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Improving the efficiency of material transfer system using Value Stream Mapping (VSM): A case study in the shoe industry

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ABSTRACT

This research was conducted in one of the shoe industries in Indonesia, which has a problem with material buildup in production material storage. The buildup of material can cause the production material transfer system less efficient. The research aims to identify waste in the production material transfer process using current state value stream mapping (VSM), recommend improvement strategies using future state VSM, and design a more efficient production material transfer system. First, we develop a causal loop diagram because it can map the problem. Then, we identify and fix the problem through value stream mapping for more efficient use of resources. The waste identified in the current state value stream mapping consists of waste of over-processing, waste of motion, and waste of useless transportation. In the future-state VSM, the lead time of the material transfer process is reduced by 840 seconds or 14 minutes, the cycle time of the material transfer process is reduced by 731 seconds or 12 minutes, the area needed is reduced by 43.2-meter square, and the total workforce reduced to two people. A 4-hour material transfer system is recommended as a more efficient production material transfer system.

1. Introduction

The shoe industry is one of the priority and mainstay industries, where the company absorbs 795 direct and labour-intensive workers. It has contributed 0.3% to the quarterly 2 in 2018 National GDP. It makes the shoe industry one of the priority industries. Indonesia is ranked fourth as a leading global shoe producer after China, India, and Vietnam, with a total share of world production of 4.6%. Furthermore, Indonesia is the sixth largest shoe exporter in the world. As a result, Indonesia can potentially increase the export value of the shoe industry [1]. The industry must be efficient and minimize waste in its production process to compete with other companies [2]. Companies need to implement lean manufacturing methods to increase company profitability by eliminating production processes that do not provide added value and maximize customer value [2].

Lean manufacturing has positively impacted company development and performance [3]. Lean manufacturing is a multidimensional approach adopted by many large companies to streamline production processes and achieve resource optimization [4]. The eight types of waste in lean manufacturing are waiting times, overproduction, steps without added value (over-processing), unnecesary transportation, excessive inventories, unnecessary human movements (motion), under-utilization of human potential, and defective part production (quality defects) [3]. There are several tools and techniques for implementing lean manufacturing, but the starting point for implementing lean manufacturing is Value Stream Mapping (VSM) [5]. VSM acts as an improvement tool that helps visualize the overall production process, representing every material flow and information in a system [6]. VSM is a technique that allows users to see wasted resources across the entire process flow [7].

Causal Loop Diagram (CLD) is a tool of systems thinking that maps the complexity of the relationship between system components using a linear chain of cause and effect [8]. CLD is a diagram often used in mapping problems that consider dynamic systems' complexity with a systems approach [9]. CLDs are represented by components and arrows (cause-and-effect relationships between components). The positive arrow (+) indicates the direction of the unidirectional relationship, i.e., the relationship of the component (cause) to the next component (effect) will increase or decrease together. The negative arrow (-) indicates the direction of the opposite relationship, i.e., an increase in one component causes a decrease in the other related component. When this causal relationship starts and ends at the same component, it will form a feedback loop in the form of reinforcement (R) or balancing (B). Loop (R) means a mutually reinforcing or weakening relationship. Loop (B) means a balanced or reciprocal relationship [10].

This research was conducted in one of the shoe industries in Tangerang, Indonesia. This company is one of the companies actively adopting a continuous improvement strategy to compete in its sector [11]. Intense competition has forced this company to improve its production system. Lean manufacturing is important in encouraging company performance, especially at the operational level [12]. The shoe industry has a problem in the form of material buildup in the production material storage, as seen in Fig. 1. The material is a production material that comes from the raw material warehouse, which will be cut on the production line.

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Figure 1. Material buildup in the production area

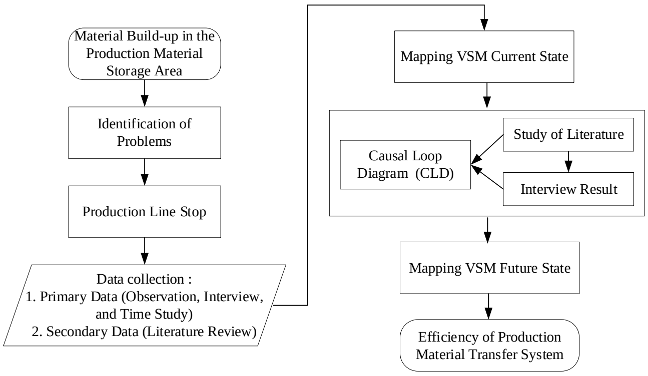

Figure 2. The steps of the research

This buildup occurs because the material is not directly cut on the production line. One of the reasons is that production has stopped line due to several obstacles in the process. While the raw material warehouse, regardless of whether production has a stop line, material expenditure is still carried out according to the planning needs per production day. The buildup of material can cause the production material transfer system less efficient.

