Design of Sustainable Value Stream Mapping to Improve the Sustainability Indicator: Case in MDF Company

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Abstract. Plywood production is a complex process. Because it uses wood as raw material, then causes several activities involved in it, including forest cutting, has relatively little efficiency, produces waste, and the level of occupational safety and health has not been considered. Therefore to get sustainable manufacturing, it is necessary to pay attention to several aspects, including economic and environmental factors. And social aspects. This study aims to design the three mentioned aspects for sustainable-VSM in plywood companies. Sustainability indicators of his study by performing a literature study and validating it by in-depth interviews with its top management. The study results are time efficiency level was 81%, the quality level was 93.5%, the material consumption efficiency level was 59.3%, and the worker health level was 75.75%. This study also recommends potential solutions that are expected to improve the sustainability performance of the plywood company.

1. Introduction
The concept of lean manufacturing (LM) focuses on reducing waste and costs. In contrast, the idea of sustainability focuses on developing processes and products that are environmentally friendly while remaining focused on economic goals and being socially responsible [1]. Increasing environmental issues, companies have begun to shift traditional business policies that only focus on minimizing costs to techniques that also concern to implications of the production process on the environment and society [2–4]. This paradigm’s development encourages progress in the manufacturing system from traditional manufacturing systems and LM to green manufacturing and then sustainable manufacturing [3, 5].

LM uses value stream mapping as a useful system analysis tool to diagnose manufacturing system problems and identify opportunities for improvement [6, 7]. Value stream mapping (VSM) captures the flow of material, information, and corporate decision making [8, 9]. Non-value added activities are the basis for making improvements and redesign the manufacturing system [10] so that the concept of Sustainable Value Stream Mapping (Sus-VSM) was developed to assess activities in the economic, environmental, and social dimensions [11].

Several studies on sus-VSM have been developed in the satellite dish [11], furniture [4, 12], beverage [13], stamping [14], apparel company [15], bonnet-manufacturing industry [16], dan small-medium enterprise [14]. Each company has different characteristics, so that it also has different indicators [11]. Until now, defining a general methodology for implementing sus-VSM...
that can be applied at different levels and operational contexts is still a barrier [14]. Therefore, research on sus-VSM is still interesting to study, how is the implementation of sus-VSM in different types of companies, what are the barriers to application, and how can sus-VSM improve company performance.

This research aims to study the application of sus-VSM to evaluate the performance of plywood companies. A plywood company is a company that uses wood as raw material. Wood is a natural material taken by deforestation, which causes global warming. Although they can use wood waste from wooden furniture companies, plywood companies also produce waste. Besides evaluating environmental aspects related to material, it is also essential to assess economic and social factors’ performance. Many products are the defective, bottleneck, and many workers experience illness complaints, so it causes many workers to be absent every day.

2. Sustainable Manufacturing

2.1. Lean and Sustainable Manufacturing

LM has many definitions. In general, LM is a systematic action to reduce non-value-added activities by making continuous improvements to increase customer satisfaction [17]. To minimize this non-value-added, several techniques were developed to achieve LM. The methods to be applied by a company depends on the company needs. Value stream mapping is the most considered technique in the LM implementation process [18]. Few studies had involved sustainability issues in VSM, but they provided only operational and environmental metrics [19,20].

Although various researchers have defined the concept of sustainable manufacturing from different perspectives, sustainable manufacturing has three pillars (economy, environment, and social), and its benefits in human development well-received by all researchers [21]. A new definition of sustainable manufacturing was proposed by [22], ”Sustainable manufacturing is a value-added recovery process, which can reclaim the end-of-life value of the product or throw it away.” The study of ”sustainable manufacturing” shows an increasing interest in the growing public awareness of the environment [23].

2.2. Sustainable-Value Stream Mapping

Sus-VSM is a development of value stream mapping by involving environmental and social indicators [24]. The companies that use Sus-VSM will benefit from visual identifying potential problems during the production process [15, 24]. Possible solutions will be proposed in future sus-VSM to improve company performance. If the company implements changes and continues to improve its processes, it will grow and develop into a formidable competitor [16]. This is of barriers to the implementation of sus-VSM [14]. The performance of sus-VSM has become more challenging. Data collection is time-consuming, costly, and challenging to obtain. Meanwhile, companies usually rarely have data and challenging to get accurate information.

3. Method

3.1. Production Process

The Sus-VSM design will consider three pillars in sustainable manufacturing is economical, social, and environmental. The first step is to understand the flow of information and material flow in the production process (Figure 1). Then, the relevant indicators are selected by interviews with the company’s top management. After the chosen right hand, the assessment is done by direct observation and measurement.

3.2. Selected Indicator and Scoring

Based on top management interviews, the selected indicators are time efficiency, quality efficiency, material consumption, health level, and safety level. The formula used to assess
indicator performance is described in Table 1.

