# Designing safe, green and sustainable vessels for Indonesian coastal transport and fishing operations

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**Abstract.** Indonesia is the world's largest archipelago state with 17,508 islands, of which 6,000 are inhabited. This makes sea transportation a major part of people's everyday lives. Furthermore, fishing is extremely important for Indonesia with around 6.4 million people engaging in fishing activities. However, a significant amount of the current fishing fleet is outdated and could be improved to become more efficient and safer to operate. Currently, 28% of fishing boats in use are non-powered boats and 39% are propelled by an out-board engine. Through a detailed understanding of the unique needs of Indonesia and the requirement for the development of sustainable, safe and efficient designs, the capacity of sea trade can be increased, to enhance the current economy and living conditions. This paper outlines the framework and early results of a joint research project (SUVESIN) funded by the British Council's Newton Fund scheme. The SUVESIN project brings together two reputable research institutions, the University of Strathclyde, Glasgow and Institut Teknologi Sepuluh Nopember, Surabaya to achieve the design of safer and more efficient vessels with renewable and locally available raw materials in Indonesia. Within the project, the gap analysis, identification of needs, requirements and opportunities on a renewable and sustainable raw material for Indonesia's ship industry have been carried out. The background of the project and the early results, including gap analysis, a modern construction process for Indonesia's ship industry and preliminary results of optimisation of the traditional Indonesian ship are presented in this paper.

## 1. Introduction

Indonesia is the world's largest archipelago state with 17,508 islands, of which 6,000 are inhabited. This makes the sea transportation part of people's everyday live. A fleet of outdated passenger transport vessels is being used nowadays. The severe deforestation is a big problem in Indonesia and 1,315,000 hectare forest was reported to be lost annually [1]. It makes the wood and wood product more and more rare and expensive. It is a big crisis for boat industry in Indonesia whose majority of passenger and fishing boats are made in wood. Thus, there is a need to find alternative materials to be used in boat building. Fiberglass is also used in the boat-building industry in Indonesia. However, it leads to environmental pollution, so its use should be minimised. A recent work of Supomo et al. [2] indicated that bamboo would be an ideal material to replace the traditional use of teak wood in the construction of small fishing/transport vessels in Indonesia. Bamboo is widely available in tropical and subtropical regions. It has been widely used in many

areas since the ancient time. It can be used as a construction material after 3 to 4 years' growth, which is 8 years lesser than teak wood [2]. therefore, among all the alternative materials, bamboo has a high potential to be used in boat building given that is safe, cheap, abundant availability and sustainability.

Furthermore, some traditional transportation and fishing ships have taken service for a long time, the hydrodynamic performance, operability analysis and life cycle assessments of these traditional ship haven't been tested and optimised. These are necessary to carry out for these ship in the near future, so that the efficiency and performance of these types of ship could be enhanced. Such a large-scale optimisation requires an extensive study encompassing all aspects of ship design, such as hydrodynamics, structure, manufacturing and construction. In the SUVESIN project a through optimisation study will be performed using various numerical and experimental methods.

Through better understanding of the unique needs of the country and developing sustainable, safe and efficient designs, the capacity of sea trade can be increased, hence, the current economy and living conditions of people can be enhanced.

In this paper, a detailed gap analysis will be performed for this research. The review of the traditional transportation ship in Indonesia, a Phinisi, will be discussed. The deforestation issue and alternative material for shipbuilding industry in Indonesia will be studied. The key issues including skill gaps, safety of operation, decommission and recycle will also be investigated. Finally, the preliminary results on the identification of renewable raw materials, and development of improved construction framework will be presented.

## 2. Common types of vessels currently used in Indonesian maritime transportation

Wooden ships as marine transportation means are still chosen and preferred by most Indonesian people. Aside from being a mode of water transportation (mostly in the sea), wooden ships are also widely used as means of catching fish in the sea. Starting from the time of the kingdom of the archipelago until to date, fishing boat made from solid woods are still widely used by Indonesian fishermen. Reality in everyday life proves that majority of the population of fishing vessels found in various Fish Landing Sites (TLS) in Indonesia are made from solid wood.

