Modernization of facility layout design in earthenware craft industry with green productivity approach

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Abstract. Entering the Industrial Revolution 4.0 as of now there are still many earthenware craft industries that are traditional, both in terms of equipment and materials, procedures for making, and layout of facilities. Layout facility is one of many factors to determining factors of level of productivity workers. If arranged more modern, then the work operation becomes more effective and efficient so that the productivity of the industry will increase. The purpose of this research is to redesign the layout of the earthenware craft industry facilities which are modern and having good work environment, improve the work quality of the workers, and increase the profitability of the earthenware craft industry itself. The stage of this research starts from determining the alternative layout of the best facilities, analyzing the layout of the facility using the 5S Method, and analyzing the productivity of the facility layout with the concept of Green Productivity. The results achieved from this research are the best facility layout found in alternative 1, where percentage reduction in path length reached 40% of initial layout. 5S analysis results have a positive impact for time of production process earthenware by reduction in processing time is 42.75% and the electricity savings reduce electricity costs 55.02%. Rate of productivity in this earthenware craft industry has increased by 2.31%.

1. Introduction

One of the handicraft industries in Indonesia is the earthenware craft industry. The earthenware craft industry is a handicraft industry sector that has long been occupied by the Indonesian people. According to [1], this handicraft industry usually goes down from generation to generation. In the era of Industrial Revolution 4.0, there are still many earthenware craft industries that are traditional, both in terms of equipment and materials, production process, and layout of facilities. The impact of these traditional conditions will have a negative impact on the work productivity of earthenware craftsmen. If not addressed, over time the earthenware craft industry will die, and people will lose their livelihoods.

Facility layout is one of the determining factors of the level of productivity of workers. According to [2] that a well-designed facility layout will generally contribute positively to the optimization of the company's operating process and ultimately will maintain the company's survival and the success of the company. Whereas according to [3], that the plant layout includes planning and setting the location of machines, equipment, material flows and people who work at each work station. If arranged properly, the work operation becomes more effective and efficient. In addition to considering the layout of modern facilities to support productivity, good environmental must still be considered. One good concept that can be implemented in small industries such as earthenware craft industry is the concept of green
productivity [4]. This concept emphasizes on the achievement of high productivity with a focus on three main elements, they are environment, quality and profitability.

2. Research Methodology
The steps of this research are shown in Figure 1:

2.1. Identification of problems
At this stage, researchers conduct direct observations into the object of research, study the production process of earthenware, record the facilities in the field, measure the work area, take documentation, calculate the level of productivity of the earthenware craft industry, and determine the problems to be solved. After identifying the problems that exist in the object of research, researchers formulate the problems that will be examined to be resolved.

![Flow Chart of Research](image)

**Figure 1.** Flow Chart of Research

2.2. 5S analysis
In this stage researchers will analysis some of the literature on the 5S method in accordance with the problems that have been formulated, then the researchers will analysis the overall layout of the work facilities and processes in the object of research with the 5S Method so as to produce a neatly arranged production work area and green work environment.

2.3. Designing facility layout with Systematic Layout Planning by ARC Method and Green Productivity Approach
After getting a neatly arranged work area, then the researchers will make some redesign of the work area facility layout needed based on the SLP method and the concept of Green Productivity. In this stage researchers will make two redesigned facility layouts.

2.4. Evaluation and testing
At this stage, the researcher will evaluate some of the proposed facility rearrangement designs and test the level of worker productivity between worker productivity in the previous facility and productivity
in the proposed facility layout. After the evaluation and analysis have been carried out, the researcher will determine the best design of the facility layout that produces the highest level of productivity.

3. Facility Layout Design

The layout of facilities is the procedure for managing various types of facilities by optimally utilizing the area to support the smooth production process [2]. The design layout of the facility is usually described as plan production facility layout, which is the composition of physical facilities (equipment, land, buildings, and other facilities) to optimize the relationship between executing officers, goods flow, information flow, and procedures for achieving business objectives [5]. The purpose of designing the facility layout is to optimize the utilization of available areas, empowering the use of machinery, labour, and production facilities; minimize material handling; reduce waiting time; provide security, safety and comfort for workers; minimize the manufacturing process; reduce intermediate goods inventory; facilitate supervision activities[2]. One method used to optimize facility layout is Systematic Layout Planning. Systematic Layout Planning is an approach to layout planning with a systematic approach step [5]. Considerations used for planning must be based on data on production activities, both ongoing and future.

