

Improvement of Manufacturing Processes Utilizing Value Stream Mapping Technique: Cement Sacks Factory as an Industrial Case Study

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Abstract— Lean manufacturing is a production system, which was first developed by Toyota Production Systems (TPSs) to reduce wastes while improving the operational and environmental performance of manufacturing and industrial businesses. While the global industrial market suffers from gnarled competition, lean manufacturing philosophy is providing an effective methodology to reduce cost and maximize profit. In addition, the market no longer accepts waste caused by out of control production or inefficient processes. A commitment to quality and lean operations will result in quality improvement, waste elimination and reduction in time and costs.

Value stream mappings (VSMs), a lean manufacturing tool, which originated from the Toyota Production Systems (TPSs), is known as "material and information flow mapping." This mapping tool uses the techniques of lean manufacturing to analyze and evaluate certain work processes in a manufacturing operation. This tool is used primarily to identify, demonstrate and decrease waste, as well as create flow in the manufacturing process. VSM can be created merely using paper and pencil; however, more advanced maps are created using Microsoft Visio as well as Microsoft Excel.

This paper describes practical implementation strategies for using lean manufacturing and an industrial case study (Cement Sacks Factory) is included. After lean manufacturing methodology has been applied to the case, results are produced as Cement Sacks Factory process efficiency is raised by 4.31% and the TAKT time is reduced about 56%.

Index Terms— Lean Manufacturing; Value Stream Mapping; Waste elimination; Facility layout; inventory; transportation; Case study.

1. INTRODUCTION

THE critical starting point for lean thinking is value. As stated Womack et al. [1] value can only be defined by the ultimate customer. Moreover, it is only meaningful when expressed in terms of a specific product (a good or a service, and often both at once) which meets the customer's needs at a specific price at a specific time. Value is created by the producer. From the customer's standpoint, this is why producers exist.

With going on years, world has achieved great steps in industrial life to people, thus made countries to compete with them in grossing their industrial fleet. Therefore, industrial associations expanded to include many sectors in the same association. With competition between power centers in world and war between them, industrial association has begun to find systems to manage its big factories. Hence, many systems appeared, such as "lean", "six sigma" and "lean six sigma".

1.1 Lean Manufacturing System

Lean Manufacturing is the systematic elimination of waste from all aspects of an organization's operations, where waste is viewed as any use or loss of resources that does not lead directly to creating the product or service a customer wants when they want it. In many industrial processes, such non-value added activity could comprise more than 90 percent of a factory's total activity [1].

Lean manufacturing is the processes, techniques, strategies and initiatives being implemented by companies around the world

that aim to reduce unnecessary and unproductive tasks, activities and behaviors in the work environment. In other word, lean manufacturing is implemented in order to reduce waste and improve the organization production and morale.

There are many tools and techniques in lean manufacturing that can be implemented but the selection of effective lean tool, and technique in lean manufacturing is hard to choose. Wrong decision will affect the waste and time. Lean thinking is a highly involved method of managing an organization to improve the productivity, efficiency, and quality of products and services.

1.2 Lean Manufacturing Benefits

T. MELTON [2] stated the benefits of lean manufacturing are:

- Help to produce business outputs as fast as possible.
- Convert a business enquiry to a finished output; then it can hold less raw material and finished stock inventory.
- Hold lower inventory levels means need less cash to run the business.
- Able to produce work faster.
- Can do more with the same resources (machinery, people).
- Can complete work faster than competitors.
- Reduce the cash required for your business attractive.

1.3 More Common Practices of Lean Manufacturing

A few of the more common practices of the lean manufacturing are:

- Just In Time: Producing only what is needed, when it is needed, and in only the needed quantities; reducing work-in-process inventory.
- Kanban: A card that signals production of a set quantity of goods once that number of goods has been used by a customer process.
- Production leveling (or heijunka): Spreading production evenly over time; reducing batch sizes to one.
- Setup time reduction: Reducing the time to changeover between producing different products; required leveling production.
- Standardized work: Documented, detailed work procedures religiously followed by everyone doing the job such that the work is performed the same way every time.
- Multi-skilled workers: Workers trained in multiple job tasks so work can be assigned flexibly to balance the line dynamically.

