Technical and Economical Analysis of Shipyard Re-Layout for Product-Oriented Work Breakdown Structure Implementation

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Abstract. The ship building method used by many shipyards in the world has led to work effectiveness and efficiency. One of them is Product-Oriented Work Breakdown Structure Concept (PWBS). PWBS belongs in group technology. In this method the parts that will be produced for ship building are categorized based on the similarity in form and production process. In Indonesia, not many shipyards have implemented this method. If a shipyard will change its production method, layout adjustments will be required. This research was conducted to analyze the technical and economic changes in the layout of the PT X with study in the case of 2 x 1800 HP tugboat. The technical analysis is done by observing the conditions of the production process and the existential shipyard layout. Furthermore, it also analyzes the investment costs to make changes of the shipyard’s layout and analyzes the feasibility value of the investment. Fabrication parts of tugboat are grouped into 4 categories, those are category A: internal parts from plate or part piece of plate, B: parallel parts, C: curved parts (bent plates) and D: shapes (miscellaneous operation). The new layout can reduce the distance of material handling in category A by 2-19%, category B by 29%, category C by 57% and category D by 2-56%. Fabrication costs are estimated to be reduced to IDR 36,152,935 and sub assembly cost reduced to IDR 27,178,200 by applying this group technology concept. Investment costs to make changes the layout is IDR 7,471,954,000. This project is worth to do with 11% IRR value and payback period will occur in the 3rd year.

1. Introduction
Shipbuilding method used in many shipyards in the world has led to work effectiveness and efficiency. In the conventional method, the ship is seen as a system. So that the ship is built system by system. This method makes the ship building process slow. This encourages scientists and experts in the field of shipping to create other, better methods. One method is the Product-Oriented Work Breakdown Structure (PWBS). PWBS belongs to the technology group. In this method, the parts to be produced for shipbuilding are grouped based on the similarity in shape and production process.

Product-Oriented Work Breakdown Structure (PWBS) concept has not been widely used by large shipyards in Indonesia to carry out ship building. In PWBS concept the division of labor is oriented towards the products produced by each production workshop, so that work can be carried out based on
the division of the ship's zone. In the construction process, the ship is divided into several work packages and classified based on the similarity in design and fabrication processes. Building a ship using this concept will involve an integration of hull construction, outfitting and painting. The purpose of using the PWBS concept is to increase shipyard productivity.

Changes in production technology at the shipyard must be supported by increased facilities and changes in the layout of the shipyard from the existing form. The new layout must be adjusted to the size of the land and the location of the existing production facilities, especially in medium-scale shipyards. Changes in layout as much as possible do not change the position of vital shipyard facilities, such as building birth and dry dock. Layout changes include rearranging the layout of production machines in the workshop, adding an assembly area, setting up work stations, placing warehouse areas and arranging other supporting facilities. In this research, a technical and economic analysis of changes in the layout of the shipyard will be carried out for the application of the PWBS concept in a medium-scale Indonesian shipyard.

2. Literature Review

2.1. Shipbuilding Process

The ship building process is broadly divided into two stages, namely the design stage and the physical construction stage. The design process is the process of translating the owner's requirements into an image that will be used as a reference for ship building. Construction of ship construction includes making parts / components, joining parts / components, building blocks and erection (merging blocks) [1].

In the initial estimation process and design stage, the ship is divided into work packages based on a system or what is called a System-Oriented Work Breakdown Structure (SWBS). However, this division based on SWBS cannot be used to distribute work during the planning, scheduling and physical construction process of ships. Therefore, in these activities, the division of work is carried out based on the product produced or with the Product-Oriented Work Breakdown (PWBS) system. The distribution is adjusted to the design that has been produced from the previous stage [2].

