



# The Application of Steel Frames for Supporting the Sustainability of Traditional Wooden Fishing Boat Construction in South Sulawesi

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## ABSTRACT

South Sulawesi Province is situated in the heart of the Indonesian Islands, renowned for its role in crafting numerous traditional Indonesian wooden boats. These boats serve various functions, including inter-island passenger transport and fishing activities. However, the limited availability of specific wooden materials crucial for constructing sturdy boat frames poses a challenge for skilled boat craftsmen striving to complete their creations. To address this issue, researchers have explored the integration of alternative materials that can maintain the boats' authentic characteristics. Among these alternatives, the possibility of replacing traditional wooden frames with steel frames has gained attention. This study investigates the practical application of steel frames within the construction of a traditional wooden fishing boat, preserving the essence of craftsmanship within a South Sulawesi Province shipyard.

## 1. Introduction

South Sulawesi province is a renowned hub for wooden boat construction in Indonesia. Notably, the pinisi boat, designated as intangible cultural heritage by UNESCO in 2017, stands out among these creations. Pinisi boats serve various roles, including cruise and cargo transportation. Within the province, skilled wooden boat craftsmen also specialize in crafting smaller vessels used for inter-island passenger crossings and fishing activities. These traditional wooden boat yards are located in several districts of South Sulawesi, such as Mamuju, Barru, Takalar, Bulukumba, and Sinjai. The construction of wooden boats hinges on various wood components, each selected based on specific requirements. To ensure feasibility, the Indonesian Classification Bureau [1] has established criteria for wood suitability in boat construction. Poor construction, which is frequently found in most traditional wooden boats in Indonesia [2], particularly in the joints between the planking, is the main reason that hulls are not sufficiently water-tight. Among the approved types are "kayu ulin" (*Eusideroxylon zwageri*) and "kayu jati" (*Tectona grandis*) [2]. Nevertheless, the predicament arises when it comes to sourcing the right wood, particularly for the intricate curvature of boat frames. The scarcity is compounded by environmental factors like illegal logging

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and forest fires, which further deplete the available resources. This concerning scenario directly threatens the continuity of Indonesia's wooden boat construction, particularly within South Sulawesi.

In pursuit of solutions, Bochary *et al.*, [4-6] embarked on a research journey exploring alternative materials to supplant wood in the realm of wooden boat construction. Their inquiry zeroed in on the intricate replacement of the wooden boat frame, a task acknowledged for its dual challenges - the scarcity of appropriate material and the necessity to conform precisely to the boat's curvature. Amidst this backdrop, steel materials emerged as the prime candidate. The researchers meticulously assessed the steel's compatibility, meticulously tailoring its form and dimensions to harmonize with the boat's distinctive characteristics and dimensions. This comprehensive endeavor encompassed a spectrum of wooden fishing boats, spanning 10, 20, and 30 Gross Tonnages (GTs), all prevalent within the maritime landscape of South Sulawesi. Across this tonnage range, the study meticulously determined the optimal dimensions and configurations of steel frames, poised to seamlessly take the place of their wooden counterparts. This calculated approach not only addresses the scarcity of traditional wooden materials but also promises to reshape the future trajectory of wooden boat construction in the region.

Introducing an innovative shift, Bochary *et al.*, [7] have brought forth the concept of substituting wooden frames with steel counterparts in traditional wooden boat construction. This novel approach has sparked enthusiasm among traditional wooden boat craftsmen, who are keen to implement steel frames in their boat crafting process. Eager to gain practical insights, they seek guidance on the fabrication and installation of these steel frames onto their boat structures. In response, a prototype combining wooden boat craftsmanship with steel framing has been meticulously crafted. Here, craftsmen engage in constructing the boat body, while the steel frame takes shape within the construction laboratory of Hasanuddin University's Naval Architecture Department. This study's primary objective is to delineate key techniques for seamlessly integrating steel frames into the wooden boat body, fostering a seamless fusion of tradition and innovation.

