Warehouse Improvement Evaluation using Lean Warehousing Approach and Linear Programming

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Abstract. Lean manufacturing tools have been applied for several years to improve company’s internal logistic. Furthermore, a lot of factors such as globalization, competition and shorter life-cycle product force companies to create production process more efficient and cheaper. The acceptance of lean philosophy in the company means not only respecting the lean principles in the manufacturing area, but also in all the process that performed inside the company. The implementation of lean principles in the warehouse area is a certain step of improvement warehouse process and performance, but also the whole company. However, the implementation of lean principles in warehouse area is relatively new subject in logistics. Most of the research that has been done before only focused on eliminate waste and didn’t count the cost that can be saved after lean implementation. This paper’s objective is to identify waste that might be able to appear in warehousing process using value stream mapping. After the waste successfully identified, the next step is doing improvement using lean tool and count the implementation cost using linear programming. The result of this paper is choose which tool that make lower implementation cost and higher time reduction

Keywords: Lean warehousing, value stream mapping, linear programming

1. Introduction
In this modern era, factors such as digitalization, competitiveness, shorter product life cycle, advanced technology and shorter time-to-market have a greater impact than in previous eras on the logistics activities of a company [1]. In fact, to meet the customer needs, warehousing activities must be more optimal in reducing inefficiencies and making warehouses more reliable in terms of cost [2]. Warehouse is a place where there is a movement of goods in which there are activities of receiving, storing, orders picking, sorting and delivering goods [3]. Warehouse is one of the main elements in the supply chain because it involved in every company’s business processes such as planning, purchasing, production and distribution processes [4]. The trend in the current era is how to change the warehouse to be more flexible to face demand changing, increase inventory transparency and efficiency of each process in the warehouse [5]. The most popular approach of continuous improvement is lean. When the company decides to implement lean, the company’s main focus will shift to how to reduce waste and become more efficient. According to the principles of lean management, there are eight types of waste: waiting, transportation, over-processing, over-production, inventory, motion, defect or errors and underutilised employees [6] [7].
The implementation of lean management not only in manufacturing area but also in another area in company such as supply chain, warehousing and even organization itself. The lean principle must be made a priority when a company wants to maintain and improve its competitive advantages. However, it isn’t true to believe that lean management and company’s competitiveness can be possible by only achieving lean production. All business processes involved in the company must have the same understanding so that the main goal of lean is achieved by reducing unnecessary activities that do not provide added value. Warehousing is one of the many aspects that are important in achieving lean implementation goals. Lean warehousing is a concept that requires stability, systematic continuity and measurable improvement that involving all employees [8]. Lean warehousing can also be defined as the concept of reducing waste in the upstream or downstream parts of the supply chain to direct customers to the right time and place [9]. In lean warehousing area, a lot of researches have been done with different combination of lean tools and results. Studies that have been done by Swank, 2003 have an effect of reduction in response time 60%, 28% labour cost reduction and 40% reduction of reissues due to errors, Cook et al, 2005 (71% decrease in inbound cycle time, 76% decrease in inventory levels, required storage space decreased by 51%), Pan et al. 2010 (Used value stream mapping in shorting delivery time), Jaca et al. 2012 (9,34% improvement on the whole warehouse productivity), Bozer, 2012 (Development ‘house of lean warehousing’ and identified fundamental operational or asset-based changes required to implement lean principles in a warehouse), Dehdari et al. 2013 (Increase warehouse productivity by at least 5%) and Dotoli et al. 2013 using VSM to identify non value added activities and used Gemba Shikumi technique to choose the best response actions [10] [11].

Implementation of lean concepts in warehouses can increase value and reduce costs because warehousing activities are not only a source of cost, but also a source of competitive advantages to achieve higher service levels [12]. The implementation of lean warehousing can also have an impact on internal and external improvements, as indicated by McKinsey study in 2010. The improvement in internal warehouse area could be people (Increase labours’ efficiency and flexibility by 1-5%), process (2-9% Reduce handling movement for each product between receiving and shipping), performance management (2-5% Assure continuous improvement of efficiency) and layout (3-4% optimize layout structure and align with local requirements and restrictions). Area of improvement for external warehouse could be interaction with third party (Matching supplier and customer requirement to warehouse restriction) and ownership (Optimise contract of service provider) [13].