One of the most common type of vessels that can be found in the Indonesian waters is a boat called Phinisi. Phinisi is a traditional Indonesian two-masted sailing ship. It was mainly built by the Konjo tribe, a sub-ethnic group of Bugis-Makassar, mostly residents at the Bulukumba regency of South Sulawesi, but was, and still is, used widely by the Buginese and Makassarese, mostly for inter-insular transportation, cargo and fishing purposes within the Indonesian archipelago. The hull of the ships looks similar to that of a dhow while the fore-and-aft rigging is similar to western schooners, although it might be more correctly termed to resemble a ketch, as the front mast is the larger. The large mainsails differ from western style gaff rigs though, as they often do not have a boom and the sail is not lowered with the gaff. Instead, it is reefed towards the mast, much like a curtain, thus allowing the gaff to be used as deck crane in the harbor. The lower part of the mast itself may resemble a tripod or is made of two poles. Phinisi may be 20 to 35 meters long and 350 tons in size. The masts may reach to 30 meters above the deck [3] [4] [5]. Fig. 1 shows a typical Phinisi ship.

The Indonesian Government recognises the Phinisi type of boat plays an important role in supplying the small islands, though the development of such boats leaves a lot to be desired. These Phinisi boats are designed to carry from 300,000 to 500,000 tons of cargo to small islands.

The traditional ship, Phinisi plays an important role in local population's everyday life. The existing Phinisi ships are made from wood. However, we believe that Phinisi ship must be constructed by using laminated bamboo slats to overcome the wood resource exhausted in the near future. In addition, our investigations have shown that the Phinisi hull form has not been thoroughly optimised. In the SUVESIN project we will perform an optimisation analysis incorporating the hydrodynamics and operability of the boat as well as the life cycle assessment of this traditional vessel. The SUVESIN project aims to systematically investigate and improve the performance and

safety of Phinisi ships in a sustainable manner through testing new materials, ensuring recyclability, improving hydrodynamic performance and operational safety.

**Figure 1 A traditional Phinisi ship in Indonesia [6]**

## 3. Deforestation and alternative material for the shipbuilding industry in Indonesia

High population and the fast industrialisation causes serious environmental problems to Indonesia. These are often given a lower priority due to high poverty levels and weak, under-resourced governance. Large-scale deforestation in Indonesia, most of which are illegal, involves the long-term loss of forests across much of the country. It has had massive environmental and social impacts in Indonesia. Since wood is used as a raw material in shipbuilding industry for a long history and still widely needed in the modern society, the deforestation issues led to a scarcity of raw material for the shipbuilding industry in Indonesia. This fact is very disturbing for shipping, transportation and marine fishery communities. It was due to the government policy of Forest Management Rights (FMR) to the private companies. The implementation of this policy has led to the massive exploitation of forest wood took place between the decade of the 1980s and 1990s.

The fact of as high as 98% of forest loss in Indonesia was caused by deforestation in the region of high density forests of the islands of Sumatera, Kalimantan (Borneo) and Sulawesi (Celebes), i.e. locations in which the forest conversion occurs as a result of industrial tree plantations. Extensive development of oil palm plantations is very dramatic happens during the last two decades. Riau Province in Sumatra Island was ranked the highest in terms of the destruction of forests for oil palm plantations [7].

The above situation has caused the following consequences in Indonesia: [8] 1) the price of wood is more expensive (currently IDR 30 million/m3), 2) type of wood that is no longer varied and lead time of wood procurement tends to be much longer, 3) the personal/individual ship-owner is less likely to build wooden ships due to uncertainty in quality, procurement time and price of woods, 4) government projects being transferred to a vessel made of GRP because of the difficulty in obtaining wood materials, 5) many fishermen are still unsure of the materials other than wood because it does not float well at sea, lake, or river, and then 6) many SMI traditional wooden shipyards are collapsed.

Based on these facts it is considered necessary to carry out a research of new materials as an alternative to wood as a material for fishing boat building. These alternative materials should be inexpensive, strong, malleable, renewable and environmentally friendly. Before making further discussions about alternative materials, some of the materials used in the shipbuilding industry should be reviewed. The materials in question include solid wood, steel, aluminium, fiberglass and ferro cement. However, this type of materials is mostly expensive and less applicable to traditional vessels which tend to be small in size.