The research aims to identify waste in the production material transfer process using current state VSM, recommend improvement strategies using future state VSM, and design a more efficient production material transfer system. This study uses a causal loop diagram because it can describe and map the problem. Next, it identify problem fixes through value stream mapping for more efficient use of resources [13].

This study does not consider improvements in the cost aspect. This research is unique because the existing research has not looked at the production material transfer system, especially in the shoe industry, as an interesting thing to study. The use of the causal loop diagram method as a causal diagram of a problem in collaboration with the value stream mapping method as a problem-fixing tool still needs to be done in previous research, thus making this research very important and interesting.

2. Materials and methods

This section presents the methodology of this research, which consists of the type of research, location and time, and the research's steps. The type of research used is qualitative research [14]. Qualitative research with field observations and time studies maps it into the current and future state of VSM. This study focuses on CLD for broad problem mapping as a qualitative conceptual model development. This research was conducted in Tangerang, Indonesia, from January 2022 to February 2022.

Fig. 2 explains the research framework that begins with the problem of material buildup in production material storage (in the production area). After identifying the problem, the buildup of the material is caused by the production line stopping (stop line) [15]. This study collects data in the form of primary data and secondary data [16]. Primary data comes from observations, interviews, and production cycle time analysis. Interviews were conducted with three resource persons who are experts in their fields: a raw material warehouse manager, a production manager, and a PPIC (production planning and inventory control) manager [17]. Secondary data consists of literature reviews in journals related to lean manufacturing, VSM, and CLD [18].

The current state of VSM is identified and analysed to determine the current conditions in transferring production materials from the raw material warehouse to the production cutting line. The mapping process of the problem is clearly on a complex system using a CLD. The mapping of future-state VSM is done to make improvement strategies. The result recommends a more efficient material transfer system design.

3. Result and discussion

This section presents the results and discussion of research consisting of the production material transfer process, VSM current state, CLD research, VSM future state, and a more efficient proposed system design.

3.1. Producion material transfer process

The material transfer process starts from the raw material warehouse to the production material storage (production area) to the cutting line production. The detailed flow process can be seen in Fig. 3. The warehouse issues production materials based on the day sheet (planning needs per production day) at one time per day.

In the first step, the operator (warehouse) setting the material first takes the roll material from the beam rack (by day sheet) and then places it on the layering table for cutting. The material is cut, trimmed, and placed on the raw material lorry (by day sheet). The material warehouse setting operator performs the handover with the warehouse-production material transfer operator. Operators transfer raw material lorries to production material storage (in the production area). Materials placed on the raw material lorries are transferred to the cutting material rack by the warehouse-production material transfer operator. Warehouse-production material transfer operators transfer empty lorries to warehouses.

The layering storage operator takes the material (by kanban cutting) from the cutting material rack and places it on the layering table for the layering process (folding the material according to the respective material standards). The material that has been layered is placed on the raw material lorry (by kanban cutting).