2.2. Shipyard

Shipyard is a place designed to build and / or repair and maintain ships. Generally, shipyards are built on land directly adjacent to the water or sea level. Inside the shipyard there are facilities and facilities used to support ship building activities. Not only that, it also includes facilities for other operational activities. The facilities and facilities owned by the shipyard will affect the performance and capacity of the shipyard in carrying out ship building or ship repair. These facilities include:

- Production workshop
- Building berth
- Launching area
- Warehouse
- Office building

2.3. Shipyard Layout

Careful consideration is required of area availability, topography, hydrography and weather conditions which contribute significantly to the overall characteristics of the layout design. The flow of material is determined from the parallel work stages, which have been carried out and succeeded, so that the end result will be harmonious and balance the production facility. The factors that influence the shape of the shipyard layout are [3]:

- Range of ship types built and the number / year
- Room required
- Available room
- Number of “mechanisation”
- Material handling
Group technology layout or commonly known as process lane construction is an arrangement of work stations in a workshop equipped with production machines, materials and labor to form a construction with the same shape and the same type of machine usage [4]. Figure 1 is type of workshop layout which applies group technology concept. Part production processes that are straight with parts requiring a distinguished bending process.

![Figure 1. Type of Shipyard Workshop](image)

2.4. Product-Oriented Work Breakdown Structure Concept
The PWBS concept is the result of the development of the technology group on ship building. The ship building process using this concept will divide the ship into work packages. The parameters used to divide the work are shape, size, tolerance, material, type and complexity of the production machine.

PWBS classifies interim products based on the four aspects needed to control the production process. Systems and zones are related to the ship design function, while areas and stages are related to the ship's production function. The four aspects are defined as [2]:
1. The system is a structural or operational characteristic of a product.
2. Zone is a division of production objects based on geographic division.
3. Problem Area is the division of the production process into similar types based on the form, quantity, quality, type of work and others.
4. Stages are the division of the production process based on the sequence of the production process.

2.5. Supervision
Zone-oriented shipbuilding scheduling is necessary to regulate the flow of work over the various process lines so that the manufacture of intermediate (additional) products only when needed. Scheduling must coordinate hull construction, outfitting and painting work so that the completed work package can enter the next stage of work. The goal is to minimize the waiting work packets (buffer) [2].

2.6. Learning Curve Theory
The basic principle of the learning curve is easily explained, such as: if a person performs a task that is repetitive in nature, the time required to complete the next task will decrease until it can no longer be reduced. Initially the learning curve focused on the relationship between cumulative quantities and cumulative average times (the amount of cumulative time divided by the cumulative quantity) [5]. General form of learning curve is
\[ Y = aX^b \]  \hspace{1cm} (1)

where,
\[ \begin{align*}
Y &= \text{cumulative average times per unit/batch} \\
a &= \text{time required for the production of initial quantities} \\
X &= \text{cumulative unit of production} \\
b &= \text{learning curve index, is } \log \text{learning curve percentage } / \log 2
\end{align*} \]

In shipbuilding, in general learning curve is 8\%-10\%, meaning that the time needed to complete each production unit is generally reduced by 8\%-10\% from that required by the previous unit [6].

2.7. **Productivity**
Productivity is used to measure the performance of operations management. Productivity is a measure of how well a resource is managed and utilized to achieve the desired result. Productivity is generally expressed as the ratio of output to input, or the ratio obtained to resource consumption [7].

3. **Research Methodology**

3.1. Identification of Problems
The initial stage of working on this research is the identification of the problem which includes activities such as explaining existing problems, determining research boundaries, and describing things that need to be explained in problem solving. In this research, the problem raised is the lack of use of the PWBS concept in the Indonesian shipping industry and planning changes to the shipyard layout that must be done to support the PWBS concept.

3.2. Literature Review
At this stage, relevant literature is collected to support this research. The literature used discusses shipyards, shipyard facilities, layout concepts, learning curves, productivity, and investment. The literature used is in the form of domestic and foreign journals, books and similar research that has been done before.

3.3. Existing Condition Analysis
Analysis of existing conditions is carried out to determine the initial conditions of the shipyard which will be used as a research case study. The analysis is carried out directly by visiting the shipyard which is the object of research and asking for primary data. The data used in this study are the shipyard layout, the layout of the machines in the workshop, a list of shipyard facilities and data on new buildings of ships being built.

3.4. Data Management
The data that has been obtained from the survey results are processed with reference to relevant literature and realistic thinking.

3.5. Technical Planning
After the data is processed, the next stage is technical planning. Technical planning is carried out in the form of shipyard layout planning, planning of new facilities, calculating technical changes that occur. Planning is carried out by looking at the conditions of the shipyard, regulations regarding standard office facilities and the concept of building a ship using PWBS which is the topic of this research.