Various materials have been used in ship construction. There are a number of disadvantageous for these materials, namely:

1) FRP (Fiberglass Reinforced Plastic) – still not fully accepted by the majority of fishing communities in Indonesia;

2) CRP (Carbon Reinforced Plastic) – strong construction but costly and could only found by importing;

3) COCO Fibre Reinforced Plastic – still in the stage of tension test and has not been implemented in ship construction;

4) Ferro Cement – fishermen are afraid to use it because of the impression of heavy construction;

5) Bamboo Fibre Reinforced Plastic – still in the stage of strength examination and has not been implemented in ship construction.

It has found its use in other engineering fields, such as civil constructions. For this reason, the use of bamboo for shipbuilding is the key motivation for SUVESIN.

The experience gained from the use of bamboo in housing construction has shown that it is necessary to consider global excess of bamboo as materials for fishing vessels. The key features of bamboo are given as follows: 1) bamboo has a lot of types and variation; 2) bamboo population spread almost throughout the country; 3) planting and care of the bamboo plant is easy to do; 4) the growth of some bamboo species can reach 30 ~ 100 mm per day [9]; 5) bamboo with only 3-year of age could be ready to be used as a construction material; 6) prices are relatively cheap compared to wood; and 7) sufficient mechanical properties as construction material.

Based on surveys in several locations in East Java, it can be said that the spread and availability of bamboo is very abundant, both in terms of type and quantity. Ori species of bamboo (Bambusa arundinacea) is widely spread in the lowlands (0 ~ 300 masl) in almost all the paddy fields outskirts. While bamboo of Betung type (Dendrocalamus Asper) spreads only in the highlands (350 ~ 700 masl) and is available in almost all the slopes of the mountain in East Java. Two types of bamboo are trusted by the community and has been for generations used as the building material and handicrafts.

Based on the above factual argument it would be extremely important to further investigate bamboos in terms of academic and practical purposes. From an academic point of view, there is not much research dedicated to the use of bamboos in ship building. Without a doubt, academic studies will stimulate the applications of bamboos in the industry.

The problems of SMI traditional shipyard whose products are mostly fishing vessel faces several obstacles ranging from raw material (solid wood), labour, equipment, to marketing the product ships. The main problem actually lies in availability of wood as the raw material for boat building, but it is also strongly associated with government regulation which was relatively late to be applied to limit deforestation and its environmental impact. Given that many fishermen have long faced difficulties in connection with ship construction time schedule, vessel quality, vessel prices, and competition in fishing boat production, it is necessary to look for alternative solutions so that some of the problems faced by SMI traditional shipyards can be reduced or even eliminated.

## 4. The key issues to be addressed towards a sustainable ship building practice in Indonesia

**Skill gaps.** There are lots of traditional shipbuilding companies based in Indonesia. Most of them are still using outmoded methods to construct ships. It will lead them to build unqualified ships and let the ship building process inefficient. In addition, the current ship construction skills cannot deal with the modern ship constructions and the alternative renewable and sustainable raw material for shipbuilding.

Another area is the current skill base. There is a lack of sufficient skills in design construction and operation of ships in Indonesian maritime sector. If an alternative material such as bamboo will be used for building new boats in Indonesia current skill base needs to be trained and brought up to the standard. In SUVESIN project, the current skill gaps will be further analysed and bridged.

**Safety of operation.** Fishing is a labour intensive and difficult job, which generally attracts workers from the less privileged parts of the society. Most of them work under harsh conditions with vessels not completely fit for purpose. When this is combined with the absence of safety culture and low education levels amongst fishermen the condition becomes even worse [10]. It is reported that 143 people lost their lives from 16 shipping casualties in Indonesia during 1996 to

2005 [11]. This has a dramatic negative impact on the safety and as a result, the most of maritime accidents occur in fishing vessels globally and many lives are lost every year [12].

This is not surprising as these vessels are built based on traditional practices and the current advances in knowledge and the relevant regulations are not always implemented in design, construction and operations. Similarly, small vessels are utilised for island transportation, where the same factors, including safety culture, training, inappropriate vessel design, and lack of understanding of the operational conditions may lead to bigger catastrophes with higher number of fatalities.

Therefore, in order to ensure safety and efficiency of maritime operations further attention should be given to provide training and practical guides to human on board who are day to day involved in managing these vessels. It will have enclosed in the present project.

