Design of lean production system with simulation model approach in agar powder production

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Abstract. PT. XYZ is a company that produces agar powder. This research aimed to minimize waste that happens in the production process of agar powder by using Lean Manufacturing concept with Value Stream Mapping and Simulation Model. The results of this research indicate there is waste such as human potential, inappropriate design, unnecessary, and with the highest waste is in the form of waiting time. It caused by inconsistent of raw material, unresponsiveness worker, lack of tools that help operator, bottleneck process and unscheduled process. Recommendations for improvement are embracing capacity in filtering workstation, equip workstation with timer, and making production schedule. Based on the simulation that have been done shows reduced total lead time of 2.94 days to 2.27 days or efficiency process increased 22.81%.

1. Introduction
PT. XYZ is a company engaged in food processing, especially in processing seaweed into agar powder. Agar powder produced by PT. XYZ is a “Business to Business” product that is sold in large quantities as raw material for other company. The main target of PT. XYZ is producing agar powder that has a good quality with a controlled, effective and efficient way to compete with competitors of similar products. Several approaches exist in increasing efficiency such as supply chain and statistical analysis [1]. One of the most successful approaches is the Lean Production System (LPS). LPS is the systematic approach to increase product value and process efficiency continuously which has implications for increasing customer value [2]. The application of LPS in this study has used several methods including Value Stream Mapping (VSM), Value Stream Analysis Tools (VALSAT), and system modeling simulations. VSM is used to map the product flow and flow of the time and information from a system as a whole [3]. There are two types of VSM, include the current state map to describe the existing problem from current conditions and is the future state map to describe the improvements to be made [4]. VALSAT is used to simplify the understanding of the value stream by analyzing the common waste and improvement of waste that has been identified [5]. System modeling and simulations are used to evaluate and improve system performance through representations that have been presented [6].
2. Materials and Method
The scope of the study was limited to the main processes of agar powder production and did not analyze the production cost. The study was conducted until giving a recommendation of improvement. There were several stages in this research as follows:

a) Construct the current state map
   Current state maps are formed by describing information flow, material flow, and timeline [7]. The standard timeline is obtained through cycle time observation with the stopwatch time study method. This method is used to measure the time taken by workers to complete a task at a normal pace [8]. Cycle time data was processed as follows [9]:
   - Normality test
   - Uniform distribution test
   - Sample sized test
   - Cycle Time (Ws) formula:
     \[ Ws = \text{Average time between completion of units} \] (1)
   - Normal Time (Wn) formula:
     \[ Wn = \text{Cycle Time} \times \text{Rating factor} \] (2)
   - Standard Time (Wb) formula:
     \[ Ws = Wn \times \frac{100}{100 - \text{allowance}} \] (3)

b) Waste identification

c) VALSAT tools selection

d) Construct the future state map

e) Simulation with model scenario

3. Results and Discussion
3.1. Construction of the current state map (CSM)
The timeline was obtained from the observation of 32 process activities of agar powder production using the stopwatch time study. The data required in the standard timing were 30 replications in each process. Data cycle time (Ws), normal time (Wn), and standard time (Wb) are shown in Table 1. Data in Table 1 is the result of the observation about one cycle of the production process, including extraction, filtration and freezing, pressing, drying, milling and quality control. The current state map was constructed from the current condition of the agar powder production. Information flow is related about order information, production information, until delivery information. Material flow is related to material movement through various facilities or processes [10]. Figure 1 shows that filtration and freezing process has the highest time. Based on the result of CSM, the value-added time was 2139.51 minute and non-value added time was 2003.30 minute.

3.2. Identification waste
Waste identification was performed by giving assessments through a questionnaire to value stream manager. The value stream manager is the production staff from PT. XYZ. Table 2 explains the results of the questionnaire given. Based on Table 2 the results showed that waste with the highest type is waiting. It occurs because a bottleneck exists in the cooking workstation to the filtering workstation. The main cause is that there is no production activity schedule and the filter capacity is too small.
Table 1. Data of cycle time (Ws), normal time (Wn), and standard time (Wb)