The Activity Relationship Chart method is part of the SLP. The method consists of three stages, namely analysing the flow of material, analysing the area needs of the available needs. Next is the planning phase of the space relationship diagram and the design of alternative facility layout. The final stage is to make a selection of several alternative layout facilities that have been designed. The SLP stage with the ARC method is data collection and activity, analysis of material flow, preparation of work diagrams, determination of area requirements, consideration of available area, creation of space relation diagrams, layout modifications based on practical considerations, selection and evaluation of alternative layouts [6].

4. 5S Analysis

The 5S Method is an adapted method from Japan, it is consisting of Seiri, Seiton, Seiso, Seiketsu, and Shitsuke. This method is designed to eliminate waste and is a movement which is a determination to make arrangements, cleanse, maintain steady conditions and maintain the necessary habits to carry out the work well [7]. According [2] that by using the 5S concept, each work area can be arranged more efficiently because in each work area there is only material, equipment or activities needed. 5S is a tool that is often used in lean methods in improving systems to reduce waste, clean-up work areas, and improve labour productivity [9]. This is because the application of 5S in the organization can maintain the smooth and efficient flow of each activity and provide results in the form of material reduction, movement, time, and area needed to carry out operations [10]Stages in the 5S method analysis are Seiri, equipment removal or items that are not needed at work. Seiton, arrangement of tools or goods needed. Seiso, cleaning tools or goods and workplaces that have been neatly arranged so that they are not dirty. Seiketsu, maintenance of a neat and clean work environment is a work standard. Lastly, Shitsuke, self-awareness of good and right work ethics. The work ethic includes discipline towards standards, mutual respect among workers, shame for violations, and pleasure in making improvements.

5. Green Productivity

According to the Asian Productivity Organization of 2008 in [4], this concept is part of good environment productivity improvement program in order to answer global issues about sustainable development, which combines two important things in the development strategy, they are productivity improvement and environmental protection. According to [11] Green Productivity is an approach that can help companies to increase productivity while reducing environmental impacts. The concept of GP is very beneficial for industrial activists, this is due to a combination of efforts to increase productivity and mitigate environmental impacts for the achievement of sustainable development. The application of this method is an effective and efficient technique, technology and management system for the industry to produce goods and services. The GP method approach is expected to evaluate and provide alternative
solutions for improving productivity and environmental performance in the future so that the company will be able to improve productivity and performance in the management of a green environment. Productivity be formatted as:

\[
P = \frac{\text{Output}}{\text{Input}}
\]

(1)

The stages in implementing GP method are:

a. Beginning, at this stage the process flow diagram, layout, and material balance are carried out.

b. Planning. This stage is planned for what will be done in creating a green environment of work environment by identifying the causes and problems faced so far.

c. Implementation, in this stage, a layout will be designed that meets the objectives, it is a green environment facility layout.

d. Supervision and review, his stage is calculated and compared between before and after the implementation of the GP method.

e. Repair and evaluation, in this final stage a structured system is established to ensure that productivity improvements are green environment.

6. Analysis and discussion

6.1. Analysis of Facility Layout

Below is Figure 2, which shows the initial facility layout:

![Initial Layout Block Diagram](image)

**Figure 2. Initial Layout Block Diagram**

The flow of material by describing a map of the process of earthenware operations such as Figure 3.
The following is the calculation of the material handling distance of the initial facility layout presented in Table 1 below:

**Table 1. Length of Material Handling Path Initial Facilities Layout (m)**

| To   | From | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total (m) |
|------|------|---|---|---|---|---|---|---|---|---|----------|
| 1    | 2    | 4 |   |   |   |   |   |   |   |   | 4        |
| 2    | 3    | 6 | 5,5| 2,25|   |   |   |   |   |   | 6        |
| 3    | 4    |   | 5,75| 2,25|   |   |   |   |   |   | 7,25     |
| 4    | 5    |   |   | 7,25|   |   |   |   |   |   | 7,25     |
| 5    | 6    |   | 5,75| 5,75|   |   |   |   |   |   | 5,75     |
| 6    | 7    |   |   |   | 11,25|   |   |   |   |   | 11,25    |
| 7    | 8    |   |   |   |   | 0 |   |   |   |   | 0        |
| 8    | 9    |   |   |   |   |   | 0 |   |   |   | 0        |
| 9    |      |   |   |   |   |   |   | 0 |   |   | 0        |
|      |      |   |   |   |   |   |   |   | 0 |   | 47,75    |

Where:
1. Raw materials work station
2. Mashing work station
3. Mixing work station
4. Forming work station
5. Drying work station
6. Refining work station
7. Staining work station
8. Display area
9. Guest room

The total production area needs are shown in Table 2.

**Table 2. Total Requirements for Overall Area**

| No. | Work Station            | Dimension of Area (m²) | Quantity of Facility | Total Area (m²) |
|-----|-------------------------|------------------------|----------------------|-----------------|
| 1   | Raw materials work station | 10.5                  | 1                    | 10.5            |
| 2   | Mashing work station     | 13.5                  | 1                    | 13.5            |
| 3   | Mixing work station      | 3.5                   | 1                    | 3.5             |
| 4   | Forming work station     | 9.0                   | 1                    | 9.0             |
| 5   | Drying work station      | 16.5                  | 1                    | 16.5            |
The next stage is to analyze the activity in the form of Activity Relationship Chart (ARC) as Figure 4, which is the basis for making alternative designs by taking into account the modifications and limits of effectiveness and efficiency so that productivity can increase.

**Figure 4. Activity Relationship Chart**

6.2. *Alternative redesign layout 1*

In designing the layout of alternative facility layout 1 there is a displacement of the layout at the mixing work station, where after the clay raw material is pounded and mixed with sand and water, the mixture will be transported directly to the mixing work station which is adjacent to the mixing work station to mix until easily formed. This alternative design is illustrated in Figure 5.
Figure 5. Block Diagram of Alternative Facilities Layout 1

Based on the design of the layout of alternative facilities 1 above obtained requirements area as follows Table 3:

| No. | Work Station              | Dimension of Area (m²) | Quantity of Facility | Total Area (m²) |
|-----|---------------------------|------------------------|----------------------|-----------------|
| 1   | Raw materials work station| 7                      | 1                    | 7               |
| 2   | Mashing work station      | 9                      | 1                    | 9               |
| 3   | Mixing work station       | 6                      | 1                    | 5.25            |
| 4   | Forming work station      | 12                     | 1                    | 11.25           |
| 5   | Drying work station       | 16.5                   | 1                    | 16.5            |
| 6   | Refining work station     | 7                      | 1                    | 7.5             |
| 7   | Staining work station     | 7                      | 1                    | 6.75            |
| 8   | Display area              | 9                      | 1                    | 8.75            |
| 9   | Guest room                | 9                      | 1                    | 10.5            |

Total Service Production Area 82.5

6.3. Alternative redesign facilities layout 2

In designing the alternative facility layout 2, the layout of the facility is designed to resemble the previous alternative. It's just that the difference is found in the material handling flow pattern, where the staining station will be parallel to the guest room and directly adjacent to the display room, as illustrated in Figure 6.

Figure 6. Block Diagram of Alternative Facilities Layout 2
The area requirements in designing the layout of alternative facilities layout 2 above are as follows Table 4:

| No. | Work Station                  | Dimension of Area (m²) | Quantity of Facility | Total Area (m²) |
|-----|-------------------------------|------------------------|----------------------|-----------------|
| 1   | Raw materials work station    | 7                      | 1                    | 7               |
| 2   | Mashing work station          | 9                      | 1                    | 9               |
| 3   | Mixing work station           | 6                      | 1                    | 5.25            |
| 4   | Forming work station          | 12                     | 1                    | 11.25           |
| 5   | Drying work station           | 16.5                   | 1                    | 16.5            |
| 6   | Refining work station         | 7                      | 1                    | 7               |
| 7   | Staining work station         | 7                      | 1                    | 6.75            |
| 8   | Display area                  | 9                      | 1                    | 8.75            |
| 9   | Guest room                    | 9                      | 1                    | 10.5            |

