Manufacturing Efficiency Improvement Through Lean Manufacturing Approach: A Case Study in A Steel Processing Industry

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Abstract. The idle and delay time in an industry is categorized as production waste that will cause problems such as production quantity below the target. In addition, the waste also leads to cost losses and eliminate opportunities for the industry to gain profit. The need of waste analysis to optimize the costs incurred due to the idle and delay time. Lean manufacturing approach can be used to minimize that production waste. Value stream mapping (VSM) is one of lean tools that can be used to identify all production activity for an industry. This study is conducted in a steel processing industry. The result shows that the dominant production waste is delay time. There are seven factors causing the main production waste, i.e. operation, mechanic, adjustment, electric, computer, instrument, and utility. These factors are the cause of production waste and production activities that do not add value to product. A maintenance improvement program is developed to reduce the production waste. Manufacturing cycle efficiency in actual condition is 68,08% while efficiency value in the future condition is 71,3% so from proposed improvement plan that can increase manufacturing cycle efficiency equal to 3,75%.

1. Introduction
The need for steel in recent years is increased to create some infrastructures in Indonesia. The national steel demand in 2017 reached 14 million tons in line with the realization of a number of projects Master Plan of Acceleration and Expansion of Indonesia Economic Development (MP3EI) [1]. However, the steel industry in Indonesia is only able to produce 8 million tons of crude steel, so 6 million tons of steel are imported [2]. The deficit in crude steel supply is predicted to reach 8,9 million tons in 2020 and 15,9 million tons by 2025 [2].

The rapid growth of steel usage leads to an increasing needs of an efficient manufacturing system in a steel processing industry to produce products according to the quality that consumers expect. Generally, the steel industry in Indonesia produces integrated steel from iron ores until it becomes the final product in the form of wire rod, plate, hot rolled steel and cold rolled steel. The problem faced is the production quantity that is not in accordance with the target because of production wastes. The impact is increasing energy usage and long production lead time. Therefore, this research is done to reduce production waste and improve manufacturing efficiency.

The implementation of lean production can enhance the manufacturing performance [3]. LM is broadly used among industries because LM can reduce production waste without additional resources requirement [4]. LM implementation creates a better working environment, reduce product defect, reduce training cost and improve tools life [5].
Lean manufacturing tools, i.e. value stream mapping (VSM) and single minute exchange of dies (SMED) are used to eliminate production wastes in Indian garment industry [6]. An integrated lean tools and sustainability concepts using discrete event simulation modeling creates a positive impact to environment, society and financial improvement of furniture industry [7]. VSM application with simulation model is used to evaluate LM design for an organization of furniture production [8]. The application of 5S and VSM can reduce production waste and improve manufacturing performance [9]. A specific lean tool is used based on type of organization and its problem [10].

LM also successfully implemented in computer integrated environment at an automotive industry to reduce machine downtime, production waste and increase productivity [11]. LM is able to reduce production cost by eliminating non value added activities of Indian steel industry [12]. The systematic approach to reduce production waste in LM, can creates eco-efficiency [13]. LM can help the industry to achieve the objective of green manufacturing [14].

Total productive maintenance and standardization are lean tools that well assured to improve productivity in the Lebanese pharmaceutical industry [15]. LM implementation in pharmaceutical industry also can reduce production lead time, work in process and distance of material transport [16]. Lean manufacturing (LM) implementation directly can improve productivity, flexibility, employee performance and continuous improvement culture in food and beverage manufacturers [17]. LM tools is a proven approach for time and resource savings, process improvement and eliminates waste [18]. Lean scheduling in a job shop environment is successful in reducing lead time, inventory, production cost and improve space utilization [19].

Most of industries achieve a productivity improvement through LM implementation, this trends will continue in Industry 4.0 environment [20]. A holistic implementation of LM provide a significant impact for business performance among Indonesian manufacturing industries [21]. The concept of LM and value engineering are used for process optimization in textile industry [22]. Lean concept is used as basic steps for a sustainable manufacturing [23]. LM is mostly implemented in manufacturing industry with batch or line production characteristics [24].

There are three characteristics of manufacturers that can successfully implement LM, i.e. non-unionized facilities, new age of plant and large manufacturers [25]. Lean best practices should be aligned with business strategy and manufacturing environment to improve the LM performance [26]. There are five stages to implement LM for multinational companies with production subsidiary in Brazil, i.e. awareness, planning, setting up, implementation and perfection [27].

2. Theory

Lean manufacturing is a production practice used to increase the value added of products for customers by eliminating production waste [28]. There are seven types of production waste, i.e. [29]:

a. Overproduction that occurs because the amount of production is more than the customer needs.

b. Delays (waiting time) is a delay for machines, equipment, raw materials, suppliers, machine maintenance and so on.

c. Transportation is moving the material with a long distance from one process to the next process so that the material handling time increases.

d. Over processing is an additional process or unnecessary work activity.

e. Excess inventory which may lead to additional handling activities that should not be required.

f. Motions is a movement of people or machines that do not add value to goods and services that will be delivered to the customer.

g. Defect products require rework and if the product is defective it must be destroyed.

One method to identify production waste is value stream mapping (VSM). VSM is one of the lean manufacturing tools that visualize all production activities. VSM is used to find and eliminates production waste along value stream [30]. There are 16 steps to develop VSM, i.e. drawing customers, suppliers, and production controls, including monthly and daily consumer demand, calculating daily production adjusted for customer demand and container capacity, drawing out bond shipping symbols
and trucks with delivery frequency, drawing inbound shipping symbols and trucks with delivery frequency, adds a process box in sequence from left to right, adds a box of data that includes cycle time, person time, scrap rate, adds communication arrows, writes method along with its frequency, adds the process attribute loaded in the data box, adds operator symbols and their numbers, adding location and inventory levels in production units, adding push, pull and FIFO (first in first out) symbols, adding other useful information, adding hours, and counting total cycle time and total lead-time [31].