According to that fact, most of the research in lean warehousing only focussed on reducing waste. None of them calculate the impact of lean improvement from cost’s point of view. It might be happen when a company try to implement lean tool but it takes costly and even the benefit that the company got was less than the cost that company’s spent. Therefore, this paper will try to calculate the cost of investment that will be spent in implementing lean tool using linear programming. Linear programming (LP) is a tool for solving optimization problem [14]. Linear programming consist of three component; decision variables, objective function and constraint. Decision variable is a decision variable is a variable whose value will be sought; objective functions a quantitative statement of an optimization case such as maximizing profit or minimizing operating costs while constraint is a number that limited the value of decision variable. This paper will introduce some variable that related on lean warehousing which will be taken into consideration in the selection of lean implementation tools. The overall variables that will be used in considering alternative choices will lead to implementation costs and the tool that resulting the lowest implementation/investment cost to be chosen. The objective function of this problem is minimizing total implementation cost and the decision variables will be in areas such as man, machine, material, method and time.

The aim for the research is to create leaner warehousing system using lean warehousing approach and choose the alternative that given the lowest investment cost using linear programming. In order to deliver the purpose of the research project, the following objectives have been established: Identify the current activities/processes that appeared in warehouse, develop current value stream mapping, calculate current cost that spent for warehousing activities, analysis and eliminate waste based on current value stream mapping using fishbone diagram and 5whys, develop future value stream mapping that have
been implementing lean tool such as kanban, 5S and re-layouting and then calculate total implementation cost after applying improvement and choose the tool that resulting lowest implementation cost.

2. Methods
There are two main methods that used to make this paper, value stream mapping and linear programming. Both of the method will be described in subsection below.

2.1. Value Stream Mapping
Value stream mapping (VSM) is one of the lean tools that can be used to find out the latest conditions of the company's business processes, in which there is a flow of information and material flow that serves as a consideration for solving problems and helping to make improvements for the future [15]. VSM application in warehouse operation can be used to underline the waste activities (value/non-value added) by concentrating on present state of value stream map. As we know, implementation of lean techniques (both information flow and material flow). There are several step of draw VSM: 1) Draw current state map; 2) Analyse existing conditions. Existing conditions are used to determine waste, bottlenecks and other obstacles; 3) Remove waste. How to eliminate waste in the existing conditions depends on its priority; 4) Draw future state map. After being eliminated, a future map was made and 5) Implementation.

2.2. Linear Programming
After creating VSM and eliminate waste that found on it, the next step is implementing lean tool for improvement. The decision to choose which lean tool will be used must be consider the implementation/investment cost. In this paper, linear programming used to calculate the implementation/investment cost by optimizing on variable that related on lean warehousing such as man, machine and materials. The notation used in this simple mathematical model is as follows.

| LT       : lean tool       | SLI     : salary of indirect labour |
| TCi      : total investment cost of tool i | LI      : number of indirect labour |
| Ii       : implementation cost of tool i | Ei      : material handling i |
| TCPi     : total cost of man power of tool i | HDi     : total handling cost of material handling i |
| TCMi     : total cost of machine of tool i | Mt      : maintenance rate/time |
| TCIi     : total cost of inventory of tool i | Mr      : movement rate per day |
| W1       : warehouse raw material | Er      : energy consumed by material handling i |
| W2       : warehouse finished good | HC      : holding cost |
| SLD      : salary of direct labour | To      : turnover rate |
| LD       : number of direct labour | SS      : safety stock |

2.2.1. Choose lean tool. After waste successfully identified, the next step is choose lean tool that will implement in warehouse. The tool that will be chosen must consider the total cost of implementation. The consideration can be described as follow:

\[ LT = \min \{TC_1, TC_2, TC_3 \ldots TC_n\} \] (1)

The total investment cost can be described as follow:

\[ TC_i = I_i + TCP_i + TCM_i + TCI_i \] (2)

2.2.2. Cost of man power (man). This mathematical model used to determine number of direct labour (warehouse operator) and indirect labour (administration officer). The calculation can be described as follow:

Objective function:
\[ \min TCP_i = (SLD \times LD_{W1}) + (SLD \times LD_{W2}) + (SLI \times LI_{W1}) + (SLI \times LI_{W2}) \]  

Subject to:

\[ LD_{W1} + LD_{W2} \leq TLD \]  
\[ LI_{W1} + LI_{W2} \leq TLI \]  
\[ LD_{W1}, LD_{W2} \geq 1 \]  
\[ LI_{W1}, LI_{W2} \geq 0 \]  
\[ LD_{W1}, LD_{W2}, LI_{W1}, LI_{W2} \text{ integer} \]  

Constraint (4) describe the maximum number of direct labour in warehouse 1 and warehouse 2 while constraint (5) describe the maximum number of indirect labour in warehouse 1 and warehouse 2.