1.4 Identification and Elimination of Waste

The philosophy of identification and elimination of the waste is:

- The central theme of a lean manufacturing production system.
- A dynamic and constantly improving process dependent upon understanding and involvement by all employees.
- Successful implementation that requires all employees must be trained to identify and eliminate waste from their work.
- Waste exists in all work and at all levels in the organization.

1.5 Types of Waste

There are seven types of wastes [1]:

- Over-production, producing more than needed, and/or producing faster than needed.
- Wait time, idle time that is produced when two dependent variables are not fully synchronized.
- Transportation, any material movement that does not directly support a Lean Manufacturing System.
- Processing, effort that adds no value to a product or service.
- Inventory, any supply in excess of process requirements necessary to produce goods or services Just in Time.
- Motion, any movement of people that does not contribute added value to the product or service.
- Reworks or Corrections, repair of a product or service to fulfill customer requirements

2. VALUE STREAM MAPPING

Jim Womack et al. [3] presented that a Value Stream Map-

ping (VSM) is a collection of all actions value added as well as non-value added that are required to bring a product or a group of products that use the same resources through the main flows, from raw material to the customers. These actions are those in the overall supply chain including both information and operation flow which are the core of any successful lean operation. Value stream mapping is a special type of flow chart that uses numbers and symbols known as "the language of lean" to improve the flow of material and information.

2.1 Value Stream Mapping Benefits

Ulf K. Teichgraeber et al [4] stated that there is a need to understand the entire manufacturing system in order to create VSM and gain maximum benefits, which are:

- In order to visually display where waste occurs in the process and to distinguish between value added and non-value added activities (waste), a value stream map (VSM) is drawn because the main principle of lean manufacturing is to reduce waste in an operation, such as long lead times, defects and material waste.
- Shows the linkage between material and information flow of a product
- Identifies all types of waste in the value stream and take steps to try eliminating them.
- Once the current state VSM is created, it becomes the baseline for improvement and for the creation of a future state value stream mapping FSVSM. The FSVSM can then be used as a world class manufacturing implementation road map.

2.2 VSM Creation

The procedure of the VSM creation is:

1. The Current State Value Stream Map
 - Select the product family that will be mapped
 - Decide what the goal for improvement will be
 - Form a team to collect data and map the selected value stream
 - Walk the flow and collect data on the value stream
 - Value Stream Map terminology
 - Value stream map standard symbols
 - Draw a map of the value stream
2. Analysis the Current conditions
 - Identify value added and waste
 - Choosing appropriate waste reduction methods and reconfigure process to eliminate waste and maximize value
3. Take actions and create the Future State Value Stream Map.

2.2.1 The Current State Value Stream Map

2.2.1.1 Select the Product Family That will be Mapped

Value stream maps are created for a single product, or a family of products. A family is a group of products with similar

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routings, similar process times, and customers with similar needs and demand rates. 'Similar' means that while there may be some variation, it is recognizable that all members of the group have the same set of core operations. Products may vary by color, size, or one or two steps in the production process. H.J. Warneke et al. [5] presented the reason for concentrating on a family of products is that lean improvements such as cells and kanban systems only work well if all products in the stream are similar in process times and routings.

2.2.1.2 Decide on the Goal for Improvement

There are different opinions about what the goal should be. First opinion for Advocates of the TPS style of lean manufacturing will claim that production at takt time is the only acceptable goal of the improvement process. Second opinion is that takt time is an outcome, not a design parameter. Whether the goal is to reduce cost by eliminating waste, or to produce in time with customer demand, value stream mapping is an essential tool, and it is independent of anyone production philosophy.