This paper presents its content through a sequence of sections, each contributing to a coherent narrative. It commences by delving into the composition of wooden boat construction components, aligning them with the Indonesian Classification Bureau's (BKI) guidelines. Subsequently, the traditional wooden boat construction practices of South Sulawesi are intricately portrayed, laying the groundwork for the subsequent installation of steel frames that adheres to these established sequences. The paper then provides a succinct overview of steel frames, a product of previous research, followed by a detailed exploration of their fabrication and integration onto the wooden boat body, highlighting a range of techniques employed. Proposing an innovative approach, the concept of incorporating steel frames into wooden boat construction is introduced. This sets the stage for a comprehensive discussion that critically assesses the process, weighing the merits and drawbacks of both the employed techniques and the novel approach itself.

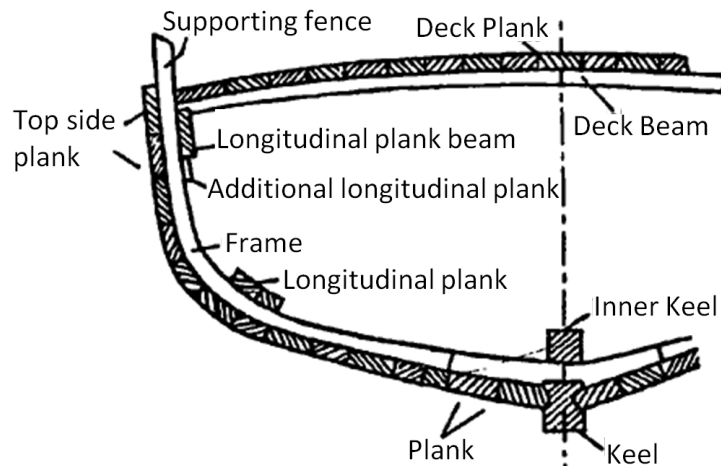
## **2. Wooden Boat Construction**

The regulatory framework for wooden boat construction in Indonesia is governed by the Indonesian Classification Bureau [1]. This directive encompasses wood type suitability, wooden strength, dimensions of construction components, and associated criteria. Approval by BKI surveyors is obligatory for wooden boats exceeding a certain length, entailing design endorsement prior to construction. However, the traditional wooden boat crafting in South Sulawesi deviates from formal regulations, as craftsmen rely on ancestral skills, crafting boats devoid of formal designs. Intriguingly, despite the absence of formal or informal shipbuilding education, these craftsmen create exceptionally resilient traditional wooden boats. Withstanding the test of time and serving various

functions [8], these boats have gained recognition as intangible cultural heritage by the United Nations Educational, Scientific and Cultural Organization (UNESCO) [9].

### 2.1 Wooden Boat Construction Component

A wooden boat body's construction consists of keel, stem and stern, frames, deck beams, planks, deck plank, longitudinal plank, and longitudinal plank beam (Figure 1).



**Fig. 1.** Wooden boat construction components [2]

- i. Keel – the central beam that runs along the bottom. The keel construction is the ship's backbone and thus supports most of the workload. It was connected to the stems at the fore and stern at the ship's rear. For small ships, the keel consists of only one continuous wood, while for larger ships, the keel consists of more than one continuous wood. Depending on the dimensions of the boat, an inner keel must be installed to support the keel construction [3].
- ii. Wooden plank – the arrangement of planks that stick to the boat's wooden frame. The planks are installed longitudinally from the boat stern to the stem.
- iii. Longitudinal plank – quite similar to the wooden plank, but they are installed longitudinally inside the boat body and stick to the inside part of the wooden frame. Depending on the boat's main dimension, three types of longitudinal plank will be installed on the wooden boat: longitudinal plank itself, additional longitudinal plank, and longitudinal plank beam [3].
- iv. Deck beam – deck beams are installed to the wooden boat construction to hold the deck plank. They are installed transversally from the end of the left wooden frame to the end of the right wooden frame. The deck beam connected the left and right wooden frames.
- v. Deck plank – located on the top of the deck beam. The deck plank is the top wooden construction installed on the wooden boat body in traditional wooden boat construction. Deck planks are installed longitudinally along the length of the boat body on the deck.
- vi. Frames – one of the wooden boat construction components which play a significant role in holding the boat body. Frames are the construction components with the wooden plank and the longitudinal planks attached. Besides, they hold the deck beam. Frames can be divided into single frames and double frames. Single frames consist of left and right frames connected with wrang. The double frames must be made continuous from the left to the right frame. In the middle of the frames, on the keel, the frame construction is to be higher than the single frames, but the height is the same with single frame wrang [3].

