Modular system construction for laminated wooden fishing vessel industry

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Abstract. The shipping of the fishing boat is expensive and time-consuming, due to the long distance between the shipyard and the fishermen locations. The main objective of this study was conducted to analyze the technical and economic aspects of the traditional fishing vessel building using the modular system construction on laminated Mahogany and Teak woods. Mahogany has the potential as an alternative raw material for wooden fishing boat because it is a fast-growth plant with the harvesting period of 15 to 20 years. The technical analysis was performed by building a prototype with a modular system construction of fishing boat with laminated wood materials. Firstly, survey was conducted to get the main dimension and design the lines plan of the existing boat. The structure of modules is made using the cold press planking method. Economic analysis is done by determining the building cost of fishing vessels with laminated wood construction using a modular system and calculating the investment of a 3 GT boat with laminated wood construction. Based on the prototype of the fishing vessel that has been built, it can be concluded that the price of a Mahogany and Teak laminate ship with a modular system is IDR 44,927,656 (USD 3,160) in comparison to the general price of IDR 30,000,000 (USD 2,110). Note the less, it can be concluded that the investment in fishing shipyard for laminated wood construction using a modular system is feasible both from technical and economic aspects.

1. Introduction
One of the materials in shipbuilding is wood. Wood is a multipurpose material that is needed by the community in building ships. Not only building ships, but also industrial production in Indonesia uses wood as well as many materials so that the availability of wood in Indonesia is running low. In the manufacture of wooden ships in Indonesia, the availability of material, especially Teak, is constrained by the high cost of bringing in materials used as the primary raw material for wooden ship production. The direct effect of the scarcity of wood supplies on the market and the price of wood on the market, which is increasingly expensive and illegal logging is not responsible for causing forest destruction and other adverse effects.

In some cases, the construction of fishing vessels in Indonesia is far from the ship's operational location so that shipping costs are expensive more. In the process of building a shipowner or ship shipping location far from the shipbuilding location (shipyard), it causes the ship delivery process to take a long time. The modular system is a development implementation system that utilizes fabrication materials and components that are made outside the project site or inside the project site, but need to be integrated in advance between the components (erection) where they should be / the position of the component.

In response to efforts to accelerate national development, especially in the field of shipping which has increased, this is supported by government policies that currently give special attention to the
maritime industry, especially in the field of fishing vessel production. This rapid growth must be utilized, one of the ways to utilize it is by using alternative technology for the construction of wooden ships that have high selling power, profitability, ease of delivery and can compete in the free market. With the construction of fishing vessels using laminated wood material with a modular system, it is expected to be an alternative base material for the construction of fishing vessels and able to facilitate shipping.

2. Literature Study

2.1 Wood Lamination Technology
Lamination technology is a technique of combining tearing aid adhesive, where small-sized building materials can be glued together to form components of the scantling structure as needed. Lamination techniques can also be used to incorporate raw materials that are not uniform or of various qualities [1]. According to Manik [2] the advantages of lamination technology are as follows:

1. Procurement of material on the market is easy because the thickness of the coating board used is a maximum of 2 cm; the length of the coating is not limited.
2. The use of wood material is efficient, the supply of wood will be faster and cheaper because thin pieces of wood (up to 5 mm), short, and have defects can still be used to make the construction.
3. Use a bit of mechanical binding material with smaller dimensions and is only a uniting surface of the glue.
4. It is easy to check defects because the dimensions of the raw materials making up the laminate are smaller and thinner — natural selection of right laminating constituents without defects.
5. Impermeability can be guaranteed, rigid or rigid construction, changes in the dimensions of wood can be obtained with effective regulation of wood fibers.
6. Multiple protections can be implemented, dried and saturated wood (wood oven) will be more resistant to damage, and the nature of the specially created glue layer is also a protection against damage as well.

However, according to Wirjomartono [3] laminated structure, such as beams, have several shortcomings, namely:

1. Preparation of compounded wood manufacturing generally requires a higher cost than conventional construction.
2. Because the good and wrong depends on the strength of the connection, then the construction requires special tools and experts.

2.2 Wood Lamination Technique
Before gluing laminated wood, the thing to note is the water content of the wooden slats to be glued together. Referring to BKI's 2013 regulation on small vessels ≤ 24 meters, the water content value for plywood/lamination before gluing is less than 20%. Wet mahogany slats (moisture content ≥ 20%) produce suboptimal adhesion of the laminate due to excess water content, which affects the curing process of the adhesive.