2.2.1.3 Form the Value Stream Mapping Team

Value stream mapping is the best done by a team in a workshop format. This is because few people really understand the entire value stream, or have the knowledge to anticipate the impacts of specific changes to it. A team with a variety of members is therefore required.

2.2.1.4 Walk the Flow

The team members should have a form for gathering data on each step (including work centers, queues, raw materials arrival, shipping to the customer, and operators).

2.2.1.5 VSM Terminologies

- **Value-added activities:** An activity that transforms or shapes material or information, the customer wants it and it is done right the first time.
- **Non value added – needed activities:** Activities which causing no value to be created but which cannot be eliminated based on current state of technology or thinking required (regulatory, customer mandate, legal).
- **Non value-added activities:** Activities that consumes resources but create no value in the eyes of the customer.
- **Cycle time:** Cycle time is the time required to execute activities in a process (including value-added and non-value added time)
- **Takt time:** Measure of customer demand - how much is required in the time available
$$\text{Takt Time} = \frac{\text{available time}}{\text{time customer demand rate for available time}}$$
- **The information flow:** Indicates how each process will know what to make. The information flow is drawn on the upper portion of the map. The information flow is drawn from right to left on the map and is connected to the material flow previously drawn.

- **Time line:** After the completion of the map, a timeline is drawn below the process boxes to indicate the production lead-time and value added time.
- **Production lead-time:** The time that a particular product spends on the shop floor from its arrival until its completion.
- **Value added time:** This time represents the sum of the processing times for each process.
- **Process cycle efficiency = Value added time/ total cycle time**
- **Value Stream Map and Selected Standard Icons:** VSM symbols is not standardized and there are many variations.

2.2.1.6 VSM Process Symbols

Value stream map uses special symbols to represent where there is waste in manufacturing processes and to help find ways to eliminate that waste.

2.2.1.7 Draw the current state map

The current state map is simply a set of connected operations and queues starting with a supplier and ending with a customer. After the data collection is complete, all of the data can be collected in a single spreadsheet or transferred directly to the value stream map from each team member's notes as follows:

- Draw customer, supplier and production control icons.
- Enter customer requirement.
- Calculate takt time.
- Draw outbound shipping icon and truck with delivery frequency.
- Draw in bound shipping icon and truck with delivery frequency.
- Add process box, in sequence, left to right.
- Add collected data box below.
- Add communication and information flow arrows.
- Obtain process attributes. Add to data box.
- Add operator symbols.
- Add inventory locations and level in days of demand and graph at bottom.
- Add push and pull icons.
- Add other information.
- Add working hours.
- Add value and non-values add time.
- Calculate total value and non-value add times.

2.2.2 Analysis the Current conditions

2.2.2.1 Identify Value Added and Waste

Value stream mapping is a process designed to reduce lead-time to make product flow and to eliminate waste (non-value added operations or activities). All for purpose of meeting customer demand at the lowest cost and with the highest quality [6]. Lean thinking relies on recognizing the "seven wastes" over-production, over-processing, inventory, motion, scrap, waiting and transportation. With simulation, it is easy to avoid the traditional problem of eliminating waste at an operation where there is no net gain [7]. That is because the

revised system's performance can be compared to the current state to see the impact of the proposed change.

2.2.2.2 Choosing appropriate waste reduction methods and reconfigure process to eliminate waste and maximize value

Matthias Holweg et al. [8] stated that there are many waste elimination methods that can be applied in a given situation, but selecting the appropriate method is not easy. Consideration must be made of cost disruption to other product families and parts of the production system, operator skills, maintenance, reliability, space and so forth.

2.2.3 Take actions and create the Future State Value Stream Map

The future state map is nothing more than an implementation plan that highlights what kind of lean tools are needed to eliminate the waste, and where they are needed in the product value stream. Creating a future state map is done through answering a set of questions concerning issues related to building of the future state map and technical implementation related to the use of lean tools. Based on the answers to these questions one should mark the future state ideas directly on the future state map. After creating the future state map, the last step is to carry it out by trying to implement the different ideas generated by the future state map on the actual value stream.