Traditional wooden boat frame construction has no base frame or opposite frame. Wooden frames must be selected according to the curvature of the boat body. According to the BKI Rules [1], the condition for the wooden frames in a wooden boat construction can be described as follows:

- i. The thickness of the frame in the boat engine room and the area around the boat mast must be increased by 20% of the required thickness.
- ii. The distance between frames can be measured between the middle part of the wooden frame's width.
- iii. The wooden frame dimension must be determined according to the BKI rules.
- iv. The wooden frames must be continuous along the length of the keel.
- v. For the curvature of the wooden frame, the selection of the wood is based on the woodgrain, in which the curvature follows the boat body curvature. If such wood cannot be found, the frame can be connected with other frames to make a single wooden frame according to the boat body curvature.

### **3. Traditional Wooden Boat Construction Process**

#### **3.1 The Boat Building Ceremony**

In the traditional boat-building process of South Sulawesi, three distinct stages shape the construction: wood collection from the forest, boat crafting in the designated area, and the ceremonial launch into the sea [10]. Amidst these stages, rituals and beliefs interweave, exemplified by the keel-cutting ceremony. Here, the keel's designated cutting point is chiselled and sanctified by an Anregurutta (a local holy figure) before being sawed by the craftsman's leader until replaced by others. Post-cutting, one keel segment is cast into the sea, while the other remains on land (Figure 2 and 3). Another belief dictates that all installed wooden components (frames, planks, etc.) must be of odd numbers, irrespective of the boat's dimensions. These rituals and convictions, distinct from modern shipbuilding, encapsulate the essence of the traditional process [10].



**Fig. 2.** Positioning and marking of the wooden keel for cutting



**Fig. 3.** Part of the keel which must be put in the sea

#### **3.2 Stages of The Wooden Boat Construction**

The wooden boat construction process is marked by sequential stages. Commencing with the keel laying, it advances to constructing the wooden stem and stern, succeeded by the installation of wooden plank lanes. Subsequently, the boat body takes shape through the installation of wooden frames, longitudinal planks, deck beams, and wooden deck planks. Within this traditional approach,

a focal point is the strength of the wooden planks, bolstered by the strategic installation of wooden and longitudinal frames at specific intervals [11-13].

### *3.3 Techniques for the fabrication and installation of wooden boat frames*

The installation of the wooden frame on the traditional wooden boat body begins with the boat body curvature pattern making using "singkolok" (local language – a traditional tool to mark patterns on a sheet of triplex). Based on the frame pattern, the selected wood with specific curvature then being cut using an ax. After being cut and chiseled according to the boat body curvature, the frame is refined before being installed on the boat planks using wooden pegs [14].

As the wooden frames required to follow the boat body curvature, the wood for the boat body frames became the most challenging material to find to compare with other construction components. The difficulty is worse with deforestation. Hence, wooden material, especially for the boat frame, is becoming more expensive. If the condition continuously happens, the sustainability of the wooden boat construction process in South Sulawesi is threatened [15]. To ensure the continuity of the wooden boat construction process, a material alternative for replacing some parts in the wooden boat construction components, especially wooden frames, is needed. The replacement process should be specifically on the inside of the boat construction components to maintain the wooden boat's characteristics.

## **4. Steel Frame for Wooden Boat**

Research has been conducted by Bochari *et al.*, [4-7] regarding alternative materials for wooden boat frames. In their research, steel has been selected to replace the wooden frame with some considerations. For example, they are easier to get, stronger than wooden material, and easier to bend according to the boat's body curvature. The form of the steel frame profile is T which is based on the consideration of the wooden boat construction duration process and connection method. The selected steel frame profile then being analyzed with various profile dimensions and distances between frames. The selection criteria are the wooden boat's strength. The result of their research is a steel frame recommendation in terms of steel frame dimension and the distances between frames for replacing the wooden frame in a certain tonnage of the wooden boat.