### Table 1: Formula of indicator scoring

| Dimension  | Indicator         | The related metrics                  | Equation                                      | Reference |
|------------|-------------------|--------------------------------------|-----------------------------------------------|-----------|
| Time (TE)  | VAT: Value Added Time |                                        | $TE = \frac{VAT}{TT}$                          | [11]      |
|            | NVAT: Non-Value-Added Time |                                  | $NVAT = \sum_{i=1}^{n}(VAT_i)$               |           |
|            | TT: Total Time      |                                        | $TT = \sum_{i=1}^{n}(NVAT_i)$                |           |
| Quality (QE) | ND: Number of Defects |                                        | $QE = 1 - ND/TT$                              | [25][4]  |
|            | TM: Total Material  |                                        |                                               |           |
|            | EQ: Quality Efficiency |                                   |                                               |           |
| Material Consumption (ME) | VAM: Value Added Material |                                        | $ME = \frac{VAM}{TM}$                         | [11]      |
|            | NVAM: Non-Value-Added Material |                                | $NVAM = \sum_{i=1}^{n}(NVAM_i)$            |           |
|            | TM: Total Material  |                                        | $TM = VAM + NVAM$                             |           |
| Health Level | NA: Number employees absent |                                 | $HE = 1 - NA/NE$                              | [26][25][4] |
|            | NE: Number employee  |                                        |                                               |           |
| Safety Level | NR: Number of activities with risk Nac: Number of activities | | $RE = 1 - NR/Nac$                         | [26][25][4] |

### 4. Result and Discussion

#### 4.1. Sustainability indicator performance assessment

**4.1.1. Economic dimension.** The results of measuring time indicators describe in Table 2. While the results of measuring the quality indicator described in Table 3.

Based on Table 2, the time efficiency level in the production process is still low. This is caused by the number of non-value-added activities, such as loading and unloading plywood products, press installation activity, and the machine-setting process. Although the plywood production process’s defect rate is not high (6%), it exceeds the standard set by the company (5%). Product defects often occur in gang rip machines, usually indicated by differences in the wood’s thickness. In the finishing process, product defects are generally caused by broken or
### Table 2: Time efficiency of the production process

| Process                | WS(s) | VA(s) | NVA(s) | Efficiency (%) |
|------------------------|-------|-------|--------|----------------|
| Wood Drying            | 288000| 280800| 7200   | 98%            |
| Wood Cutting           | 11    | 10    | 1      | 91%            |
| Wood Smoothed          | 10    | 8     | 2      | 80%            |
| Wood Small Piece Cutting | 8    | 6     | 2      | 75%            |
| Wood Sorted            | 7     | 5     | 2      | 71%            |
| Wood Gluing            | 132   | 121   | 11     | 92%            |
| Wood Press             | 117   | 75    | 42     | 64%            |
| Finishing              | 13    | 10    | 3      | 77%            |
| Packing                | 2994  | 2340  | 654    | 78%            |
| **Average Time Efficiency Process** |       |       |        | **81%**        |

cracked plywood, perforated plywood, not smooth, and many spots. The defects that occur include damaged plywood, V hole and poor finishing, big area, and many places. The quality level is still in the excellent category. Wood Small Piece Cutting’s quality efficiency level is 94%, with a defect rate of 6%. The finishing part is 99.3%, with a defect rate of only 0.07%.

4.1.2. Environmental dimension. The material consumption efficiency level is 59%, which is included in the low category (Table 4). This is because wood treatment in nature is not optimal, so that the wood surface becomes broken has many spots. Moreover, the company does not process the waste material into products that have added value. Table 5 describes material efficiency.

### Table 3: Material Efficiency

| Month    | Raw Materials (m³) | Right Product (m³) | Efficiency (%) |
|----------|--------------------|--------------------|----------------|
| Januari  | 46.8978            | 59.7503            | 127.41         |
| Februari | 2926.2239          | 1452.467047        | 49.64          |
| Maret    | 2346.085           | 1192.072194        | 50.81          |
| April    | 2115.0658          | 915.4009774        | 43.28          |
| Mei      | 2562.80804         | 1169.897377        | 45.65          |
| Juni     | 1295.70912         | 595.2587888        | 45.94          |
| Juli     | 1369.33548         | 629.235984         | 45.95          |
| Agustus  | 2451.26103         | 1195.574117        | 48.77          |
| September| 2200.7342          | 1375.884159        | 62.52          |
| Oktober  | 1517.8581          | 966.2567216        | 63.66          |
| November | 2265.34343         | 1491.893007        | 65.86          |
| Desember | 2485.23431         | 1545.057647        | 62.17          |
| **Average** | 1965.213018      | 1049.06236         | 59.30          |

4.1.3. Social dimension. The number of absent workers per day is taken from company attendance data. While work accident data is obtained from reports from the company health and safety department, noise data is obtained from noise level testing results taken from company data. The safety risk is shown in Table 5.
#### Table 4: Safety risk

| Process        | Safety risk         | Category |
|----------------|---------------------|----------|
| Drying         | • Burns             | • Low    |
|                | • Hit by wood       | • Moderate|
|                | • Boiler Burst      | • High   |
| Jumping Saw    | • Torn wounds       | • Low    |
|                | • Broken fingers    | • High   |
| Double Planner | • Torn wounds       | • Low    |
| Gang rip       | • Torn wounds       | • Low    |
| Sortir         | • Torn wounds       | • Low    |
|                | • Broken fingers    | • High   |
| Glue           | • Itchy             | • Low    |
| Press          | • Pinched           | • Low    |
|                | • Itchy             | • Low    |
| Putty          | • Back pain         | • Low    |
| Packing        | • Pinched           | • Low    |