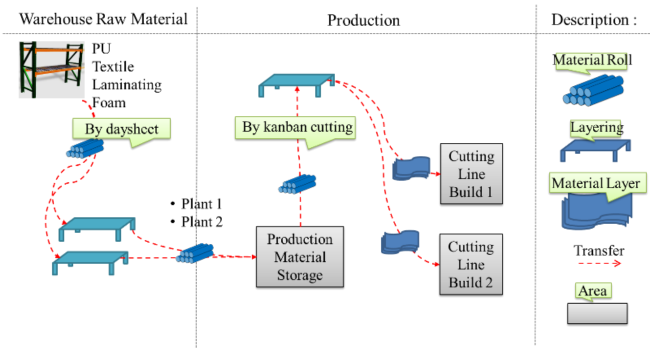

Figure 3. Production material transfer process

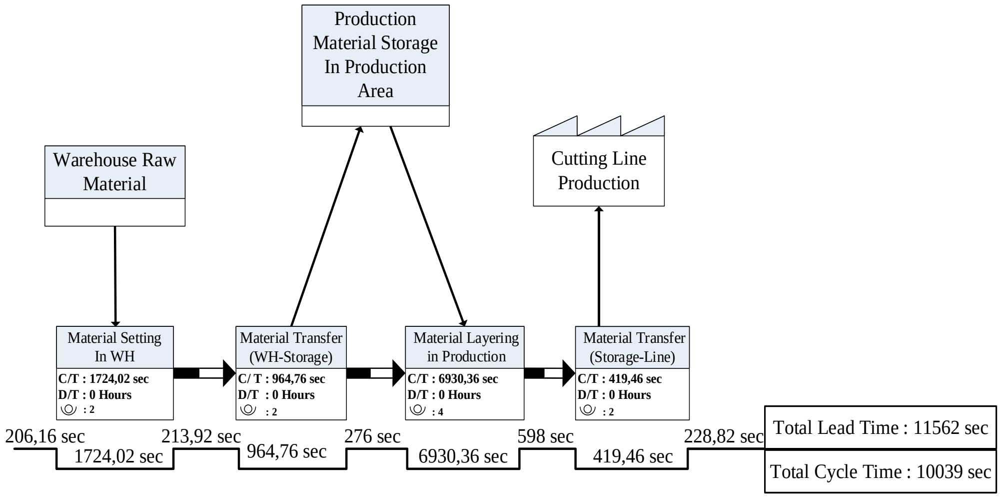

Figure 4. VSM current state

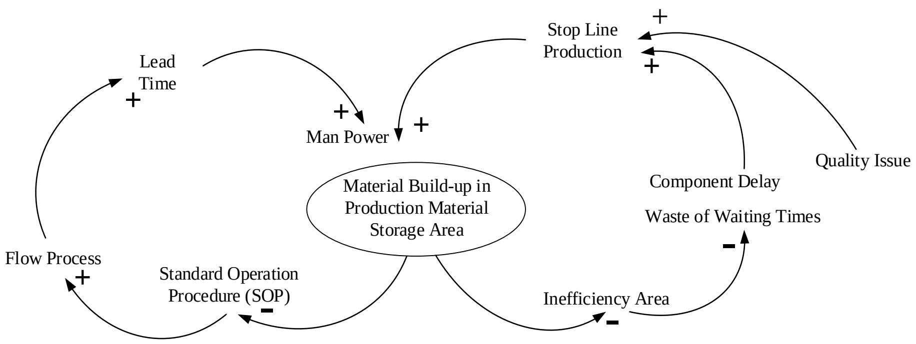

Figure 5. Causal loop diagram

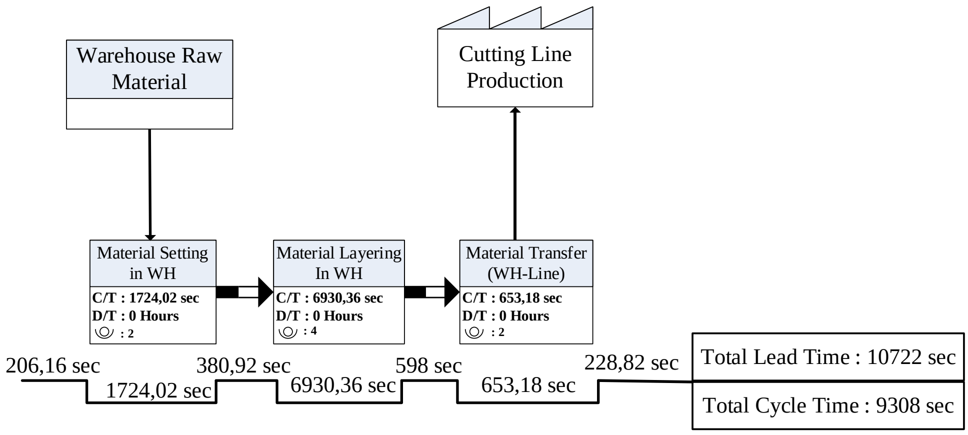

Figure 6. VSM current state

The line storage-cutting material transfer operator transfers the material set on the raw material lorry to the line-cutting production. After that, hand over the material to the line-cutting supervisor. The line storage-cutting material transfer operator transfers material from the raw material lorries to the tooling material stand cutting, then transfers the empty lorries to storage.

3.2. VSM current state

Field observations are carried out directly to determine the current condition and the process of transferring production materials. The material transfer process's cycle time is determined using a stopwatch. Fig. 4 is a current state value stream mapping (VSM) representing an overall picture of the activities currently occurring in the production material transfer process.

This VSM current state mapping maps the overall production material transfer process (production buildings 1 and 2). Cycle time calculations are carried out in the material setting process in the raw material warehouse, transfer of material from the raw material warehouse to production material storage (in the production area), layering of production materials in production material storage (in the production area) and material transfer from production material storage (in the production area). The four activities involve ten workforces in all processes.

