Productivity improvement of assembly department by using value stream mapping and computer simulation approach

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Abstract. As a matter of fact, productivity improvement is a common objective which are faced by almost every industry. Lean manufacturing is one critical key of success to achieve productivity by increasing effectivity and efficiency of an industry. A manufacturer which annually produces piano in a huge capacity has a target to improve the ability to satisfy its high demand. As a solution to the problem, this study focused on lean manufacturing design, specifically on assembly unit department. This study conducted by utilizing two methods, Value Stream Mapping and Computer Simulation technique as a system approaching tool. According to the problem identification stage using Current State Mapping, the productivity level on assembly unit department is only 0.27 unit/person/hour, still at below level of the productivity target 0.36 unit/person/hour. The problem indicates that there was many possible productions system matter, such as: production process input, which was not utilized in an optimum way, workload distribution that was not well-managed, and operator ability that is under specification. By using computer simulation approach, this study suggested couple of alternatives to answer the productivity problem.

1. Introduction
The success of an industry is not only measured by the profit generated, but also determined by how efficient, effective, duration, and quality of production processes. Lean manufacturing is one of the solutions to increase the productivity of a company. Lean manufacturing defined as a perspective of manufacturer which is seeking opportunities to reduce operation process time, improve manoeuvre and appropriate attribute [1]. A manufacturer specialized in producing piano instrument has 1000 unit of production capacity in annual. In order to fulfil the production capacity, the company wants to achieve an effective and efficient production system. Based on its current system, productivity measurement applied by company considers 4 aspects which consist of total production, number of operators, working time and overtime hours. There are four main activities on company’s production process which are wood working, painting, assembly, and packing. According to the data given from Production Engineering Department, productivity level of assembly department on June 2017 is 27% where previously in January to April at the same year productivity level was constant and tended to be slightly lower in February and March. The company wants to increase the productivity of the department to become 36%. The objective of this study is to give suggestion related to system improvement to achieve productivity target based on analysis of existing production system especially in assembly department.
2. Methodology
Lean manufacturing is a systematic approach to identify and eliminate non-value-added activities through continuous improvement [2]. According to the definition, lean manufacturing is an approach or method that is very dependent on the existence of value. It is considered as an important thing for a company to be able to compete with the others. The company must reduce or eliminate non-value-added activities in production process. Subsequently, the companies can achieve the value desired by its consumers with minimal resources [3]. Non-value-added activities are considered as waste, which is defined as all activities which not providing added value along the process flow of production [4]. By implementing lean manufacturing approach, waste can be reduced or eliminated so that the production system can run effectively and efficiently. Lean manufacturing implementation is based on five principles, which are: understand the customer value, value stream analysis, flow, pull system, and perfection [5]. Since value take an important place in lean manufacturing, the focus of this study was to analyse the value stream in existing production process then improve it by eliminating or reducing non-value added.

Value stream is a whole set of specific activities needed to produce specific products through three main jobs in the management of a business that consists of: problem solving, information management, and physical transformation [6]. Value Stream Mapping (VSM) is one of the tools in lean manufacturing to map existing production flow and identify processes that contain waste so that existing waste can be eliminated [7]. In the other words, VSM is a process of mapping the flow material and information needed to coordinate activities carried out by producers, suppliers, and distributors to deliver products to customers. By using VSM, the company can understand the information about the flow of process and the flow of information on the production process either for goods or services from the producer to consumers. The advantage of VSM is that it can visualize the process, from material flow to the flow of information needed in a process so that it can be seen or found waste that appears [8]. According to Hines and Rich [9], there are seven tools which used to help when constructing a value stream mapping, such as: process activity mapping, supply chain response matrix, production variety funnel, quality filter mapping, demand amplification mapping, decision point analysis, physical structure mapping.