2.3 The Lean Facility Layout

Layout is an integral part of a Lean manufacturing strategy. Meaningful restructuring requires corresponding physical changes in the layout. Flow is one of the main five concepts of lean manufacturing, but in order to achieve smooth flow important decisions must be taken and that is to plan and design a layout that is integrated to other concepts of lean along with the flow.

Facility layout decision is based on criteria aimed at creating an effective and efficient workflow and high standard production. Conversely, a layout re-design can be the catalyst for re-structuring. A layout project properly done can demonstrate the need for change to an organization reluctant to tear itself apart and rebuild. Therefore, requirements for effective layout are:

- Minimize material handling costs
- Utilize space efficiently
- Utilize labor efficiently
- Eliminate bottlenecks
- Facilitate communication and interaction between workers, between workers and their supervisors, or between workers and customers.
- Reduce manufacturing cycle time and customer service time
- Eliminate wasted or redundant movement
- Facilitate the entry, exit, and placement of material, products, and people
- Incorporate safety and security measures; Promote product and service quality

- Encourage proper maintenance activities
- Provide a visual control of operations or activities
- Provide flexibility to adapt to changing conditions

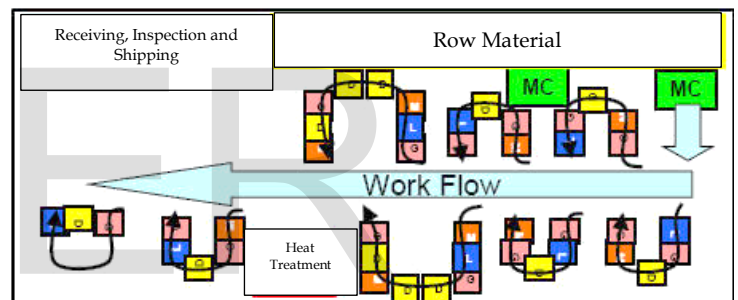
2.4 Lean Factory Design

A lean plant/shop floor layout have significant impact on the organization's performance. Material and information flow is organized and streamlined. A lean plant layout is an effective way to improve profitability and throughput while increasing safety [9]. The elimination of wasted movement and implementing line balancing can significantly reduce costs and reduce cycle time to provide speed of delivery and improved throughput.

2.5 Process Flow Analysis

Figure 1 shows an example for process flow analysis, which allows visualization of the movement of people or materials. This can quickly lead to an understanding of where inefficiencies exist and how to eliminate them. It is critical to layout work in the order it will occur to the greatest extent possible, in order to eliminate the waste of movement.

Fig. 1. Processes flow



3. CEMENT SACKS FACTORY

3.1 Cement Sacks Factory Information

- Name: Cement sacks factory
- Area: 6250 m²
- No of products: 2X (for itself & other factories)
- Layout: Figure 3 represents the cement sacks factory layout

3.2 Sequence of Production Processes

Figures 2 to 11 show the sequence of production processes in the Cement Sacks factory case study.



Fig. 2. Transport the craft paper roller with the forklift



Fig. 3. Set the craft paper roller in the beginning of the production line



Fig. 4. Get ink from ink tank (printing)



Fig. 5. Select the suitable Crile

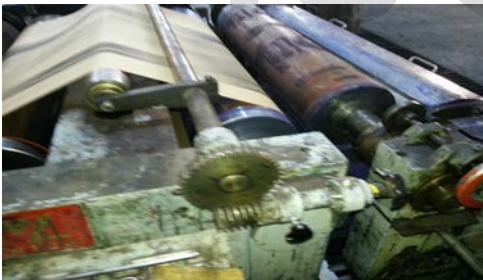


Fig. 6. Installation of the Crile



Fig. 7. First steps in sacks forming (overlapping)



Fig. 8. Guides to improve the overlapping process and movements



Fig. 9. Sacks stick (tubing)