Lamination technology used as ship construction must have a thickness of each layer in the range of 5-20 millimeters [4]. As for the width and length of the layer, there are no restrictions, but to achieve the standard, the size of the slats must be uniform. According to the 2013 BKI on small vessels ≤ 24, plywood or lamination as a whole as a construction material must have a tensile strength higher than 42,169 MPa, while for buckling strength, the required permit stress for Strength Class III wood bending strength is a minimum of 71,098 MPa.

In the manufacture of traditional wooden ships, several technologies used for the installation of planking or hull skin, including:

- Carvel planking is a traditional method of installing leather on the hull in general by attaching wooden boards with a frame (ribcage/frame) or longitudinally (stringer) using nails, screws, or
rivets. After mounting the board or hull skin that produces the shape of the hull, then it is applied to the gaps in the attached board which are filled with pine wood slats and then given adhesive.

- Lapstrake planking is a method of mounting the skin of the stomach where the boards overlap or overlap — fastening the boards using rivets of sufficient length that can bind the two overlapping boards. Installation of the skin with this method results in a stronger stomach. Gaps that occur due to overlapping installations can be sealed by filling gaps with epoxy gluing or the like.
- Strip planking is a method where the strip method is slatted. The difference is this method uses strips or wooden slats, not boards as used in the carvel method. Strips or blades that are formed in the form of a basin at the top, convex at the bottom and tied (tightened) with nails so that the adhesive in its installation. To make it stronger, then the strips or slats are coated with adhesive before fastening. Can also be rectangular strips or blades with the same binding as above. This shape is not easy to repair because the strips or slats used are tied together. [1]

2.3 Wood Connection

A wooden joint is two or more logs that are joined together so that they form one long log[5]. To make a solid wood block connection must meet the following requirements [6]:
- Wooden joints are made as simple as possible but sturdy
- Avoid using wood that is damaged or defective
- The nature of the wood, especially on traceability, development, and withdrawal is of particular concern
- Punching wood cannot be too deep because it can weaken the relationship of the wood itself
- The shape of the joints and connections must be resistant to the forces acting on the wood
- Placement of the connection must be considered to be supported evenly or in certain places because it will affect the position of the beam itself

2.4 Production Cost

Shipbuilder must be able to calculate the cost of production in order to determine the selling price of the goods produced. However, to be able to calculate the cost of production, they must first understand the concept and understanding. Production costs are several economic sacrifices that must be sacrificed to produce an item. Determining production costs based on this understanding requires carefulness because some are quickly identified, but some are difficult to be identified [7] The theory of production costs is closely related to the theory of expenditure functions. Both are influenced by the law of diminishing marginal productivity. Also their analysis of the short run and the long run [7].

a. Short Term: The period during which several factors of production cannot be added to the amount.

b. Long Term: The period during which some factors of production can change.

c. The concept of short-term costs is as follows:
- Variable costs are costs that vary depending on how much the output produced. The greater the amount of output, the higher the variable costs that must be incurred.
- Included in this variable cost is the cost of raw materials, direct labor costs, fuel, electricity, etc. These fixed costs and variable costs add up the total costs.
- Total Variable Costs \( (TVC) \) are costs that are large or small following the many outputs. The figure shows that the total variable cost curve continues to rise. So the more output produced, the higher the variable costs will be.
- If between fixed costs and variable costs are added up, the result is called total cost \( (TC) \). So, \( TC = TFC + TVC \). Total Cost \( (TC) \) is in the vertical distance at all points between Total Fixed Costs \( (TFC) \) and Total Changeable Costs \( (TCC) \), which is equal to \( n \).
- Included in these fixed costs include salary for administrative staff, depreciation of machinery, depreciation of buildings and other equipment, land rent, office rent, and warehouse rental. In the long run these fixed costs will change.

3. Research Methods
The initial stage of the study is determining the original size of the ship. The first thing to do in this respect is the survey. The survey was conducted in three locations namely Geronga for the first location, Panggungrejo for the second and third locations. At this stage, what will be done is to compare the best craftsmen from their work and measure the vessels they have made. After getting the original size of the ship, the lines plan was made, as shown in Figure 1.

![Lines plan of wooden boat](image1)

**Figure 1.** Lines plan of wooden boat

The general arrangement is further established, as exhibited in Figure 2, using the AutoCAD application by taking data from lines plan that has been made aimed to determine the shape of the ship with 2-dimensional images.