2.2.3. Cost of material handling (machine). This mathematical model used to determine the number and type of material handling that will be used in both warehouses. The calculation can be described as follow:

Objective function:

\[ \min TCM_i = \sum_{i=1}^{n} (HD_1 \times E_1) + (HD_2 \times E_2) + \ldots + (HD_n \times E_n) \]  

Subject to:

\[ E_1 + E_2 + \ldots + E_n \leq Mt \]  
\[ E_1 + E_2 + \ldots + E_n \leq Mr \]  
\[ E_1 + E_2 + \ldots + E_n \leq Er \]  
\[ E_1, E_2, \ldots, E_n \geq 1 \]  
\[ E_1, E_2, \ldots, E_n \text{ integer} \]  

Constraint (10) describe the maximum number of maintenance rate/time for each type of material handling, constraint number (11) describe the maximum movement rate per day for each type of material handling in a day and constraint (12) describe the maximum of energy consumed for each type of material handling.

2.2.4. Cost of inventory (material). This mathematical model used to determine the maximum number of inventory that kept for each warehouse. The calculation can be described as follow:

Objective function:

\[ \min TCI_i = (HC \times W1) + (HC \times W2) \]  

Subject to:

\[ W1 + W2 \leq To \]  
\[ W1 + W2 \leq SS \]  
\[ W1, W2 \geq 1 \]  
\[ W1, W2 \text{ integer} \]  

Constraint (15) describe the maximum number of turnover rate for each warehouse while constraint (16) describe the maximum inventory level based on safety stock for each warehouse.

3. Result And Discussion
Before creating VSM, first thing that have to do is identify all the process in warehouse. In this case, warehouse that the process will be observed divided into two warehouse types; raw material warehouse (warehouse A) and finished good warehouse (warehouse B). Both the warehouses consist of same activities; receiving, storing, picking and shipping. From all the process, there are some differences activities in the process of receiving and shipping. In warehouse 1, the goods that received by the warehouse comes from suppliers (raw material) while in warehouse 2 received finished good from production floor. Shipping activity for warehouse 1 is deliver raw material into production area while in warehouse 2 deliver finished product to the customer. Warehouse 1 consist of 27 activities (receiving with 11 activities, storing 5, picking 8 and shipping 3) while warehouse 2 consist of 26 activities (receiving with 2 activities, storing 7, picking 9 and shipping 8). Here is the VSM for warehouse 1 and warehouse 2

![Figure 1 Current VSM for Warehouse A](image-url)

Figure 1 Current VSM for Warehouse A
After creating the current VSM, the next step is to identify waste that came up from the current VSM and find lean tools for improvement based on linear programming consideration. The proposed lean tools for this case are: re-layouting, invest new material handling, e-kanban, poka-yoke and 5S. Here is the cost and time comparison for the entire proposed lean tool.
Figure 4 Time Consumed for Each Lean Tool in Warehouse 1

Figure 5 Time Consumed for Each Lean Tool in Warehouse 2

4. Conclusion

Lean warehousing can be used as one of the powerful tools for improves warehouse operation. The combination between lean warehousing and linear programming could make lean warehousing more powerful by considering cost of implementation for each lean tool. Figure 3 showed that the lowest lean implementation cost is 5S, but figure 4 and 5 showed that there is no significant time improvement for implementing 5S. The most significant time improvements are using E-kanban for warehouse 1 and invest new material handling for warehouse 2. Invest new material handling is the most expensive investment cost. Top level management must give the best solution for this problem to find the best solution. This study could be done better by doing simulation for each tool to make sure that the chosen tool gives the best improvement for warehouse performance and using multi criteria decision making to prioritise between cost and time saving.
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