Fig. 10. Preparing for the final sacks (separation)



Fig. 11. Final product ready to store

3.3 Requirements of the production line processes

Table 1. Processes requirements

| Step | Process Description | No. of Worker | Distance (m) | Task time (min) | Wait time (min) |
|------|---------------------|---------------|--------------|-----------------|-----------------|
| 1 | Remove cover | 1 | 12.5 | 2:00 | 0 |
| 2 | Printing | 1 same worker | 12.5 | 00:05 | 02:00 |
| 3 | Overlapping | 1 same worker | 12.5 | 00:05 | 0 |
| 4 | Guides | 1 same worker | 12.5 | 00:05 | 0 |
| 5 | Glutinous | 1 same worker | 12.5 | 00:05 | 0 |
| 6 | Tubing | 1 same worker | 12.5 | 00:05 | 0 |
| 7 | Separation | 1 same worker | 12.5 | 00:05 | 0 |

3.4 VSM of the Cement Sacks Factory

As reported before, VSM is the tool of lean manufacturing, "Simple Follow product's production path from customer to supplier and carefully draw a visual representation of every process in the material and information flow". VSM is all the actions (both value added and non-value added currently required to bring a product through

the main flows essential to every product. Figure 12 presents the current layout of the Cement Sacks factory.

3.4.1 Current VSM

Figure 13 presents the current VSM of the Cement Sacks factory.

VSM Data Set:

- Product flow unit of 10,000-cement packs.
- Handling using two forklifts with speed = 47 m/min each.
- Coding time for one 5,000 sacks pallet = 1 min.

Product:

Cement packs consist of:

- Craft paper
- Glue
- Ink

Fig. 12 Current Layout of the Cement Sacks Factory

Customer Requirements:

- Pallet=5000 packs.

Working Time:

- Shift time = 6.75 hr.
- Break time = 1.25 hr.

Manufacturing Process:

Manufacturing processes for a sample consists of 10000 packs are shown in table 2