3.6. Economical Analysis
Economic analysis was conducted to calculate the costs of changing the layout and purchasing new facilities. As well as an analysis of the feasibility of investing on shipyard income based on research case studies.
4. Existing Condition of Production Process and Layout

Observation and survey of existing conditions are needed to obtain real field data regarding the ship production process being carried out and the position of the existing facility layout. This data will be used as a basis for planning a new layout according to the PWBS concept.

4.1. Production Process

The production process in ship building consists of hull construction, outfitting manufacture and installation, to the painting process. The process is carried out in each workshop with the facilities in it. Once a complete or nearly complete construction is formed, the ship will be launched. Then, the finishing, commissioning and sea trials are carried out. At the time of this research, PT X shipyard was building a tugboat 2 x 1800 Hp with the following sizes:

|  |   |
|---|---|
| Loa | 30 m |
| B  | 11.6 m |
| H  | 5.1 m |
| T  | 3.5 m |
| Main Engine | 2 x 1800HP |

The tugboat parts were assembled in the south building area and part of the fabrication process was carried out in the south hull workshop. The fabrication process includes marking, cutting, bending and several joining activities. The result of this process is in the form of parts that have a shape according to the previously planned design. Plates and profiles that have gone through the fabrication process will be assembled in the building area. However, there is no clear barrier between the storage area for new material and waste material, so that many piles of new plates are mixed with used plates. In the building area the workers will assemble the fabricated parts into a panel in an empty place and randomly selected so that there is no clear process lane.

4.2. Shipyard Layout

This shipyard has a land area of approximately 57,000 m² and a sea area of approximately 70,000 m² with a waterline length of 1,200 m. There is an indoor work area of 11,525 m² and an outdoor work area of 11,949 m².

This shipyard has two large hull workshops in a separate area because apart from serving the construction of new building ships, this workshop is also active in serving ship repair and maintenance requests. The northern hull workshop was used to build ships with large dimensions such as tankers. Meanwhile, the southern hull workshop is used to build smaller ships such as tugboats. Apart from the two hull workshops, this shipyard also has a machine shop and an outfitting workshop. There is also a woodworking shop and a mold loft area which is now no longer used.

Apart from that, this shipyard also has a storage area. Storage facilities are used to store company-owned inventory and store raw materials for the production process. The types of storage facilities at this shipyard are divided into two, namely open storage with an area of 5,250 m² and closed storage area of 2,750 m². The steel-stock yard at the shipyard is divided into 4 areas. These four areas are quite far apart. For pipe storage an indoor area measuring 29 m x 7.5 m is provided. The paint shop is also an indoor area measuring 29 m x 9 m.

4.3. Shipyard Facility

Ships will not be built with empty-handed. The existing facilities in the shipyard are the foundation for ship building. There are various types of shipyard facilities, such as docking undocking facilities, material handling facilities and workshop facilities.

Docking and undocking facilities are facilities used to raise and lower ships from the water surface to the land. This shipyard has several types of docking undocking facilities including slipway, transverse slipway and floating dock. This shipyard has 4 floating docks which are used in the ship repair process. Meanwhile, for the ship building process, the usual facility used is the slipway.
Material handling facilities owned by this shipyard are various, such as forklifts and cranes. The largest capacity of the means of transport is a floating crane of 75 tons. These cranes are commonly used to transport blocks from the north hull workshop to the transverse slipway in the south and vice versa.

Apart from the above facilities, this shipyard also has various kinds of production machines located in its workshops. These machines include bending machines, cutting machines, drilling machines, lathes and others.

5. Shipyard Layout Design For PWBS Implementation

After analyzing the existing shipyard condition and based on the theory from previous research, the next step is implement the PWBS theory in production process to be the basic of new layout. Design of new workshop layout depends on the production process.