## **5. Traditional Wooden Boat Construction Process Using Steel Frames**

Techniques for installing the steel frames are adjusted according to the traditional wooden boat construction sequences. Since different materials are being used, the types of equipment for fabricating and installing the steel frame are also different. The required equipment is a welding machine, plate rolling bending machine and blender (cutting torch) machine. Based on this equipment, additional materials are required besides the steel plate itself, such as electrodes, LPG and oxygen gas.

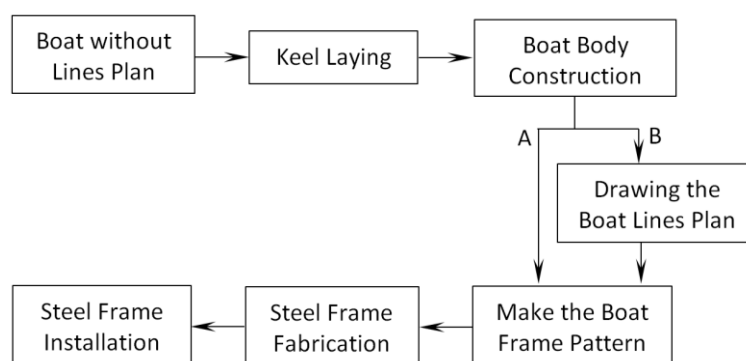
A welding machine is used to join the base plate, web plate, and face plate for holding longitudinal planks with the web plate. In this research, a 900-watt welding machine is being used for simplicity. A blender-cutting machine is used to cut the steel plate according to the marking on the plate, while a grinding machine is used to clean the remaining welding crust. The blender-cutting machine can make a hole in a steel plate for bolts and nuts. A plate rolling bending machine is used to bend the T profile based on the curvature pattern of the boat body. Besides, the line heating bending method can also be used for bending the base plate before connecting it to the web plate.

### 5.1 Technique for the Construction of Steel Frame on a Wooden Boat

The craftsmen conducted the traditional wooden boat construction process based on their knowledge and skill from their predecessors. They do not have any ship/boat design before the boat construction begins. Hence, to ease the craftsmen in applying the steel frame to replace the wooden frame on their wooden boat construction, the fabrication and installation process of the steel frame follow their traditional wooden boat construction sequences. In addition, by continuing to preserve the traditional wooden boat building method, Unesco's recognition regarding the traditional wooden boat building method as the intangible cultural heritage of humanity can be maintained.

Traditionally, the boat body is built before any frame is installed. The fabrication and installation of the steel frames to the wooden boat body had some difficulties since the ship lines plan to be used as a main basis for the frame pattern making did not exist. Hence, the technique and procedure for installing steel frames on the wooden boat body construction are essential and required. However, two techniques can be applied to install steel frames on the wooden boat body construction following traditional boat building sequences: technique A – without lines plan but with frames pattern and technique B – with lines plan.

Technique A is the technique of steel frame installation without any ship lines plan as a basis for the frame pattern making. In this technique, the frame pattern is measured and made directly according to the boat body curvature, while in technique B, the frame pattern can be made based on the lines plan design which has been made before. The lines plan design is made from the direct measurement of the boat body coordinate (Figure 4). In detail, the description of each technique can be seen in the following.



**Fig 4.** Techniques for the steel frame installation

#### 5.1.1 Technique A - without the boat lines plan

After the boat body is constructed without any frame (Figure 5), a frame pattern in each position must be made. The frame pattern will be the basis for steel frame construction. Frame patterns are made by measuring the boat body curvature in each frame position (Figure 6). The frame pattern making uses a simple traditional tool called “Singkolok” (a traditional tool for making frame pattern). With this simple tool, the boat body curvature can be printed in a sheet of triplex, roughly made according to the boat body curvature. Each frame pattern then be projected and marked on a sheet of plate. For the base plate, the plate bending according to the boat body curvature in each frame position can be done using a rolling bending plate machine.