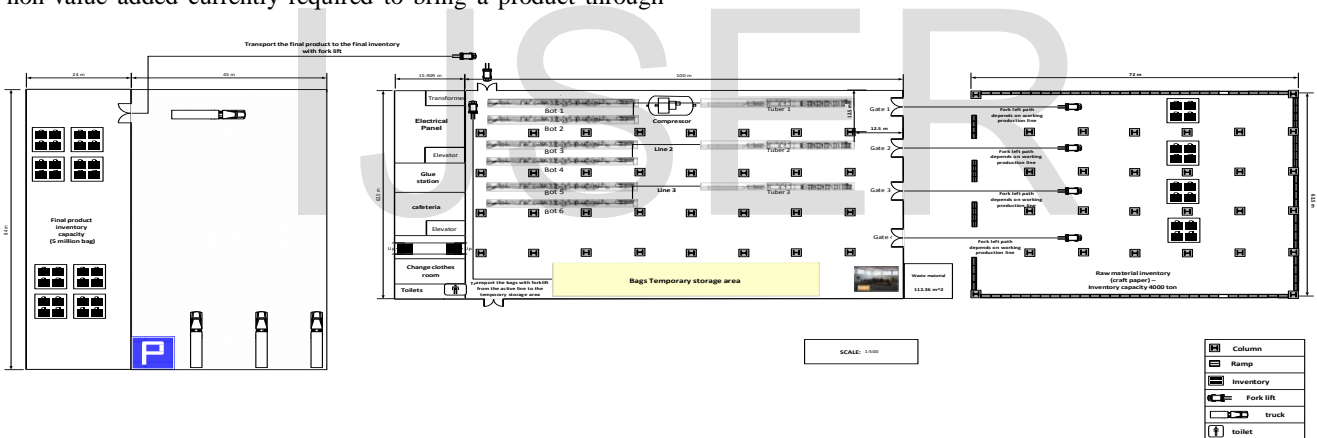


Fig. 12. Current Layout of the Cement Sacks Factory

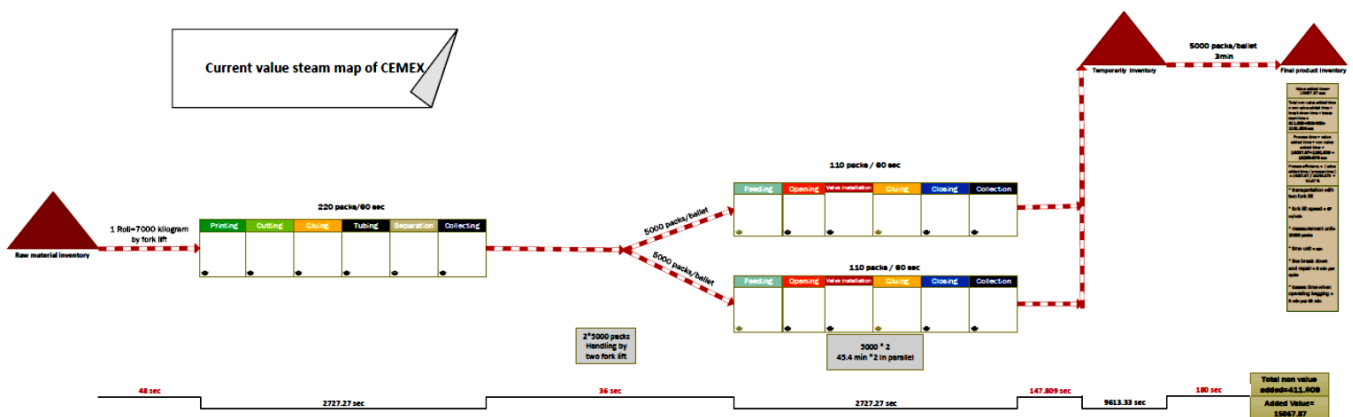


Fig. 13. Current VSM of the Cement Sacks Factory

Table 2. Value and non-value added times of the manufacturing processes for the cement sacks factory case study

| Step | Description | Time |
|---|--|------------------------------------|
| - Handling of raw material | From raw material inventory to the production line by using forklift. | Non value added time = 48 sec |
| - First stage of production: - Manufacturing primary product (size = 2 ballet) | It includes the following processes: <ul style="list-style-type: none"> • Printing • Cutting • Glowing • Tubing • Separation • Collecting | Value added time = 2727.27 sec |
| - Handling primary product to the final production steps | By using two forklifts to handle the two ballets in the same time. This activity time includes: <ul style="list-style-type: none"> • The time for set the last 220 packs on the pallet. • Forklift down time. • Forklifts time to handle pallets between the two production stages. | Non value added time = 36 sec |
| - Second stage of production: - Final manufacturing steps | It includes the following processes: <ul style="list-style-type: none"> • Feeding • Opening • Valve installation • Gluing • Closing • Collection | Value added time = 2727.27 sec |
| - Handling final product to the temporary inventory | The time for this process includes: <ul style="list-style-type: none"> • The time for set the last 220 packs on the pallet. • Forklifts caring and down time. • Forklifts time to transfer the pallets. • Coding time. | Non value added time = 147.809 sec |
| - Temporary inventory | This step is taken for sacks to drying glue | Value added time = 9613.33 sec |
| - Handling pallets to the final product inventory | This uses two forklifts to handle the two pallets | Non value added time = 180 sec |
| - Final product inventory | Final sacks storage | Out of process description |

3.4.2 Current process efficiency

- Break down and repairing time for one cycle = $8 / 45 = 0.178$ min.
- Total value add time = 15067.87 sec.
- Total non-value added time = non-value add time + break down time + losses time.
 $= 411.809 + 480 + 300$
 $= 1191.809$ sec.
- Process time = $15067.87 + 1191.809 = 16259.679$ sec.
- Process efficiency = $15067.87 / 16259.679 = 92.67\%$.