5.1. Production Process

In the ship building process using the PWBS concept, the ship will be divided into several work packages. The ship is divided down to its simplest part. Starting from level 0 which is a complete ship to level 4 which is the raw material. All parts of this tugboat facility are classified into 4 categories where:

- A category is internal parts from plate.
- B category is parallel parts.
- C category is curved parts (bent plates).
- D category is shapes (miscellaneous operation).

| Part                | Dimension | Category |
|---------------------|-----------|----------|
| Keel plate          | 14        | C        |
| Bottom plate        | 12        | C        |
| Tank top plate      | 12        | B        |
| Longitudinal        | FB 150x16 | D        |
|                     | L 75x75x6 | D        |
| Transverse          | FB 150x12 | D        |
|                     | L 100x100x | D    |
|                     | 6         | A        |
| Side girder         | 10        | A        |
|                     | FB 100x10 | D        |
| Centre girder       | 10        | A        |
|                     | FB 100x8  | D        |
| Bracket             | 9         | A        |
| Side shell          | 10        | C        |
| Frame               | 9         | A        |
| Tank plate          | 9         | B        |
| Tank plate stringer | L 100x100x | D |
| Bridge deck plate   | 6         | B        |
| Wheel house plate   | 6         | B        |
| Side wall           | 6         | B        |
| Side wall stringer  | L 75x75x6 | D        |
The results from analysis in Table 1 of the division of parts category, the percentage of parts in category A was 30%, category B was 24%, category C was 14% and category D was 31%. The output from the fabrication process is in the form of a piece part with edge preparation for the welding process at a later stage. Once formed, the piece parts are joined at the sub-assembly stage to produce a panel. This stage is dominated by fitting and welding activities. Generally, the sub-assembly stage is divided into:

- Sub-assembly for flat panel
- Sub-assembly for curved panel

At the assembly stage, the panels will be connected to form a more complex block unit. In addition, at this stage an outfitting installation is also included which is included in the on block outfitting. Assembly is carried out from the lowest to the top panel position. Assembly is carried out over the pin jig. Just like the previous stage, the assembly stage is divided into two, namely, assembly for flat blocks and assembly for curved blocks.

The erection stage is the stage of joining blocks resulting from the joining process at the assembly stage. The tugboat erection block process at this shipyard is carried out at the transverse south slipway. Blocks are transported using 2 tower cranes.

5.2. Layout Design

Layout design is carried out by considering the existing layout position. In addition, design is carried out by looking at the needs in ship building using the PWBS concept. Layout planning also takes into account the ease of access to materials, vehicles and employees at work.

Changes to the workshop area were carried out in the hull construction workshop area. These changes are in the form of rearranging the process lane in the workshop. The layout of the workshop is arranged using the group layout technology concept with the type of cell manufacturing production system. In this concept, the production floor will be divided into several process lanes and each process lane contains several work stations with machine and operator facilities in it.

This layout change was made for the two existing hull workshops. The southern hull workshop was used to build ships of smaller dimensions. Meanwhile, the northern hull workshop was used for larger ships. In this design, the south hull workshop will be divided into two areas, namely the fabrication area and the sub assembly area. Several work stations planned for the fabrication stage are pre storage material, marking, cutting, bending, and edge preparation. Figure 2 is comparison between the existing layout with the new layout. The colored lines show the material flow of each category.

In addition, in the sub-assembly area two process lanes are also planned, namely the process lane for the manufacture of the internal structure from the flat panel and the process lane for the manufacture of the internal structure from the curved panel. The panels that have been formed in this workshop will then be brought to the assembly area to be combined into blocks. The assembly area used is the existing assembly area, there is no significant change, only the area of merging the sub-blocks into blocks is arranged in erection order.

5.3. Impact of New Layout Application

| Learning index | -0,120294234 |
|----------------|--------------|
| Number of Fabrication | Hours         |
| 1   | 945,2599133  |
| 2   | 869,63912    |
| 3   | 761,9809819  |
| 4   | 644,9407029  |
| 5   | 531,4197923  |
| 6   | 428,3814107  |
One of the advantages of the technology group concept in the manufacturing industry is that it can shorten the material handling distance. This can happen because the machines are placed close together. In addition, the production process flow is also designed to minimize looping work processes. Based on the layout plan above, the results of the reduction in material handling distance from the existing condition to the new condition are quite significant. For material in category A, the reduction was 2-19%, category B was 29%, category C was 57% and category D was 2-56%.

| Number of Fabrication | Hours        |
|-----------------------|-------------|
| 7                     | 338,976,9715|
| 8                     | 263,957,2999|
| 9                     | 202,648,6922|
| 10                    | 153,620,6405|

Figure 2. (a) Workshop Layout Existing, (b) New Layout Design
Apart from reduced material handling distances, the technology group concept also affects production time. Workers who perform the same type of task over and over will be able to reduce the working time on the next task (learning curve theory). Table 2 and Table 3 is estimated time for ship fabrication and sub assembly tugboat 2x1800 HP. From Table 2 and Figure 3 also Table 3 and Figure 4 It is seen that the most significant reduction in time at the fabrication stage occurred in the early days of concept application. However, this production time can go back up if there are workers who are moved or there are worker rotation activities carried out by the shipyard. Not long after that the production time will return to normal again. To maintain the stability of the performance of workers and machines, regular training for workers and maintenance of production machines is still required.