**Fig. 5.** Part of constructed boat body without frame



**Fig. 6.** Frame pattern making

The detailed procedure for fabrication and installation of the steel frame with this technique can be described as follows:

- i. Determine the exact location of each frame.
- ii. Making the frame pattern for each frame position in a traditional wooden boat construction using “Singkolok” in a multiplex.
- iii. The frame pattern is then put on a sheet of plate.
- iv. Marking the frame pattern on the plate sheet (each frame requires two parts: base plate and web plate) according to the dimension and the frame form for each frame, including the position of the bolt.
- v. Marking the plate for the face plate (the number of the face plate is according to the number of longitudinal planks).
- vi. Cutting the plate according to the marking for each frame (cutting plate can be done using grinding or blender cutting machine and for each face plate for longitudinal plank).
- vii. Bending the base plate according to the required boat body curvature using a rolling bending plate machine.
- viii. Making a hole in a base plate for each bolt position (can be done using a blender cutting machine) – this process must be conducted outside the boat body to not damage the boat plank. This process must be conducted for the face plate as well.
- ix. Welding the web plate to the base plate for each frame.
- x. Welding the face plate to the frame
- xi. Primer painting the frame.
- xii. Marking the base plate for the bolt position.
- xiii. Marking the wooden plank for bolt position.
- xiv. Making a hole in the wooden plank for the frame position according to the bolt position.
- xv. Fitting and installation of the steel frame to the wooden plank in each frame position.
- xvi. Binding the base plate to the wooden plank using a bolt and nut for each frame.
- xvii. Installing the longitudinal plank on each frame.
- xviii. Installing the whole steel frames to the wooden planks.

#### *5.1.2 Technique B - with the boat lines plan*

Using a boat lines plan drawing of the boat body makes the frame pattern-making process more straightforward as the frame curvature formation only follows the curvature of the boat frame from the lines plan drawing. However, it requires an effort for the lines plan drawing since the boat does not come with the drawing. The lines plan drawing is made by directly measuring the boat body

curvature. Data from the direct measurement become the basis for the lines plan drawing, which then is translated into the plate frame. The prior design of a boat lines plan makes the process of marking, cutting, and bending the plate easier. The detailed procedure for fabricating and installing the steel frame with technique B is the same as technique A. The difference lies only in the boat lines plan making before the frame pattern can be made.

The comparison between the techniques can be seen in Table 1 below regarding the equipment, materials needs and the fabrication and installation method.

**Table 1**

Summary of the steel frame construction techniques

	Technique A	Technique B
<b>Equipment and materials needed</b>		
Singkolok	√	-
Triplex	√	-
Marking chalk	√	√
Blender cutting machine	√	√
Rolling bending plate machine	√	√
Bolts and nuts	√	√
Plate for the frame	√	√
Welding machine	√	√
Electrodes	√	√
LPG gas	√	√
Oxygen gas	√	√
<b>Fabrication and installation method</b>		
Boat Lines plane	-	√
Frame pattern	√	√
Marking plate	√	√
Rolling Bending Plate Machine	√	√
Welding	√	√

## 6. A New Approach to Wooden Boat Construction using Steel Frames for Traditional Craftsmen in South Sulawesi

In the previous section, it has been discussed the current approach of the traditional wooden shipbuilding method, which will apply steel frames on their wooden boat. The advantage of the current approach is that it is adjusted with the current traditional boat-building method so that the craftsmen can easily learn and apply the new techniques. Unfortunately, the level of accuracy for the steel frame installation is reduced as the steel frame construction from the steel frame pattern making, steel frame fabrication and the installation process is conducted based on the already constructed boat body. Hence, the frame must be made based on the current boat curvature.

