The integrated lean and green manufacturing system: a case study at the peeled loaf production

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Abstract. The bakery industries soared as bread become one of the staple food for many people. UD. ABC is one of the bakeries in Banda Aceh that produces various types of bread and jam includes the peeled loaf. Peeled loaf uses many machines for its production process thus will produce waste and consume lots of energy. This study aims to analyze waste and measure energy use in the production process of peeled loaf based on the integrated Lean and Green Manufacturing concept. There are VSM and EVSM as a tool to describe the flow of material and energy usage from the production process. The activities of Value Added (VA), Non-Value Added (NVA) and Necessary Non-Value Added (NNVA) will be analyzed using PAM. The tool for improvement recommendations is five whys analysis. Then, the Future State Map (FSM) shows the improved design with a reduction in the lead time of 20.28 minutes. From this study also obtained the results of saving energy use as much as 0.13 kWh. This energy-saving will realize a lean and environmentally friendly production process at UD. ABC.

1. Introduction

There is a common requirement for today's companies to increase their work system's efficiency and their production system for the overall productivity of their company. The company can perform several actions in term of working and production systems to enhance efficiency, such as the use of raw materials, equipment, space and also the amount of labour required. It is necessary to control and supervise the whole process in the company to ensure all these aspects work accordingly and environmentally friendly without waste. Waste defined as an activity in a process which adds cost and time but doesn't add value to a product/service from a consumer point of view.

Waste is the focus major on the lean manufacturing system[1] as its goal is to have a waste-free production. Muda is a Japanese word that means waste [2] which is related to lean manufacturing system. The idea is to make improvements on things that cause waste and are related to the environment. The industry should be aware of the issues of global warming, natural resource scarcity, and waste management. The manufacturing industry is an industry that consumes a lot of energy in the production process. However, many companies now concern about the environment and trying to make an environmentally friendly industry (Green Manufacturing). Green manufacturing mostly focuses on the philosophy area instead of standard or process [3]. The whole idea of green thinking is to understand that nature is limited [4]. In addition, the word "Green" is a verb to portray a process as an activity to reduce the environmental impact of the manufacturing process or system. Energy
consumption is one focus on green manufacturing with the philosophy of environmental impact as the prior issue.

UD. ABC is one of the bakeries in Banda Aceh that produces various types of bread and jam includes the peeled loaf. There are varieties of machines and equipment on the production floor which requires lots of energy such as electricity. In term of the peeled loaf, the production needs as much as six machines from the whole production process activities.

The whole production of the peeled loaf which starts from raw materials process until it becomes the final product requires electricity. Therefore, it takes a lot of electrical energy in one production process. Based on the observations, the waste on the production process mostly happened during the waiting time and defects. The defect causes energy waste in the production process as well as the raw material consumption. It leads to company loss in term of financial and productivity because the company has to pay the additional costs and time for managing waste.

Therefore, the research aims to solve the problem at the production system of the peeled loaf using the integration of Lean and Green Manufacturing. This study consists of steps such as identification of waste, identification of activities, mapping the state map and energy consumption, analysis, and future suggestion.

2. Methodology
2.1. Data Collection
The data collection consist of two stages which are collecting the primary and secondary data. The primary data consists of process sequence data production, cycle time data and engine power. Meanwhile, secondary data consists of data number of production, number of workers and hours work.

2.2. Data Processing
Data processing begins with testing data uniformity and adequacy for cycle time. Then, we calculate the standard time for the Current State Map (CSM) design and the energy consumption for the Energy Value Stream Map (EVSM). The next step is to analysis the CSM and EVSM for further waste identification using PAM. After that, the waste analysis is using the five whys tools. The last step is to design the Future State Map (FSM) to presents alternative solutions to the problem.

3. Results and discussion
3.1. Current State Map making
The Current State Map (CSM) refers to the calculation of standard time that consists of tests data uniformity, data sufficiency test, normal time calculation and standard time calculation.