![General arrangement of wooden boat](image2)

**Figure 2.** General arrangement of wooden boat
Design of the module which is used as a reference in the construction of ships. The modules that will be made include frame module, keel module, skin hull module, bulkhead module, transom module, chine lock module, and pretty modules. The next step is the preparation phase. There are several processes in the preparation stage [8]:

- **Purchase Materials**
  The primary material needed in this study is Mahogany wood where Mahogany can be obtained from wood suppliers in the Pasuruan area. The Mahogany wood used is aged over 15 years because what is needed in this study is Mahogany with a diameter of 2 m above the material. The second material from this study is Teak for lamination.

- **Wood Cutting**
  Solid wood is cut transversely to get the required length. From the length of the wood that has been cut into what is needed, the wood is thinned by a cutting machine or commonly called a planer machine to get an average thickness of 1 cm and 3 cm.

- **Ship References Manufacture**
  Ship references are made using CNC laser cutting with a design that has been made by AutoCAD. The hull was deliberately made in order to facilitate fabrication process of the material and its installation.

- **Wood Planing Process**
  Planer machine functions to smooth the surface of the wood that has gone through the process of cutting wood so that the size to be produced is the same as the requested size. For that in the material planer process required accuracy in checking the size. Planer process is done after knowing the thickness of the module to be made.

- **Jig Preparation**
  A jig is a tool that serves to direct one or more cutting tools in a position that is by the work process. In this study the jig uses concrete beams and U-bars, where U-bars serve to support the ship's longitudinal construction and concrete beams to support transverse construction. U-bar concrete beam used has a length of 7.5 meters. Jigs that have been installed in the paint to avoid corrosion. Determination of the size of the jig adjusted to the length of the ship to be built.

After the preparation phase has been carried out, then enter the next stage, namely the fabrication stage. The fabrication process is a series of management activities from raw material to sub-module form. This process consists of several activities, including:

- **Marking**
  In the marking process, a mall is needed to adjust the size of the ship to be built. Malls that have been made are attached to intact wood that has been cut and cut the whole wood by the mall that has been made. The marking process is essential for accuracy control where the size to be made is the same as the size that has been made.

- **Cutting**
  Marked wood will be cut according to the shape of the marking, to adjust the shape to be made, the next tool that will be used is a ruler to elbow the size of the wood so that it is not mistakenly cut and the result will be following the references. The tools used for the cutting process are table saws, rulers, elbows, and gauges.

- **Trimming**
  This trimming process serves to smooth the wood and equalize wood thickness as expected. In this process, perseverance is needed in equalizing the thickness of the wood where wood can only be taken 1 mm per trimming process

- **Frames modules setting**
  The module is formed after the wood has passed the marking process until the planner. In this process, accuracy is needed to form a module so that it makes the process of accuracy control in the assembly process more straightforward. Tools needed in the formation of modules are nails, hammers, glue, and hardener. Brackets that have passed the cutting and planner process. The
finished bracket is numbered to simplify the assembly process. Brackets that will be paired with frames will be rechecked to find out the precise shape. After the frames and bracket forms are finished, the next step is to install these two objects into one module to simplify the assembly process. Frames and bracket are adjusted to the numbers that have been made to facilitate the formation of modules. Then after frames and bracket matching, the mounting process is carried out using nails and glued together.

- **Solid floor Setting**
  After going through the process of connecting the solid floor with frames solid floor placement is done on the jig that has been prepared. The first step in placing solid floor is to put a distance mark on each solid floor that will be installed on the jig. The marking is done so that the floor placement can take place according to the shipbuilding plan that has been made and is easier. The marking position is carried out above the jig and also below the solid floor which is taken in the centerline so that the placement of the solid floor will be by a predetermined distance. Solid floor placed in an upside-down position so that a flat base is obtained with a jig.

- **Making keel knitting and chine lock lanes**

- **The process of making a chine lock module**

- **The process of making the keel and Stem modules**

- **The process of making a coolie module**

- **Release the module**
  After the fabrication stage, the delivery stage is carried out where the finished modules are sent to the ship's buyer. This process goes through several more processes, one of which is the packing process. In order to ship a fish with a modular system, it is effortless to order the ship in shipping. The packing process is carried out when the modules have been finished setting on the ship. For shipping modules, many agents sell shipping services. Ship modules can use a container for shipping by land and sea. There is also delivery by using a truck [9]. The most extended module owned by this fishing vessel is the keel module; the length of the keel module is 3 meters. Therefore only using a container truck or pickup car is possible. When shipping, the boat buyer can offer training on the construction of the assembly or assembly stage, because the assembly itself has a difficulty level if the buyer does not understand how to unite the ship properly. In this case the training of workers is crucial to know the stages of assembly in building fishing vessels with a modular system.