In order to plan a better production system, a systemic approach is needed to reduce the possibility of giving the inaccurate solution for the whole system. A system is defined as a collection of entities, such as humans or machines, which interact to each other to produce a certain logic [10]. There are two basic approaches to obtain system planning models namely simulation and optimization [11]. Simulation is one of the most useful method to evaluate and improve manufacturer production system. Simulation is defined as an imitation of the operating process of a real condition or system from time to time [12]. By using simulation technique, usual mistakes made on trial and error can be avoided and expensive cost can be eliminated as well. A simulation model constructed by using the following step: analyse the problem and gather information, collect data, build simulation model, verify and validate the model, design the simulation scenario, run an output analysis, and make the final recommendation [13].

This study take place in a piano instrument manufacturer which annually produce two kind of products, Silent Upright Piano (UP) and Grand Piano (GP). The Silent UP production process improvement, especially in assembly process, became the main focus of this study since the product is the prime and its demand is most of the other products. So that, the productivity improvement in Silent UP production process become important. The assembly process of Silent UP product goes through seven different working units, which are key block assembly, electrical assembly top, electrical assembly bottom, regulation 1, regulation 2, regulation 3, and electrical check. The overview of UP production process including the flow of information, production, and timeline are illustrated in figure 1 below.
**Figure 1. Current State Map**

Design of simulation model created based on the current state map which would be given changes according to the improvement plan and some experimental designs. The design of this model divided into several stages, namely determining the object, workstation capacity, process time, arrival time interval, use of triggers, number of works in process, global table and division of work for each operator. Simulation model used standard measurement unit, such as meter for distance and second for time. In the simulation preparation, inter-arrival time and processing time for each element was already measured and fitted to some distribution. The details of elements name, capacity, number of operators, number of inventory or work in process, and process time and arrival time distribution for simulation process are shown on table 1 below.

**Table 1. Simulation model details**

| Name of element          | Type    | Capacity | Num of operator | Num of inventory | Process time distribution                      |
|--------------------------|---------|----------|-----------------|------------------|-----------------------------------------------|
| Source/Arrival           | Source  | -        | -               | -                | Weibull (605.912, 880.190, 3.53, 0)            |
| Key Block Assembly       | Processor | 1       | 1               | 1                | Beta (655.763, 835.329, 0.693, 0.753)          |
| Electrical Assembly Top  | Processor | 1       | 1               | 2                | Johnsonbounded (812.856, 1331.138, 1.204, 0.785) |
| Electrical Assembly Bottom | Processor | 1       | 1               | 2                | Beta (965.749, 1211.727, 0.452, 0.633)         |
| Regulation 1             | Processor | 1       | 1               | 2                | Beta (1773.265, 2539.328, 1.662, 1.933)        |
| Regulation 2             | Processor | 1       | 1               | 1                | Johnsonbounded (627.983, 792.590, 0.164, 0.443) |
| Regulation 3             | Processor | 1       | 1               | 1                | Beta (853.869, 1360.442, 2.553, 0.968)         |
| Electrical Check         | Processor | 1       | 1               | 2                | Johnsonbounded (1162.819, 1424.920, -0.068, 0.308) |
3. Results and Discussions

Simulation was performed in 10 replications for 9 hours or 32400 seconds, which determine company working hours. The output of simulation shown in table 2 below.

Table 2. Simulation output

| Replication | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|-------------|----|----|----|----|----|----|----|----|----|----|
| Output      | 20 | 20 | 19 | 20 | 19 | 19 | 19 | 19 | 20 | 20 |

average = 19.5; σ = 0.527; α = 0.05; n = 10; manpower = 7

Simulation model result then validated by using t-test to compare simulation output and real data based on mean. There are two hypotheses tested in validation step $H_0$: there is no mean difference between simulation output and real data; $H_1$: there is a mean difference between simulation output and real data. The t-test calculation is shown on the following formula.

$$t_0 = (\bar{Y} - \mu_0)/\left(\frac{\sigma}{\sqrt{n}}\right) = (19.5-20)/(0.527/\sqrt{10}) = -0.158$$

According to validation result, the null hypothesis was accepted since $-t_{0.025} < t_0 < t_{0.025}$ so the simulation model was valid as it could represent the real system. By using simulation, the status of each process could be determined, including processor and operator utilization, idle, and blocked along the simulation time. The simulation result for processor and operator of current state map shown in table 3.