3.1.1. Standard time calculation
The data uniformity test including calculate the average cycle time, standard deviation, Limit Upper Class (BKA) and Lower Class Limits (BKB) and create control maps for activities of the production process of the peeled loaf. If the data is enough, then we conduct a data sufficiency test. Data sufficiency test using the confidence level at 95% (k = 2) and an error rate of 5%. Table 1 is a summary of the adequacy test data. Normal time calculation is using an adjustment factor based on westing house tables and cycle times. Table 2 is a recapitulation of time calculations normal. Standard time is using the allowance factor and value normal time. Table 3 shows the recapitulation of standard time.

3.2. Current State Map
Figure 1 represents the CSM of the process production of peeled plain bread. The CSM shows that the longest process of the whole peeled loaf production is a process of forming/rolling and placing of dough that is for 99.38 minutes. The fastest processing time is the time for moving the dough to the table dough that is 0.50 minutes. Lead Time from the production process of the peeled loaf is 466.89 minutes with the value-added time of 292.80 minutes.
### Table 1. Recapitulation of data adequacy test.

| Activities                              | N'  | N   | Information |
|-----------------------------------------|-----|-----|-------------|
| Mixing and stirring of raw materials    | 1,52| 5   | Enough      |
| Weighing and rounding dough             | 3,69|     | Enough      |
| Forming / rolling and placing of dough  | 0,31|     | Enough      |
| Baking dough                            | 0,03|     | Enough      |
| Loaf cooling                            | 1,01|     | Enough      |
| Peeling loaf                            | 2,85|     | Enough      |
| Loaf cutting                            | 4,04|     | Enough      |
| Loaf packaging                          | 2,96|     | Enough      |

### Table 2. Recapitulation of normal time calculation.

| No | Activities                              | Ws  | Adjustment | Wn  |
|----|-----------------------------------------|-----|------------|-----|
| 1  | Mixing and stirring of raw materials    | 20,60| 1,11       | 22,87|
| 2  | Weighing and rounding dough             | 8,67 | 1,05       | 9,11 |
| 3  | Forming / rolling and placing of dough  | 75,84| 1,12       | 84,94|
| 4  | Baking dough                            | 50,49| 1,12       | 56,55|
| 5  | Loaf cooling                            | 60,49| 1,11       | 67,15|
| 6  | Peeling loaf                            | 13,39| 1,05       | 14,06|
| 7  | Loaf cutting                            | 39,72| 1,05       | 41,70|
| 8  | Loaf packaging                          | 32,78| 1          | 32,78|

### Table 3. Recapitulation of standard time calculation.

| No | Activities                              | Wn  | Leniency Factor | Wb  |
|----|-----------------------------------------|-----|-----------------|-----|
| 1  | Mixing and stirring of raw materials    | 22,87| 0,17            | 26,64|
| 2  | Weighing and rounding dough             | 9,11 | 0,16            | 10,57|
| 3  | Forming / rolling and placing of dough  | 84,94| 0,17            | 99,38|
| 4  | Baking dough                            | 56,55| 0,21            | 68,14|
| 5  | Loaf cooling                            | 67,15| 0,12            | 75,21|
| 6  | Peeling loaf                            | 14,06| 0,17            | 16,45|
| 7  | Loaf cutting                            | 41,70| 0,14            | 47,54|
| 8  | Loaf packaging                          | 32,78| 0,14            | 37,37|
3.3. Energy Value Stream Mapping (EVSM)
The calculation of energy consumption for Value Added (VA), Non-Value Added (NVA) activities and Necessary Non-Value Added (NNVA) is the basic for EVSM design (Figure 2). Table 4 is a recapitulation of energy consumption in the process production of the peeled loaf.
Table 4. Recapitulation of energy consumption in the process production of the peeled loaf.