3. Research Method

This research is done to implement lean manufacturing for hot strip mill production in an Indonesian steel processing industry. An observation is done to identify production data, i.e. number of workers, number of production shift, raw materials inventory, work in process, finished goods inventory, production capacity, number of workstations, production flow and production time. The data then being used to calculate the current process value added time, non-value added time, inventory lead time, process lead time and manufacturing cycle efficiency. A current state map of VSM is develop to analyze seven type of production waste that occurs, i.e. overproduction, unnecessary motion, excessive transportation, inappropriate processing, waiting/delay, defect, unnecessary inventory. Based on that analysis, a dominant production waste is identified. Some factors that cause the production waste are analyze to find the root cause. A manufacturing improvement program is generated to reduce the production waste and a future state map of VSM is developed. The effectiveness of the program is evaluated using manufacturing efficiency indicator.

4. Result and Discussion

The value added activities in hot strip mill production is 555,53 seconds as shown in Figure 1.

![Figure 1. VSM-Current State](image_url)

The value added activities consist of some process, i.e. slab heating, chemical reaction cleaning process, thickness reduction process, rolling process, cutting process, and labelling process. While the necessary non value added is 260,46 seconds which derived from some process, i.e. removal of slab from warehouse to reheating furnace, slab arrangement before entering into reheating furnace, slab travel to water dis-caller, slab to sizing press, slab to roughing mill, slab trip to station Integrated, travel coil to labelling condition, production process activity is categorized as inefficient because the value added activities is below 70% , i.e. 68,08% and a high non value added activity that equal to 31,92%. This condition occurs due to the production delays in the process.
To develop the production process, it can be done by making an analysis of some factors that can cause the production waste. In this case, activities that do not add value in the hot strip mill production can be categorized into seven factors based on delay time generated. These factors are operation, mechanic, adjustment, computer, electrical, instrument, and utility as shown in Figure 2.

![Graph of Delay Time](image)

**Figure 2.** Graph of Delay Time

The factor that creates the highest delay time is mechanic at 11.26%. Identification of some potential causes of production delays on each factor is made using a fishbone diagram to make it easier for troubleshoot problems and find solutions to be performed. There are 35 potential causes for all factors, 74% of potential causes are categorized as equipment/machine failures. Therefore, the improvement that can be done to reduce the delay time is to do maintenance improvement program as seen in Table 1.

**Table 1.** Maintenance Improvement Program

| No | Factors   | Improvement Activity                                      | Impact                                           |
|----|-----------|----------------------------------------------------------|-------------------------------------------------|
| 1  | Mechanic  | Conduct routine checks and treatments on water discaller | Water can spray against slabs without any constraints |
| 2  | Mechanic  | Replacing machine components that are past their lifetime | No damage to the machine during the production process takes place |
| 3  | Mechanic  | Caring for cranes and forklifts                          | Slab and coil connections can run faster         |
| 4  | Mechanic  | Replace the roll that is already operating ineffectively | No interruptions during slab trips               |
| 5  | Operation | Doing activities slab identification with care            | The process of slab positioning can run faster   |
| 6  | Operation | Scheduling for roll table checking once every 3 months    | Slab travel process can be faster                |
| 7  | Adjustment| Perform roll turn on down coiler on a regular basis every 6 months | Increases the performance of the coil rolling process |
| 8  | Adjustment| Perform roll repair on down coiler once every usage      | Reduces errors during coil rolling process       |
| 9  | Computer  | Updating the system used by the company                  | No errors in production data                    |
| 10 | Computer  | Perform repairs on the computer every 6 months           | Can function properly                           |
| 11 | Electric  | Set the slab temperature appropriately                    | The slab does not stick to the roll table       |
| 12 | Utility   | Conduct routine checks such as electricity, water and light | Reduce the time wasted due to problems caused by these supporting factors |
| 13 | Instrument| Doing maintenance on a routine every month               | The machine can work optimally without any small hassles |
The condition of the production process after implementing maintenance improvement program can be seen in Figure 3. The future state is a change of non-value added activities, i.e. a change of time on the process of travel from water dis-caller to sizing press of 30.10 seconds reduced to 27.79 seconds. Travel process of sizing press to roughing mill of 47.72 seconds reduced to 33.22 seconds. The travel from the roughing mill to the integrated station is 60.39 seconds reduced to 49.99 seconds. The process of travel from station integrated to labelling of 24.36 seconds reduced to 15.71 seconds.

The implementation of maintenance improvement program shows that production process flow at the hot strip mill production have a better state of the future state than current state condition due increasing number of value added activities from 68.08% to 71.83% and the reduction of non-value added activities from 31.92% to 28.6%.

The value is categorized as effective because a process runs efficiently if its value added activities is at least 70% [29]. By doing maintenance improvement program, the industry is able to increase manufacturing cycle efficiency by 3.75% which makes the industry run the production process efficiently.

5. Conclusions
The conclusion of the research is production delays become the dominant production waste in steel processing industry. Based on current state map of VSM, the current manufacturing cycle efficiency is 68.08%. The design of the improvement of production flow is done by implementing maintenance improvement program on seven types of source of production waste, i.e. operation, mechanic, adjustment, computer, electric, instrument, and utility. The value of manufacturing cycle efficiency in the future condition is 71.3%. An increase in manufacturing process efficiency is at 3.75%.

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