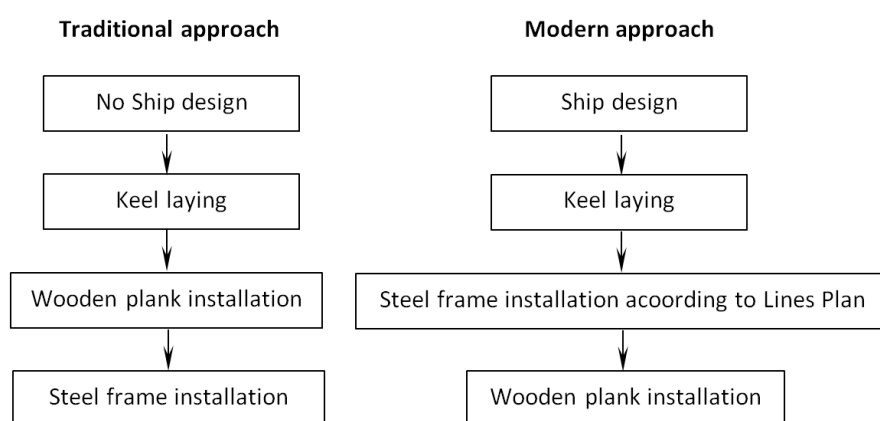
Based on the experience of building a wooden boat using steel frames for replacing the wooden frame, a modern boat-building process with steel frames can be proposed. If the current traditional wooden boat construction begins without any ship design and with the keel laying followed by wooden plank installation and wooden frame installation, the proposed approach follows the modern shipbuilding method. Ship design must be made before any construction process begins. From the ship design, the pattern for each frame will be easily identified, which will be the basis for the frame fabrication. The initial steel frame fabrication before the wooden boat body is formed will significantly change the wooden shipbuilding process as the steel frame will be installed before the wooden plank. The proposed approach follows the modern shipbuilding method. Figure 7 shows the



difference between the traditional and modern approaches based on the installation sequence of the steel frames.

## 7. Discussion

In general, the wooden boat craftsmen in Indonesia, especially in South Sulawesi, still uses traditional method in their wooden boat construction. The ship body construction started with the boat keel laying then, followed by shell plank installation, and ended with the making and installation of the wooden frame and the longitudinal plank. The boat frames are made according to the form of the respective boat body in the respective frame location. The boat's body form and dimension are made according to their experiences and traditional expertise inherited from their ancestor. Hence, the application of the steel frame in their wooden boat is conducted according to their traditional wooden boat-building method.



**Fig. 7.** Comparison of the boat building method between traditional and modern approach

Applying steel frames to replace the wooden frames on a wooden boat construction can be divided into two techniques, considering the traditional wooden boat-building method. A summary of the advantages and disadvantages of the proposed techniques, as explained in the previous section, can be seen in Table 2.

Selecting the more suitable technique for the craftsmen to build wooden boats with steel frames will depend on their respective skills. They need to consider the advantage and disadvantages of each technique, including additional effort to acquire the new skills. However, one important thing must be reminded that preserving the traditional skills in building the wooden boat must be maintained.

The significant advantage of applying steel frames to wooden boat construction, despite the total cost of installing steel frames on wooden boat construction being about 3% more expensive than wood frames [5], is; It solves the craftsmen's problem of scarcity of wooden frames, and it guarantees the sustainability of wooden boat construction in Indonesia, especially in South Sulawesi. However, the most important contribution is significantly reducing the tree cutting in the forest for wooden boat construction components [15].

**Table 2**

Advantages and disadvantages of the steel frame installation techniques

Technique	Advantages	Disadvantages
A	<ul style="list-style-type: none"> <li>- It does not require specific skills for lines plan drawing</li> <li>- Convenient position for the welding process</li> </ul>	<ul style="list-style-type: none"> <li>- Difficult, require more time and effort for frame pattern making</li> <li>- Require welding skill</li> </ul>
B	<ul style="list-style-type: none"> <li>- More effective for frame pattern making</li> <li>- Convenient position for the welding process</li> </ul>	<ul style="list-style-type: none"> <li>- Require specific skills for lines plan drawing</li> <li>- Require welding skill</li> </ul>

## 8. Conclusion

Incorporating steel frames into wooden boat construction introduces a range of techniques tailored to the traditional shipyards of South Sulawesi. This adaptation ensures efficient skill acquisition despite inherent method limitations. Notably, the proposed techniques bridge modern shipbuilding methods with traditional practices, promoting an innovative blend. However, paramount is the preservation of the craftsmen's traditional boat-building skills, devoid of formal designs, which safeguards the continuity of their revered expertise. This symbiotic approach encapsulates the essence of both innovation and heritage, upholding the delicate equilibrium between modernity and tradition.

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