Fig. 7. Material beam rack and layering table

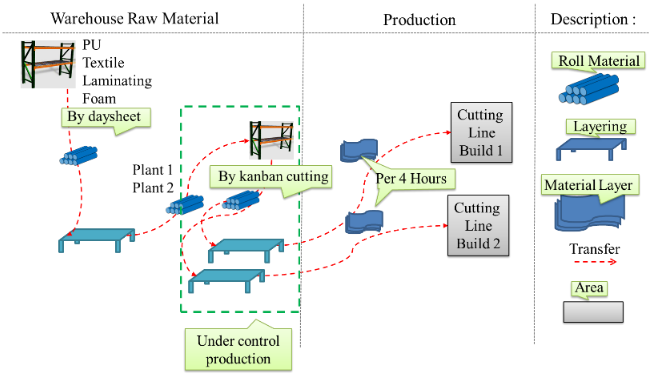

Fig. 8. Material transfer process flow per 4 hours

The total lead time of the production material transfer process for a one-day sheet number is 11562 seconds, with the total cycle time of the production material transfer process being 10039 seconds. High total lead time allows for waste of over-processing. Waste of over-processing is generated because of excessive processing, so it does not provide added value. Over-processing can also lead to waste of motion because it causes excessive operator movement or activity, so it does not provide added value. Transferring material from one area to several areas can also waste unnecessary transportation. Waste that can be identified from the value stream mapping current state is waste of over-processing, waste of motion, and waste of useless transportation.

3.3. CLD of material transfer process

CLD is a diagram often used in mapping problems that consider dynamic systems' complexity with a systems approach. The problems in the shoe industry are clearly and broadly mapped conceptually using the CLD in Fig. 5. The results of the CLD obtained from interviews with three sources show that there is no reinforcing loop (R) or balancing loop (B) because there is no causal relationship that starts and ends on the same component. Component delays and quality issues have a positive relationship with the stop line, meaning that the more component delays and quality issues that occur in the production line, the more frequent production stop lines occur. Production line stops and production material build-up has a positive relationship, meaning that the more production line stops occur, the more production material builds up because the material is not cut on time.

The production materials build-up has a negative relationship with the inefficiency area, meaning that more materials build up in the production area, resulting in inefficient use of the area (inefficiency area). The inefficient area and the waste of waiting-times have a negative relationship, meaning that the use of the area is less efficient, resulting in the emergence of waste of waiting-times. Waste of waiting-times occurs due to waste in waiting because the material is not directly cut in the production area.

The material build-up in production material storage (in the production area) and standard operation procedure (SOP) have a negative relationship, meaning that the more material build-up occurs, the existing SOP is still less effective. The SOP and flow process has a positive relationship, meaning that the SOP is less effective, resulting in the transfer process of transferring production materials being less effective. Process flow and lead time have a positive relationship, meaning that the ineffectiveness of the material transfer flow process can lead to less efficient lead times. Lead time and workforce have a positive relationship, meaning that lead time is less efficient, resulting in less efficient use of the workforce.

3.4. VSM future state

This VSM future state mapping maps the entire production material transfer process (production buildings 1 and 2). In the value stream, mapping is carried out to recommend improvement strategies in the production material transfer process. The VSM's current state and CLD become the basis for taking corrective steps. The focus of improvement in this research is to minimize the waste of over-processing, waste of motion, and waste of useless transportation. The design of this future state value stream mapping illustrates the comparison between the current state and the future state, which has been designed for improvement proposals to optimize value-added activities and minimize waste. Fig. 6 is the value stream mapping of the future state of this research.

This VSM future state mapping maps the entire production material transfer process (production buildings 1 and 2). In the VSM future state, the total lead time for the material transfer process was originally 11562 seconds to 10722 seconds (reduced 840 seconds or 14 minutes). The total cycle time of the material transfer process is from 10039 seconds to 9308 seconds (reduced by 731 seconds or 12 minutes). Ftrom Fig. 6, there is a reduced process which originally consisted of four processes into three processes (reduce waste of processing and of motion). The process that is omitted is the process of material transfer from the warehouse to the production material storage (in the production area).

The layering process originally carried out in the production material storage (in the production area) is now carried out in the raw material warehouse area. Production material storage measuring 22.4 m x 8 m (179 square meter) is removed. It can make the production area more efficient (reducing waste of useless transportation). The reduced process impacts reducing the workforce, which originally amounted to ten workforces to eight workforces. The total reduced workforce for all production buildings is two people. Two operators were reduced, namely the operator of material transfer from the warehouse to the production material storage (in the production area) in production buildings 1 and 2.