| No | Activities                                                                 | Machine                             | Energy usage (kWh) | Comment |
|----|---------------------------------------------------------------------------|-------------------------------------|--------------------|---------|
| 1  | Carry dough ingredients from the warehouse to mixing station               | Mixer                               | 0.59               | NNVA    |
| 2  | Raw materials waiting to be mixed                                         | Mixer                               | 0.03               | NVA     |
| 3  | Mixing and stirring the dough                                             | Mixer                               | 0.67               | VA      |
| 4  | Transfer the dough to the dough table                                     | Mixer                               | 0.01               | NNVA    |
| 5  | Weighing and rounding the dough                                           | Moulding Machine NFZ-380            | 0.13               | VA      |
| 6  | Transfer the dough to a rolling machine                                   | Moulding Machine NFZ-380            | 0.04               | NNVA    |
| 7  | Take a baking sheet                                                        | Moulding Machine NFZ-380            | 0.04               | NNVA    |
| 8  | Forming/rolling and placing the dough                                      | Moulding Machine NFZ-380            | 1.24               | VA      |
| 9  | Arrange a baking sheet                                                     | Oven                                | 0.19               | NNVA    |
| 10 | Waiting for the dough to rise                                              | Oven                                | 3.47               | NNVA    |
| 11 | Bring the dough to the grill                                              | Oven                                | 0.37               | NNVA    |
| 12 | Baking dough                                                              | Oven                                | 3.84               | VA      |
| 13 | Transferring and removing loaves from the pan to the cooling table        | Fan                                 | 0.02               | NNVA    |
| 14 | Arrange the loaf to be cooled                                              | Fan                                 | 0.01               | NNVA    |
| 15 | Cooling loaf                                                              | Fan                                 | 0.12               | VA      |
| 16 | Move loaf to a stripping station                                          | Bread skin peeling machine          | 0.03               | NNVA    |
| 17 | Stripping loaf                                                            | Bread skin peeling machine          | 0.14               | VA      |
| 18 | Arrange the loaf on a rack                                                |                                     |                    |         |
| 19 | Waiting for the loaf to be cut                                            | Bread cutting machine               | 0.07               | NNVA    |
| 20 | Waiting for the loaf to be cut by the worker                              | Bread cutting machine               | 0.13               | NVA     |
| 21 | Transferring the loaf to the chopping machine                            | Bread cutting machine               | 0.02               | NNVA    |
| 22 | Cut the loaf                                                              | Bread cutting machine               | 0.29               | VA      |
| 23 | Transferring loaf to the packaging department                            |                                     |                    |         |
| 24 | Do the packaging                                                          |                                     |                    |         |
| 25 | Transfer the loaf to the box                                               |                                     |                    |         |
| 26 | The loaf is moved to the distribution place                               |                                     |                    |         |
|    | **Total**                                                                 |                                     | **11.45**          |         |
3.4. Activity classification using Process Activity Mapping (PAM)

The tools for waste identification is PAM. The first step for PAM design is the classification of activities to three categories, namely Value Added (VA), Non-Value Added (NVA) and Necessary Non-Value Added (NNVA). The categories in the production process are the result of observations and interviews with four people in the industry which consists of owner, manager and two workers. Table 5 is a summary of PAM. Table 5 shows that the two highest time-consuming activities are operations and transportation with the total times are 299.47 minutes and 61.84 minutes respectively. Figure 3 is a comparison of activities VA, NVA and NNVA in percentage form. The takt time for this problem is 165 minutes/cycle which means there is no problem in the production system.

Table 5. PAM Summary.

| Category     | Time (minutes) | Total Activities |
|--------------|----------------|------------------|
| Operation    | 299.47         | 10               |
| Transportation| 61.84          | 10               |
| Inspection   | 0.00           | 0                |
| Delay        | 95.21          | 4                |
| Storage      | 10.38          | 2                |

![Activities Comparison](image)

Figure 3. The comparison of VA, NVA, and NNVA activities.