**Table 3. Estimated Time at Sub Assembly Stage**

| Number of Sub Assembly | Hours   |
|------------------------|---------|
| 1                      | 1662.249604 |
| 2                      | 1529.269636 |
| 3                      | 1339.951656 |
| 4                      | 1134.135081 |
| 5                      | 934.5073531 |
| 6                      | 753.3132639 |
| 7                      | 596.0946073 |
| 8                      | 464.1717173 |
| 9                      | 356.3598792 |
| 10                     | 270.143529 |

**Figure 3. Decreased Time at The Fabrication Stage**

**Figure 4. Decreased Time at Sub Assembly Stage**
**Table 4** and **Table 5** show that repetitive fabrication of individual components such as brackets can reduce fabrication time for subsequent jobs. This is not limited to the type of ship, because in general the shape of the parts in each ship is the same, sometimes the difference is only in the thickness of the plates used.

**Table 4. Manhour Value of Bracket and Keel Plate Fabrication**

| Plate | 208 piece bracket (1 plate = 52 bracket) | Keel plate |
|-------|-----------------------------------------|------------|
|       | Cutting (manhour)                        |            |
| 1     | 6,87922                                 | 7,2        |
| 2     | 6,67284362                              | 6,98400023 |
| 3     | 6,358353432                             | 6,65484527 |
| 4     | 5,982575139                             | 6,26154433 |
| 5     | -                                       | 5,83399982 |
| 6     | -                                       | 5,39227307 |

**Table 5. Manhour Value of Bottom Plate Fabrication**

| Plate | Bottom plate |
|-------|--------------|
|       | Bending (manhour) |
| 1     | 5,67         |
| 2     | 5,499900181  |
| 3     | 5,240690654  |
| 4     | 4,930966162  |
| 5     | 4,594274856  |
| 6     | 4,246415044  |
| 7     | 3,898396811  |
| 8     | 3,557961865  |
| 9     | 3,230492403  |
| 10    | 2,919613909  |

5.4. *Economical Analysis*

Changes in shipyard layout cannot be separated from the calculation of the investment value. It takes a number of costs that must be borne by the shipyard to make changes. In accordance with the results of the technical planning above, the total investment value is IDR 7,471,954,000.

However, changing the layout by applying the technology group concept can also cut ship building times. Costs that can be reduced include the operational costs of material handling facilities and daily costs. The cost reduction in the fabrication stage can reach IDR 36,152,935 and the cost at the sub-assembly stage is reduced to IDR 27,178,200.

So, taking this into account the feasibility value of the investment is calculated. Then this layout change is considered feasible with an IRR value of 11%, it is estimated that the payback period will occur in 3rd year.

6. **Conclusion**

After analyzing and calculating, the conclusions of this research are as follows:

1. The existing shipyard has two hull workshops which are used for the construction of new building ships. The north hull workshop was used to build ships with large dimensions while the south hull workshop was used to build smaller ships such as tugboats. The fabrication and sub-assembly stages
were carried out in the hull workshop while the assembly and erection stages were carried out in the south building area.

2. The PWBS concept can be applied to the construction of a tugboat by adjusting the layout of the workshop. Adjustments made in the form of production lane design and rearrangement of production machines. It is planned that 4 production lanes in the fabrication area and 2 lanes in the sub assembly area are planned. Each lane contains a work station for each activity. Inside this work station contains rearranged existing machines.

3. By using a workshop layout based on the group technology, costs at the fabrication stage can be reduced to IDR 36,152,935 and sub assembly to IDR 27,178,200. To make changes to the layout, an investment of IDR 7,471,954,000 is required. So that this layout change is considered feasible with an IRR value of 11% and a payback period in 3rd year.

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