3.4.3 Modified value Stream Mapping

These value stream maps show the effect of applying lean think-

ing on the efficiency of the production lines for the Cement Sacks Factory as shown in table 3. Figures 14 and 15 show the modified layout and VSM respectively of the Cement Sacks Factory.

Table 3. Impact of the lean thinking on the Cement Sacks Factory

| Modification | Reasons | Result |
|--------------|---------|--------|
|--------------|---------|--------|

| | | |
|--|---|--|
| 1- Handling between tuber and bottomers using roller conveyor rather than using fork lifts | <ul style="list-style-type: none"> The forklift cost = 100 (L.E / day) and these is huge cost add to the cost of the product. The cost of the conveyor will be illustrated in a budget study later. | <ul style="list-style-type: none"> Reduce the handling time to be =18.75 sec instead of 36 sec. Reduce the handling cost add to the production cost. |
| 2- Change factory door position and this is shown in the modified layout. | The forklift way is very long | <ul style="list-style-type: none"> Reduce the forklift way from the temporary inventory to the final product inventory and reach the maximum benefit of the forklift. Reduce time required for handling between temporary and final product inventory to be = 100.85 sec instead of 180 sec. |
| 3- Fill two pallets with 10000 packs ready to use in the next work day | The bottomer lines stop working for 45 min at the start of the shift until the tuber working for 45 min to produce the two pallets. | The two stages of production work together. |

Conveyor specifications and designation

- Conveyor length = 12 meter
- Conveyor width = 4 meter
- Conveyor velocity under zero load = 120 m/min
- Conveyor velocity under max. load = 40 m/min
- Conveyor max load = 15 ton

Cost review for roller conveyor

Table 4 shows budget statement (this budget will show the cost of three motorized conveyors)

Table 4. Cost review for roller conveyor

| Components | Number | Cost per three units |
|---------------------|--------|------------------------|
| Roller conveyor | 3 | 15000 L.E |
| Chain belt | 3 | 600 L.E |
| 15 hp. Driver motor | 3 | 190000 L.E |
| | | Total cost= 205600 L.E |

Income statement

- After applying this modification, the handling time between tubers and bottomers, will be reduced by 17.25 sec.
- The production time for one cement bag = 0.655 sec.
- This will show that in the 17.2 sec. will produce 27 bag

- The net profit for one bag = 0.2 L.E
- The daily bag production 90000 bags
- The daily net profit = 90000*0.2= 18000 L.E

Cach flow statement

After reviewing budget and income statement, the total cost = 205600L.E and capital recovery rate= 205600/18000 = 12 days

Modification results

The non-value added time will be reduced to =315.409 sec instead of 1191.809 sec. Therefore the efficiency of the production line cycle will be increased to = 94.98 % instead of 92.67 %.

4. CONCLUSIONS

Value stream mapping has proven to be an effective way to analyze a company's current production state and point out problem areas. The visual nature of value stream mapping, by combining information and material flow on one map, depicts how the two relate to the lead-time. By applying lean thinking and VSM technique in the Cement Sacks Factory case study, there are many benefits can be obtained as:

- Reduction in the handling cost which add to the production cost.
- Reduction in the forklift way from the temporary inventory to the final product inventory.
- Reaching the maximum benefit of the forklift.
- Reduction in the time required for handling between temporary and final product inventory to 100.85 sec instead of 180 sec. This means that the reduction percentage is 56.

There are many factors contributing to the lead-time, that is, order handling, planning, procurement, delivery, inspection, manufacturing, handling, picking, packing and delivery. This paper focuses on analysis of manufacturing data for reducing lead-time and addresses within Make and Plan. Future work can be carried out on design, order handling, delivery or reassembly since those are also important factors affecting production and lead-time in the company's operations.