Based on interviews with the production department, high levels of absence caused an imbalance in the production line. From data processing, it was found that the drying process’s efficiency level was around 71%, production was 84%, finishing was 81%, and packing was 67%. This causes the company production target not to be achieved, and it causes a penalty cost. Moreover, it affects the level of customer satisfaction and reduces customer confidence in the company. The poor health of workers is greatly affected by environmental conditions around the work, including air quality, residual cutting particles, and noise levels. The noise level is 66.2 dB (A), while the standard noise should be 70 dB (A), while the total particulate suspension is 248.64 µg/m3 while the expected value is 248.64 ± 230 µg/m3. The working environment conditions have a relatively high noise level, and the Total Suspended Particulate (TSP) exceeded standards. This is caused by poorly waste installation on each machine so that the waste cannot flow to the boiler perfectly.

Based on data on work accidents, in a year, 17 work accidents are consisting of 3 serious accidents such as broken bones, broken fingers, torn and pinched wounds, and 14 minor work accidents such as being pinched and pulled. Workers’ unsafe behavior pattern causes the number of work accidents because they are not used protective equipment. Simultaneously, the availability of personal protective equipment and environmental influences has a very significant effect on workplace accidents.

4.2. Sustainable Value Stream Mapping

4.2.1. Current-Sustainable-Value stream mapping. Sus-VSM of the current MDF process is shown in Figure 3.
4.2.2. Recommendation. Recommendations as an effort to improve sustainability performance can be seen in Table 5.

Table 5: Waste type, root caused, and recommendation for improvement

| Waste Type         | Root Caused                                                                 | Recommendation for Improvement                                      |
|--------------------|------------------------------------------------------------------------------|---------------------------------------------------------------------|
| Inventory          | Material order not planned                                                    | Make an optimal material ordering plan                              |
| Transportation     | The road conditions are not right. The road contours are notflat.             | Improve road facilities                                             |
| Waiting Time       | The imbalance of the track speed at the jumping saw and double planner work stations. | Adding capacity double planner machine                              |
| Quality            | There is a change in the setting of the gang rip machine because of the high intensity of use. Minimum of operator skills in operating machines | • Implemented Total Production Maintenance                        |
|                    |                                                                             | • Provide training to machine operators                            |
|                    |                                                                             | • Maximizing quality control by checking the size of the wood       |
| Material Consumption| Low-quality wood, indicated by the number of spots on the wood                | • Cooperate with plantation companies to maximize wood care         |
|                    |                                                                             | • Collaborating with SMEs to utilize pelos wood products           |
|                    |                                                                             | • Developing products based on Pelos wood waste.                   |
| Safety Risk        | The risk of processing plywood production is very high because it uses wood saws and heavy materials | • Provide Safety and Health training to workers                     |
|                    |                                                                             | • Provide standardization by providing safety and health certification facilities for machine operators (forklifts and boilers) |
| health Level       | Workers often experience health complaints that are caused by non-ergonomic work postures, as well as dusty and noisy work environments. | • Create a hydraulic table that can be adjusted the height          |
|                    |                                                                             | • Cooperate with local doctors to control the health               |
|                    |                                                                             | • Registering insurance for all workers                           |
|                    |                                                                             | • Repairing waste installation in machines to minimize the number of dust particles in the production room |
|                    |                                                                             | • Encourage workers to wear masks, earplugs, gloves, and shoes.    |

The recommended improvements to improve the MDF process's sustainability performance are shown in Figure 4, future sus-VSM.

5. Conclusion
Implementation of sus-VSM can be developed in plywood companies to include indicators of time, quality, material consumption, occupational health, and safety. The economic dimension’s
efficiency level is a useful category, where the time efficiency is around 81% and the quality efficiency is approximately 93.5%. The environmental dimension performance is low, where the
efficiency level of material consumption is about 59.3%. The social dimension performance is in the low category where workers’ health efficiency level is 75.75%. With 15 work risks and working environment conditions with a noise level of 66.2 dB (A) and the amount of dust, particulates exceed the threshold limit, and the amount of dust particulates is not standardized. Potential solutions are recommended to optimize material planning, improve transportation road conditions, implement TPM, and collaborate with companies that utilize wood waste and K3 training safety and health programs for workers. This research provides sus-VSM designs for plywood companies, and from a managerial aspect, advise plywood companies to improve sustainability performance. This research is still limited to one plywood company. Future research for several other plywood companies needs to be carried out to get a general picture of the plywood industry’s conditions in Indonesia. The study in other sectors also has the potential to be developed to realize sustainable manufacturing. Studies on waste utilization in plywood companies in the circular economy context are still interesting to do.

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