Table 3. Simulation result of current state map

| Object                  | Processor Utilization | Operator Utilization |
|-------------------------|-----------------------|---------------------|
|                         | idle | processing | blocked | idle | utilize |
| Key Block Assembly      | 3.76%| 32.68%     | 52.34%  | 56.11%| 32.68%  |
| Electrical Assembly Top | 0.00%| 53.67%     | 35.12%  | 35.12%| 53.67%  |
| Electrical Assembly Bottom | 0.00%| 46.77%     | 42.02%  | 42.02%| 46.77%  |
| Regulation 1            | 0.00%| 88.79%     | 0.00%   | 0.00% | 88.79%  |
| Regulation 2            | 59.85%| 28.94%    | 0.00%   | 59.85%| 28.94%  |
| Regulation 3            | 34.27%| 54.24%    | 0.28%   | 34.55%| 54.24%  |
| Electrical Check        | 27.93%| 60.86%    | 0.00%   | 27.93%| 60.86%  |

Based on the simulation result, it was shown that bottleneck happened in several processes, such as key block assembly, electrical assembly top, and electrical assembly bottom. The bottleneck indicated by the high value of the blocked percentage. The simulation result shows that the existing system need to be improved. By carrying out two plans of experiment, the better division of work would be proposed. First plan of experiment was focused on work division refinement by reducing number of worker or manpower in order to lower operator idle percentage. In the existing condition, each process handled by one operator. Therefore, at first experiment plan the division of work was redesigned, key block assembly and electrical assembly top process operated by one man.

Second plan of experiment was focused to level workload among operators but still with reduced number of workers as well. As it shown on table 3 above, the operator utilization on regulation 1 process was the highest, which indicated that there was an unequal workload among operators. So that the second experiment plan, the structure of first experiment was still kept and process named regulation 1 handled by two operators, where the operator from regulation 2 required to help regulation 1 operator, due to the high number of idle percentages. The simulation result from the first and second experiment shown in table 4 and 5 below.
Table 4. Simulation result from first experiment

| Object                  | Processor | Operator |
|-------------------------|-----------|----------|
|                         | idle      | processing | blocked | idle | utilize |
| Key Block Assembly      | 0.00%     | 32.71%    | 3.56%    | 0.00% | 88.79%   |
| Electrical Assembly Top | 0.00%     | 56.07%    | 4.21%    | 0.00% | 88.79%   |
| Electrical Assembly Bottom | 0.00% | 48.76%    | 40.03%    | 40.03% | 48.76%   |
| Regulation 1            | 0.00%     | 88.79%    | 0.00%    | 0.00% | 88.79%   |
| Regulation 2            | 58.36%    | 30.43%    | 0.00%    | 58.36% | 30.43%   |
| Regulation 3            | 38.33%    | 49.86%    | 0.00%    | 38.92% | 49.86%   |
| Electrical Check        | 25.54%    | 63.25%    | 0.00%    | 25.54% | 63.25%   |

average output = 16.095 units; manpower = 6 people

Table 5. Simulation result from second experiment

| Object                  | Processor | Operator |
|-------------------------|-----------|----------|
|                         | idle      | processing | blocked | idle | utilize |
| Key Block Assembly      | 0.00%     | 32.24%    | 3.56%    | 0.00% | 88.79%   |
| Electrical Assembly Top | 0.00%     | 56.54%    | 0.00%    | 0.00% | 88.79%   |
| Electrical Assembly Bottom | 36.75% | 52.04%    | 0.00%    | 36.75% | 52.04%   |
| Regulation 1            | 10.86%    | 73.91%    | 4.02%    | 14.87% | 73.91%   |
| Regulation 2            | 7.98%     | 39.46%    | 0.60%    | 8.58% | 80.20%   |
| Regulation 3            | 26.64%    | 61.37%    | 0.77%    | 27.41% | 61.37%   |
| Electrical Check        | 12.08%    | 76.71%    | 0.00%    | 12.08% | 76.71%   |

average output = 17.619 units; manpower = 6 people

According to the result from both experiments, productivity level measured by using the following formula:

\[
Productivity = \frac{Average \ Output}{Man \ Power/(Normal \ Working \ Time + Overtime)}
\]