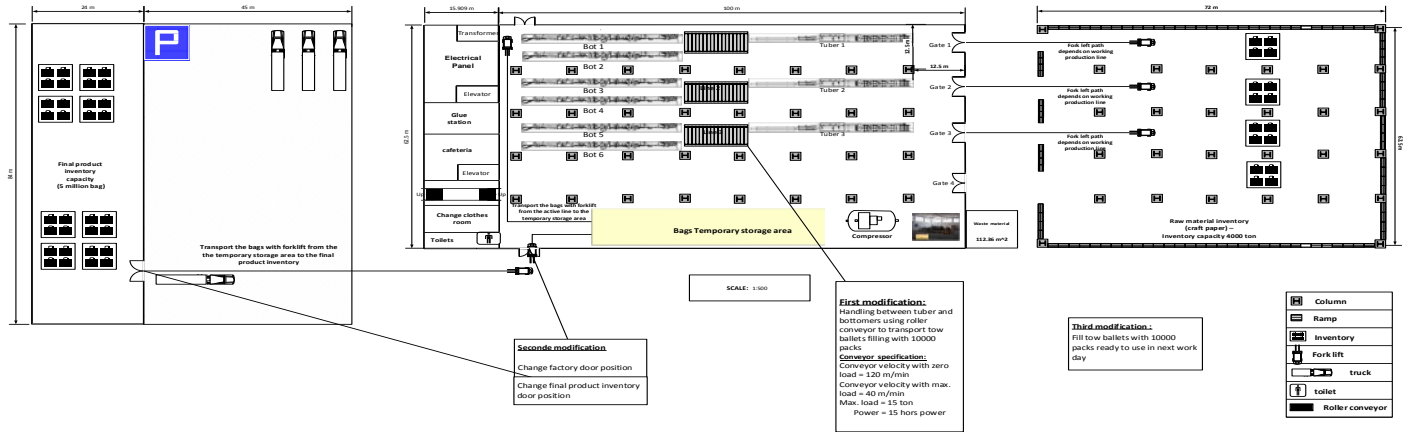


Fig. 14. Modified Layout of the Cement Sacks Factory

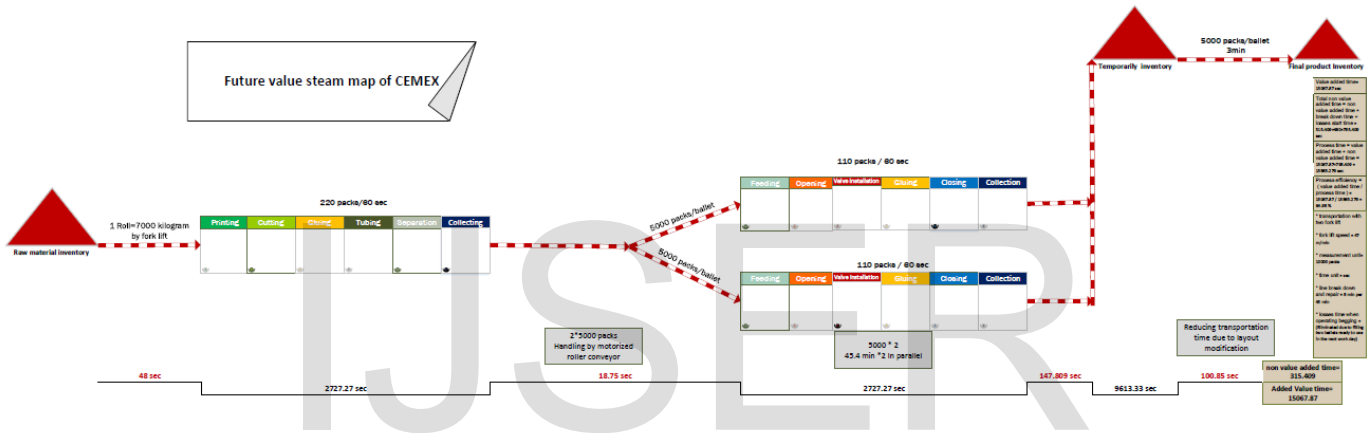


Fig. 15. Future VSM of the Cement Sacks Factory

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