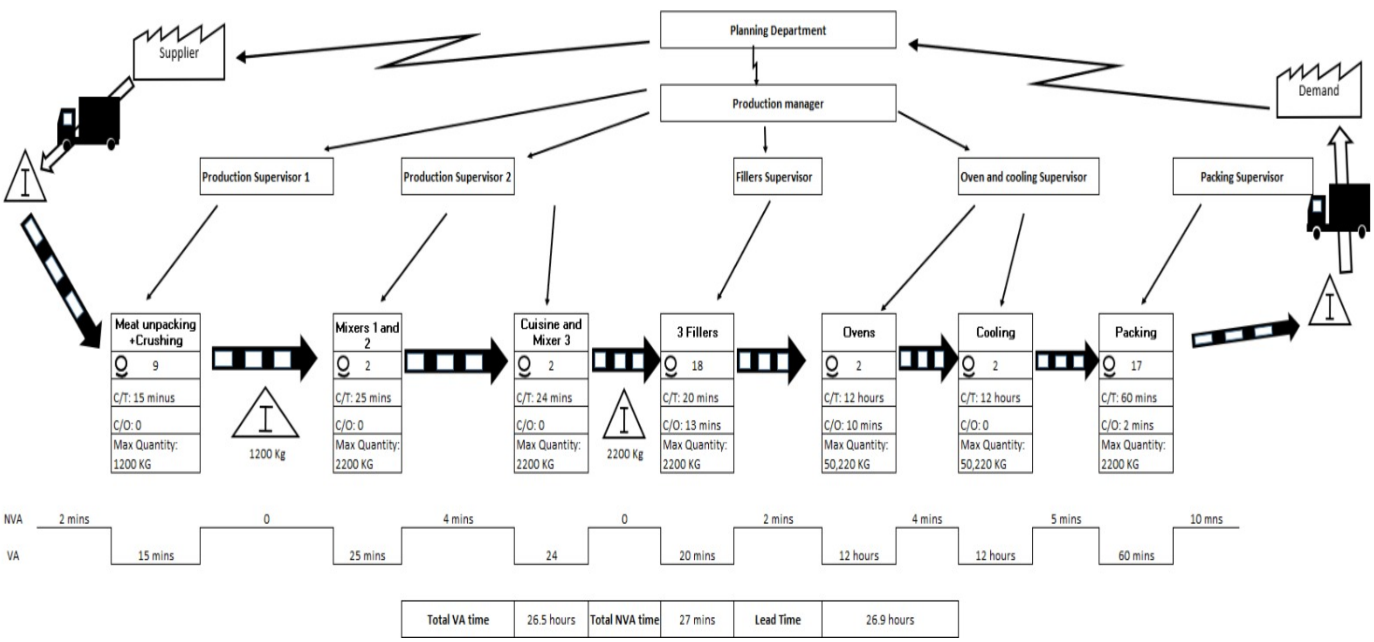


Figure 11. VSM of Future State

## 6. Conclusion and Future work

Lean manufacturing methodology is one of the excellent ways to reduce waste and increase productivity in food industry factories. In this project, the meat factory in the case study aims to transform meat production to lean production to meet the demand and increase revenue. The factory has two sections: one is before the cooking process, and the other is after the cooking process. The project is conducted in the first one of the processing. Due to the product variability, the project was carried out for the luncheon production line as it contributes to the most significant amount of total production and profit. Several visits to the factory were made to collect data and understand how luncheon is produced. Gemba walk into the factory and lets us observe some waste areas. Also, the current state of VSM reveals the bottlenecks and NVA activities that need to be reduced or eliminated. Some brainstorming and worker interviews led to the development of an improvement plan consisting of four cases. The improvement plan is based on Kaizen and 5S methods to make minor improvements to enhance productivity.

The improvement plan focuses on organizing the factory's work floor by using barrier rails for the meat carts to park in their dedicated areas instead of being everywhere without any organization. Also, a designed cart to collect empty cardboard boxes makes the work floor tidy and accessible. In addition to work floor organization, unpacking and crushing processes are combined to be one process—this process of merging leads to removing NVA and reducing the two workers. Also, adding a new mixer reduces the cycle time of the bottleneck of the processing section by 36%. All these improvements led to an increase in the total productivity by 61%, and NVA time has decreased by 47%. Also, the total number of workers has decreased by 20%.

As shown in the previous sections, productivity would increase as lean tools are implemented. Therefore, for future work, a cross-functional team can be responsible for all the improvement plans and aims to increase productivity using all industrial engineering tools such as lean manufacturing, Six Sigma, planning layout, optimization, etc. The team must have at least one member from all the departments, such as production, quality, safety, maintenance, planning, and sales. Also, the team should captivate lean methodology in the workers by conducting sessions explaining to them how to make continuous improvements on their own. Moreover, the team should develop new methods to implement lean manufacturing concepts like JIT and e-Kanban to reduce the cost of manufacturing. Furthermore, the team must Gemba walk regularly on the work floor where the value is created to observe any newly developed waste to remove it.

In addition, electronic boards can be installed on the factory floor displaying the current state of productivity, production, and other KPIs to notify the production supervisors if there is any delay or problem. Also, the boards show the stages of each production and its state. These boards must be obvious to all the workers.

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