Total Service Production Area 82.5

6.4. Selection of the Best Facility Layout
The selection of the best alternative facility layout in this study was carried out on the basis of the shortest flow of material handling, so that the production process of the earthenware craft industry was more effective and efficient. As for alternative 1, the calculation of the length of the material handling path in these alternatives is presented in Table 5.

| To | From | 1   | 2   | 3    | 4    | 5    | 6    | 7    | 8    | 9    | Total (m) |
|----|------|-----|-----|------|------|------|------|------|------|------|-----------|
| 1  |      | 4   |     |      |      |      |      |      |      |      | 4         |
| 2  | 1    | 3.75|     |      |      |      |      |      |      |      | 3.75      |
| 3  | 2    | 3   |     |      |      |      |      |      |      |      | 3         |
| 4  | 3    | 8.25|     |      |      |      |      |      |      |      | 8.25      |
| 5  | 4    | 1.75|     |      |      |      |      |      |      |      | 1.75      |
| 6  | 5    | 2   |     |      |      |      |      |      |      |      | 2         |
| 7  | 6    | 3.75|     |      |      |      |      |      |      |      | 3.75      |
| 8  | 7    | 2   |     |      |      |      |      |      |      |      | 2         |
| 9  | 8    |     |     |      |      |      |      |      |      |      | 0         |

Total Length of Material Handling Flow Alternative Layout 1 28.5

The calculation of the material handling length in alternative 2 is presented in Table 6.

| To | From | 1   | 2   | 3    | 4    | 5    | 6    | 7    | 8    | 9    | Total |
|----|------|-----|-----|------|------|------|------|------|------|------|-------|
| 1  |      | 4   |     |      |      |      |      |      |      |      | 4     |
| 2  | 1    | 3.75|     |      |      |      |      |      |      |      | 3.75  |
| 3  | 2    | 3   |     |      |      |      |      |      |      |      | 3     |
| 4  | 3    | 6.75|     |      |      |      |      |      |      |      | 6.75  |
| 5  | 4    | 3.5 |     |      |      |      |      |      |      |      | 3.5   |
| 6  | 5    | 3.5 |     |      |      |      |      |      |      |      | 3.5   |

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From the results of the analysis that has been carried out, the shortest path is the layout of alternative facilities 1 with a material handling length of 28.5 meters, as in Table 7.

Table 7. The Best Alternative of Facility Layout

| Alternative | Total Work Area (m²) | Length of path (m) | Percentage reduction in path length |
|-------------|----------------------|--------------------|-----------------------------------|
| 1           | 82.5                 | 28.5               | 40%                               |
| 2           | 82.5                 | 33                 | 31%                               |

7. Analysis of 5S Method
After obtaining the best facility layout, the next step in this research is the application of the Seiri, Seiton, Seiso, Seiketsu, and Shitsuke (5S) methods. In the application of this method, workplace conditions are regulated so that it will have a positive impact on work effectiveness, efficiency, and green productivity. In addition to the application of the 5S method in this study socialization was also carried out by providing an explanation of 5S and providing guidance on how to apply this method to the work environment. This is so that workers can understand about 5S, so that the application of 5S can be easier to implement.

Table 8. 5S Analysis

| 5S Method (Sort) | Implementation | Work Station                      |
|------------------|----------------|-----------------------------------|
| Raw material work station | The separation between a bucket containing gravel and a good bucket. Separation of earthenware fragments, used cans and used wood. The separation between broken buckets and good buckets | Raw material work station |
| Mixing work station | Separation of unused wood and sandpaper. | Mixing work station |
| Empty bucket area | The Buckets which is containing gravel are moved outside the area of the raw material work station, while empty buckets used to transport clay and sand are separated and placed in an empty bucket area. Earthware fragments are moved outside the raw material work station. Used cans and unused wood are transferred to the disposal site, while used wood is placed in equipment area. Clay pounder is hung on the wall. Broken buckets are moved to a landfill, while the bucket used to transport water has been placed in equipment area. Wet earthenware that undergoes a drying process is arranged and placed in a high place. | Empty bucket area |
| Mashing work station | Mashing work station |
| Drying work station | Drying work station |
Plastered wood and unused used sandpaper are removed from the refining work station area. The earthenware that has been stained is stacked and placed in a higher place.