Productivity level from first experiment, based on 8 working hours simulation was about 0.34 unit / person / hour, since the average output was 16.095 units. Whereas the second simulation experiment which performed for the same duration, productivity level was about 0.37 unit / person / hour. Both improvement suggestions were higher than the productivity level which showed in current state map, that was only about 0.27 unit / person / hour from 8 hours simulation. The different productivity level showed that there were strategies which could be implemented by manufacturer to improve its productivity. Manpower reduction was one solution to the problem, by reducing manpower the operator utilization could be improved and the percentage of idle time could be minimized. Division of work was another solution as well, by assigning operator in more than one processing unit could level idle time among operators.

4. Conclusion
There are 2 scenarios in the simulation model experiment. The first model simulation results an increase in the average output to 16.1 units, so that productivity became 0.34 units / person / hour. While the second model simulation results an increase in the average output to 17.62 units, so productivity becomes 0.37 units / person / hour. Furthermore, based on the proposed state map, there was an increase in productivity in the Silent UP Assembly working group of 6%. Based on the condition of the first scenario simulation there was an increase of 24% from the current state map. While based on the condition of the second model simulation, there was an increase of 36% from the current state map.
Therefore, lean manufacturing proved by discrete event simulation is an effective way to improve productivity in manufacturing industries.

5. References

[1] Kulkarni P P, Kshire S S and Chandratre K V 2014 Productivity Improvement Through Lean Deployment & Work Study Methods *Int. J. Res. Eng. Technol.* **03** 429–34

[2] Fontana A and Gaspersz V 2011 *Lean Six Sigma for Manufacturing and Service Industries, Bogor: Vinchristo Publication*

[3] Fernando Y C and Noya S 2014 “Optimasi Lini Produksi dengan Value Stream Mapping dan Value Stream Analysis Tools *J. Ilm. Tek. Ind.* **13** 125–33

[4] Hazmi F W, Karnaningsih P D and Supriyanto H 2012 “Penerapan Lean Manufacturing Untuk Mereduksi Waste di PT ARISU *J. Tek. ITS* **1** 135–40

[5] Anvari A, Ismail Y and Hojjati S M H 2011 A Study on Total Quality Management and Lean Manufacturing: Through Lean Thinking Approach *World Appl. Sci. J.* **12** 1585–96

[6] Sundar R, Balaji A N and Kumar R M S 2014 A Review on Lean Manufacturing Implementation Techniques (Tamilnadu, Elsevier Ltd)

[7] Khannan M S A and Haryono 2015 Analisis Penerapan Lean Manufacturing untuk Menghilangkan Pemborosan di Lini produksi PT Adi Satria Abadi *J. Rekayasa Sist. Ind.* **4** 47–54

[8] Yansen O and Bendatu L Y 2013 Perancangan Value Stream Mapping dan Upaya Penurunan Lead Time pada Bagian Procurement-Purchasing di PT X *J. Tirta* **1** 9–16

[9] Hines P and Rich N 1997 The Seven Value Stream Mapping Tools *Int. J. Oper. Prod. Manag.* **17** 46–64

[10] Kelton W D, Sadowski R P and Sturrock D T 2007 *Simulation with Arena* (McGraw-Hill)

[11] Loucks D P, Stedinger J R and Haith D A 1981 *Water Resource Systems Planning and Analysis* (New Jersey: Prentice-Hall, Inc)

[12] Banks J, Carson J S, Nelson B L and Nicol D M 2013 *Discrete-Event System Simulation: Pearson New International Edition* (Pearson Education Limited)

[13] Altiok T and Melamed B 2007 *Simulation Modelling and Analysis with Arena* (Cyber Research, Inc)