| Workstation   | Activity                      | Ws (min) | Wn (min) | Wb (min) |
|---------------|-------------------------------|----------|----------|----------|
| Extraction    | Acceptance Raw Material       | 17.63    | 19.11    | 22.16    |
|               | Unpackaging                   | 7.89     | 8.52     | 9.88     |
|               | Input of Raw Material         | 7.72     | 8.34     | 9.67     |
|               | NaOH Treatment                | 60       | 60       | 60       |
|               | Washing                       | 13.82    | 14.93    | 17.31    |
|               | CaClO$_3$ Treatment           | 60       | 60       | 60       |
|               | Washing                       | 14.64    | 15.81    | 18.34    |
|               | H$_2$SO$_4$ Treatment         | 60       | 60       | 60       |
|               | Washing                       | 13.93    | 15.04    | 17.45    |
|               | Extraction                    | 60       | 60       | 60       |
|               | Idle                          | 49.30    | 53.24    | 56.43    |
| Filtration and Freezing | Filtration 1               | 17.5     | 18.86    | 19.98    |
|               | Idle                          | 19.67    | 21.14    | 24.51    |
|               | Filtration 2                  | 55.36    | 59.79    | 63.37    |
|               | Transfer to Freezing Tank     | 26.71    | 28.85    | 30.57    |
|               | Freezing                      | 960      | 960      | 960      |
| Pressing      | Wrapping                      | 101.22   | 106.56   | 122.54   |
|               | Pressing 1                    | 21.14    | 22.41    | 25.76    |
|               | Transfer to Pressing 2        | 32.76    | 32.40    | 37.26    |
|               | Pressing 2                    | 26       | 27.56    | 31.69    |
|               | Idle                          | 960      | 960      | 960      |
| Drying        | Transfer to Drying            | 3.03     | 3.15     | 3.56     |
|               | Arrangement Agar Sheet        | 40.22    | 41.83    | 47.26    |
|               | Transfer to Oven              | 2.77     | 2.88     | 3.25     |
|               | Drying                        | 420      | 420      | 420      |
|               | Transfer to Milling           | 3.62     | 3.76     | 4.25     |
|               | Storage                       | 960      | 960      | 960      |
| Milling       | Milling 1                     | 59.15    | 60.92    | 68.23    |
|               | Transfer to Milling 2         | 2.03     | 2.09     | 2.34     |
|               | Milling 2                     | 29.85    | 30.72    | 34.41    |
| Quality Control |                               | 30       | 30       | 30       |
3.3. VALSAT tools selection
The selection of tools VALSAT was obtained through weighting calculations on the type of waste that has been identified. Chosen VALSAT tools are based on the comparison value between each tool and the most common waste [11]. The results indicated that process activity mapping (PAM) chosen to help in identifying waste. PAM was used to identify the detailed process activities and the proposition of activities [12]. Based on the mapping conducted on 32 activities, the results of PAM were 20 process activities, 7 transportation activities, 5 delay activities, and 1 storage activity.

3.4. Construction of future state map (FSM)
Construction of future state map is based on a reduction in time from recommendations for improvements given. Future state map shows the output of improvement based on current state map [14]. The results of mapping the FSM are shown in Figure 2 Several recommendations for improvement obtained from FSM included the increasing of filter tubs capacity so it reduced the processing time at the filtering and cooling workstations by 17%. Lead time in the pressing process could be reduced by making production schedule, idle time caused by work in process storage could be minimized so that processing time was reduced by 76.30%. The next recommendation was the use of a timer on the oven machine so that it could reduce the time on the drying workstation by 29.08%
3.5. Simulation model
Simulation modeling was constructed based on future state map data as input to provide a dynamic and detailed high-level representation of the real system [15]. Figure 3 shows the modeling performed on the FSM. Modeling was constructed with 5 types of entities that represent 5 times production process activities in one day. The main inputs were the type of resource and processing times for the processes of each entity.

3.6. Result of simulation model
Simulation is done by running a model in duration of 6 days (one-week working day). The simulation results, for 6 days the model can produce an output of 20 entities. Figure 4 shows details of time activities generated by system modeling and a comparison between the current state map time and the average time of the simulation results that based on the improvements given can reduce cycle times from 2.94 days to 2.27 days.
4. Conclusions

Based on the results of the analysis with Lean Manufacturing, waste was found in the agar powder production process at PT. XYZ. The highest type of waste is waiting, followed by human potential, inappropriate design, and unnecessary inventory that caused by bottlenecks on several workstations, less responsive operators, inadequate filter capacity, and the lack of good production schedule. Recommendations for improvements that can be made are to implement a bin system, equip several machines with timers, increase filter capacity, and implement an efficient production schedule. Based on the simulation of the recommendations given, the results are in the form of reduction of production lead time by 22.81%.

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