**Seiso** (Shine)
- Cleaning the production floor.
- Cleaning of work equipment.

**Seiketsu** (Standardize)
- Making a turntable.
- Drying racks.
- Making earthenware shelves.
- Name label creation.

**Shitsuke** (Sustain)
- Control during 7 days and the next day.
- Disciplinary efforts and self-habituation

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5S analysis results give a positive impact for time of production process earthenware as shown in Table 9.

**Table 9. Estimation of Earthenware Process Time**

| Facility Layout   | Total Output Per Day (unit) | Time Process (minute) | Percentage of reduction in processing time |
|-------------------|------------------------------|------------------------|--------------------------------------------|
| Initial           | 32                           | 6760                   | 42.75%                                     |
| Alternative 1     | 48                           | 3870                   |                                            |

8. Green Productivity

The earthenware production process which consists of 9 (nine) stages almost entirely will produce waste. This waste can be categorized into solid, liquid and gas as shown in Table 10.

**Table 10. Production Cycle Inventory Quantification**

| Process            | Input                        | Waste                      |
|--------------------|------------------------------|----------------------------|
| Preparation of raw materials | Clay                         | -                          |
| Adding water and sand       | Sand and water               | -                          |
| Mashing               | A mixture of clay, sand and water | Gravel and chalk soil     |
| Mixing                | Clay mixture                 | -                          |
| Formation             | Clay mixture                 | Polluted water             |
| Drying                | Wet earthenware              | Earthenware fragments     |
| Refining              | Dry earthenware              | Clay powder and dust      |
| Staining              | Dry earthenware              | Polluted water             |
| Finishing             | Earthenware products ready for sale | -                       |

From the table above, it is known that waste of this production is not hazardous waste. However, after the facility layout has been redesigned, electricity savings occur at lighting work stations and water pumps. Previously, lighting was installed in four work stations, then only installed at two work stations. It occurred because of the 5S application in the *seiketsu* method, where polluted water was collected and used as raw material for water in the process of mixing clay and sand in mashing work station. So that
the use of water in this industry effectively and efficiently can be utilized. The electricity saving has giving good implications for green productivity improvement.

The estimation of total production costs, after redesign layout and electricity savings occurs is shown in Table 11.

**Tabel 11. Estimation Cost of Electricity Usage Per Year**

| Facility Layout | Kwh | Electricity Usage Cost (Rp) | Decrease of Electricity Costs |
|-----------------|-----|-----------------------------|------------------------------|
| Initial         | 68  | 822,500,-                   |                              |
| Alternative 1   | 34  | 370,000,-                   | 55,02%                       |

After overhead costs, the calculation of sales, cost and profits is obtained as shown in Table 12.

**Tabel 12. Estimation of Productivity Rate**

| Facility Layout | Output (Rp) | Input (Rp) | % Productivity |
|-----------------|-------------|------------|----------------|
| Initial         | 34,305,000,-| 28,866,300,-| 119,68%        |
| Alternative 1   | 34,305,000,-| 28,210,000,-| 121,99%        |

From the table above, it can be seen that after redesigning the facility layout to become alternative 1, rate of productivity in this earthenware craft industry has increased by 2.31%.

9. Conclusion
From the results of the research that has been done, the following results are obtained:

a. The best facility layout is alternative 1, where percentage reduction in path length reached 40% of initial layout.

b. 5S analysis results have a positive impact for time of production process earthenware by reduction in processing time is 42.75% and the electricity savings reduce electricity costs 55.02%.

c. Rate of productivity of the earthenware craft industry has increased by 2.31%.

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