The next stage is the assembly stage, the process by which the modules are combined into whole ships. The activities in the assembly process are as follows:
1. Connection of solid floor module with frames module
2. Installation of chine lock
3. Install keel with frames
4. Keel lamination
5. The process of installing the skin

Moreover, for the last stage is the finishing stage where the material is sharp or not following the desired shape such as excess wood thickness, epoxy glue spills and other incompatibilities cleaned by sandpaper gradually using several grade sandpaper in the order of grade 60, grade 80 and grade 100. Besides the provision of arches (gathering) on the sides of the construction to reduce the risk of ship users injured by sharp angles. In addition to smoothing the shape of the hull and other construction, patching uses epoxy glue on the part that has bolts or screws. After that the refinement is done again in that section so that it becomes smooth and integrated with the shape of other ships.

From the design of module formation and module integration into ships, the shipyard determination process is carried out to produce ships and calculate the feasibility of the fishing shipbuilding industry with laminated wood construction using a modular system [10].

4. Results and Discussions
In the table below will be explained about the calculation of investment feasibility based on investment costs, production costs, operational costs, taxes, inflation, and income. With an initial investment cost of IDR 516,457,593 which is charged 30% of the personal capital of IDR 154,937,277.75 and 70% is a loan from CIMB NIAGA bank of IDR 361,520,314.75. The first step that will be taken is to calculate the cash flow of the shipyard industry to be built.

Table 1. Investment calculation using NPV

| Net Cashflow (IDR) | Discounted factor (%) | Net Present Value (IDR) |
|--------------------|----------------------|------------------------|
| (516,457,593)      | 1.000                | (516,457,592.50)       |
| 518,666,059        | 0.907                | 470,445,405.00         |
| (642,395,243)      | 0.823                | (528,500,156.58)       |
| (618,910,332)      | 0.746                | (461,840,419.20)       |
| (359,402,065)      | 0.677                | (243,257,464.70)       |
| (86,918,385)       | 0.614                | (53,360,348.61)        |
| 163,488,337        | 0.557                | 91,036,423.58          |
| 388,798,280        | 0.505                | 196,369,551.58         |
| 625,373,721        | 0.458                | 286,490,906.99         |
| 873,777,933        | 0.416                | 363,072,778.94         |
| 1,134,602,356      | 0.377                | 427,619,695.21         |
| 1,408,468,000      | 0.342                | 481,484,604.26         |
| 1,696,026,926      | 0.310                | 525,883,524.85         |
| 1,997,963,799      | 0.281                | 561,908,807.24         |
| 2,314,997,515      | 0.255                | 590,541,136.15         |
| 2,651,404,219      | 0.231                | 613,475,143.58         |
| NPV:               |                      | 2,804,911,995.79       |
| IRR:               |                      | 25.08%                 |

5. Conclusions
Based on the research that has been done, the following conclusions are obtained:

1. Based on the construction of the ship model that has been carried out in this study, it can be concluded that the technology of Mahogany and Teak wood lamination with a modular system can be used to build a traditional fishing boat with a size of 3 GT supported by the availability of high production forests of Mahogany and Teak wood in East Java.

2. In the economic aspect based on the calculation of the investment costs needed in the construction of mahogany and teak wood laminated fish shipbuilding industry with a modular system of IDR 516,457,593 (USD 36,306). The selling price of the product is IDR 44,927,655.90 (USD 3,160) higher than the price of the ship in general of IDR 30,000,000 (USD 2,110). The Net Present Value is found to be as much as IDR 2,804,911,995.79 (USD 197,182). Payback Period occurs in 9 years two months. IRR value of 25.08% is greater than the bank interest that has been set at 10.25%, so this investment is feasible when viewed from economic analysis.

3. Calculation of the shipping costs of prototype mahogany and teak laminated fishing boat with a modular system has been carried out and compared with a wooden fishing boat using conventional methods. The shipping price of a mahogany and teak wood laminated fishing boat with a modular system is IDR 1,461,771 (USD 103). The price of shipping a fishing boat with conventional methods is IDR 5,203,050 (USD 366) for the 20 feet size. From the above calculation it can be
concluded that the shipping costs of mahogany and teak laminated fishing boats with a modular system are cheaper than conventional wooden fishing boats.

4. Further research needs to be done on boatbuilding analysis using the modular method and technical analysis of hull and frame making process.

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