3.5. Design of material system per 4 hours

Material buildup in production material storage (in the production area) requires a new, more efficient system that can minimize the buildup of production materials. In the current VSM condition, the warehouse issues production materials based on the day sheet (planning needs per production day) at one time per day. The raw material warehouse does not care whether production has stopped line or not; material expenditure continues. VSM's future state becomes a reference in the design of this new system. This study recommends a new system, namely the material transfer system, for 4 hours. The material transfer system per 4 hours is a material transfer system that is carried out every 4 hours so that in a day, the raw material warehouse carries out material expenditure twice per day. It is done to minimize the buildup of material.

Table 1.
Comparison of the old system and the new system

No	Aspect	System		Conclusion	Change
		Old	New		
1	Frequency of material out per day from WH	1x	2x	Minimizing material buildup in the production area	
2	Material storage (in the production area)	A	NA	Area Efficiency	
3	Beam rack for storage of production materials at WH	NA	A	Storage material moved to beam rack	
4	Number of beam racks	0	1	Added 1 beam rack for 2 production buildings	
5	Number of layering table	1	2	Add1 layering table for 1 production building	
6	Production material storage area (m^2)	179	136	Saving area 43,2 m^2	24%
7	Lead time (sec)	11562	10722	Reduce 840 sec (14 min)	15%
8	Cycle time (sec)	10039	9308	Reduce 731 sec (12 min)	
9	Process	4	3	Reduce 1 process	25%
10	Manpower	10	8	Saving 2 manpower	20%

The 4-hour material transfer system is designed with a more efficient material transfer process. Production material storage (in the production area) measuring 22.4 m x 8 m (179 square meters) has been removed and moved to the warehouse area so that the transfer of production materials is carried out every 4 hours directly from the warehouse to the line cutting. Storage of production materials in the warehouse area requires an area of 16 m x 8.5 m (136 square meters). This system requires a layering table per production building and a beam rack for material storage every 4 hours, as shown in Fig. 7.

The following is the flow process of the material system per 4 hours, which can be seen in Fig. 8. In the first step, the operator (warehouse) setting the material first takes the roll material from the beam rack (by day sheet) on H-2, and then places it on the layering table for cutting. Materials are cut, trimmed, and placed on pallets (by day sheet). The material setting operator does the handover with the production layering operator. Production layering operator puts material on beam rack (under control production) by day sheet. On H-1, the production layering operator takes the material (by kanban cutting) from the beam rack and places it on the layering table for the layering process (folding the material according to the respective material standards). The material that has been layered is placed on the raw material lorry (by kanban cutting). The line storage-cutting material transfer operator transfers the material set on the raw material lorry to the line-cutting production. After that, hand over the material to the line-cutting supervisor. The line storage-cutting material transfer operator transfers material from the raw material lorries to the tooling material stand cutting. On D-day, the line-cutting operator can directly cut the material.

Table 1 compares the old system with the new system in transferring production materials in the shoe industry. This 4-hour material transfer system results in more efficient use of the area (24%), times (15%), workforce (20%), and process (25%).

4. Conclusions

The waste identified in the VSM's current state consists of waste of over-processing, waste of motion, and waste of useless transportation. Based on these results, we propose a VSM to reduce waste in its current state. VSM's future state can reduce processes, which originally consisted of four processes, into three processes (reduce waste of processing and waste of motion). The process omitted is transferring material from the warehouse to material storage (in the production area). Storage material in the production area that is removed can make the production area more efficient (reduce waste of useless transportation), namely the saving area of 43.2 square meters. The reduced process impacts two workforces for all production buildings, namely the operator of material transfer from the warehouse to material stored in the production area. The material transfer system per 4 hours is designed using a more efficient material transfer process. This 4-hour material transfer system results in more efficient use of the area (24%), times (15%), workforce (20%), and process (25%).

The suggestion of this research for further research is that further research can collaborate on causal loop diagrams and value stream mapping with the line balancing method to ensure optimal use of the proposed resources. Further research can also calculate the cost efficiency resulting from the improvement strategy.

Declarations Statement

Yuliani Fauziah: **Writing - Review & Editing.** Erik Odi Wijaya: **Conceptualization, Methodology. Supervision**. Indra Setiawan: **Resources, Visualization**. Bayu Hari Nugroho: **Resources, Validation**.

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