3.5. Waste Analysis

The waste analysis is to identify waste by observing and interviewing the stakeholders on the industry. There are three types of waste rank, namely high, medium and low. The rank is to determine the priority for improving waste. Table 6 is the rank of seven wastes, with five analysis, and corrective action plan (as shown in Table 7 and Table 8).
### Table 6. Seven wastes rank.

| Waste Types          | High | Medium | Low       | Object                                      |
|----------------------|------|--------|-----------|---------------------------------------------|
| Defects              |      |        | v         | Loaf that is burnt, deflated or wrongly cut |
| Excessive transportation | v    |        |           | Raw material transfer activities            |
| Inappropriate processing |     | v      |           | Repetitive weighing activities              |
| Unnecessary motion   |      | v      |           | No excessive movement of workers or materials|
| Unnecessary inventory |      | v      |           | Dough or bread is directly processed or distributed |
| Overproduction       | v    |        |           | There was bread returned                    |
| Waiting              | v    | v      |           | Bread waiting to be cut by workers          |

### Table 7. Five whys analysis

| No | Waste Types          | Waste                           | Why                                                                 | Why                                                                 | Why                                                                 | Why                                                                 | Why                                                                 |
|----|----------------------|---------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|
| 1  | Excessive Transportation | Raw material transportation time is too long | Long-distance between raw material place and mixing station          | The factory layout is still not following the production flow        | Workers are not yet proficient at weighing dough                   | Workers are not yet proficient at weighing dough                   | Workers are not yet proficient at weighing dough                   |
| 2  | Inappropriate processing | Over processing | There is a process with inefficient work | There is a process that takes too long | The process of weighing dough repeatedly | Workers are not yet proficient at weighing dough | Workers are not yet proficient at weighing dough |
| 3  | Overproduction        | Excess production of peeled loaf | Production of the loaf using a push or a make-to -lock system       | The company does not estimate demand                                 |                                                                      |                                                                      |                                                                      |
| 4  | Waiting               | Waiting time in the process of mixing raw materials and cutting loaf | The process does not run continuously                                | There is a buffer in the loaf slicing place                          | Waiting for workers to finish from other work                      | There are more workers at the forming dough station                  | There is no specific duty for the workers                           |
Table 8. Corrective action plan.

| No | Waste                        | Root problem                                                                 | Corrective Plan                                                                 |
|----|------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| 1  | Excessive Transportation     | Factory layout that doesn't match the workflow                               | Move raw materials to a space closer to the mixing station                        |
| 2  | Inappropriate Processing     | Unskilled workers                                                             | Provide instructions or weighing procedures by skilled workers or industry       |
| 3  | Overproduction               | The industry does not make demand forecasts or forecasts                      | Industry performs forecasts for demand or forecasting                             |
| 4  | Waiting                      | There is no specific duty for the workers                                     | A regular work schedule is applied according to the needs on the production floor|

Figure 4. Future State Map (FSM).

Figure 5. Future Energy Value Stream Map (FEVSM).
3.6. Future State Map (FSM)
Future State Map (FSM) refers to previous CSM and EVSM. Figure 4 is the FSM of the peeled loaf production process. It shows that there is a lead time reduction into 446.61 minutes. Figure 5 is Future Energy Value Stream Mapping of the peeled loaf process. There is a reduction in NVA energy consumption to 5.02 kWh.

4. Summary
There are two future suggestion refers to CSM and FSM. There should be rule modifications for placing workers on multiple workstations and elimination of the waiting for loaf cutting activity. While there are four suggestions refers to EVSM and FEVSM. The propose solutions are transferring raw materials to the other room closer to the station of raw material mixing, providing signposts for turning off the engine, performing a Just-In-Time production system, and using recycled products for packaging.

In conclusion, there are four priority wastes in the peeled loaf production which are excessive transportation, inappropriate processing, overproduction and waiting. Then the lead time is reduced by 20.28 minutes if the company successfully apply the solutions as states in the FSM. The energy consumption for one cycle of the peeled loaf production process is 11.45 kWh which can be reduced by 0.13 kWh/cycle.

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