**Decommission and recycle.** Ship decommission and recycling is a process that take apart of a ship, dismantling and reuse of the materials and components. The activity of decommission and recycling ships could date back to the existed of ship building. It further emerged as an industry since the industrial revolution. Nowadays, ship decommission and recycling is primarily performed in developing countries (such as Indonesia) as a heavy industry for their high demands on the reuse of the scrap metal and second hand equipment [13] [14].

The typical operations of ship decommission and recycling in the developing countries, such as Indonesia, are labour intensive. The workers involved in this activity have been observed being exposed to a variety of hazards materials [15] [16]. It could lead to unexpected accidents, illness of workers and even death [17].

International organisations such as the International Maritime Organisation's (IMO) Hong Kong convention, which is the International Convention for the Safe and Environmentally Sound Recycling of Ships [18] and the European Commission's Ship Recycling Regulation [19], are actively establishing a framework of improve the legislative efforts on relevant issues. Table 2 listed items of hazardous materials during the ship decommission and recycling process from the IMO which should be alertness during relevant activity in the developing countries. During the design and optimize process of the present project, the usage of items listed in Table 2 should be avoided. In addition, the alternative material we used in the present project should be recyclable.

In Indonesia, workers come from lowers ranks of society and they are not educated to handle hazmat. Their safety awareness is also very low. There skill gaps in recycling yard will be enclosed in the present project.

Therefore, materials that we use on new building should be recyclable and usage of hazmat on ships should be avoided. Specific focus of this project should be given to the design for recycling concept.

## 5. Gaps analysis study

As discussed and analysed above, the results of our gap analysis study are presented in Table 1The table summarises the gaps identified in this area, explains how these gaps will be addressed in the SUVESIN project and relates each gap to a specific work package of the project. The impact column of the project rates the expected impacts of the project from low (L) to high (H), where M refers to a medium impact.

**Table 1 Gaps analysis table**

| Gap identification | How they will be addressed in this project | Impacts | Work Packages Relations |
|---|---|---|---|
| Identification and detailed analysis on a renewable and sustainable raw material for ship industry in Indonesia is necessary | Identification and detailed analysis on a renewable and sustainable raw material for ship industry in Indonesia will be carried out | H | WP3 |
| Insufficient modern construction process for ship industry in Indonesia | Modern construction process for ship industry in Indonesia is necessary to be designed | H | WP3 |

| | | | |
|---|---|---|---|
| The hydrodynamic performance of traditional transport/fishing boats hasn't been tested and optimised | Tests and optimisation of the hydrodynamic performance of traditional transport/fishing boats need to be identified | M-H | WP4 |
| Insufficient operability analysis of traditional transport/fishing boats | Operability analysis on traditional transport/fishing boats need to be carried out | M-H | WP5 |
| Insufficient life cycle assessment of traditional transport/fishing boats | Life cycle assessment on traditional transport/fishing boats need to be carried out | M-H | WP6 |
| Insufficient of skilled technicians in Indonesia | Provide public engaged training module for Indonesia | M-H | WP7 |

## 6. Preliminary results on the identification of renewable raw materials, and development of improved construction framework

A preliminary study on the utilisation of laminated bamboo as an alternative material for construction of fishing vessel by the method of cold press planking system (CPPS) has been conducted. The key findings are listed below:

- Based on the examination on its implementation to manufacture laminated bamboo slats, the most appropriate glue in term of the adhesiveness and strength is Epoxy Polyamide.
- Results of the mechanical tests, covering the tensile and flexural strength, suggests two (2) types of bamboo suitable for fishing vessel construction are Ori bamboo (Bambusa Arundinacea) and Betung bamboo (Dendro Calamus Asper). Ori bamboo holds the characteristic tensile = 160 MPa and flexural = 84 MPa, while Betung bamboo holds tensile = 140 MPa and flexural = 84 MPa. These two types of bamboo exceed the specific strength of solid teak wood of class II (KK II), widely used in fishing vessel building, characterized by tensile = 78 MPa and flexural = 55.4 MPa.
- Bamboo slat will meet the requirement of permissible stress for fabrication if it is produced from bamboo trees, either Ori and Betung, harvested $\geq$ 3 year.
- Longevity experiment with salinity variations (25pbm, 30pbm, 35pbm) yields the strength increase at every two (2) weeks interval at the rate of averagely 0.23% and 0.25%, respectively, for Ori and Betung bamboos. However, the increase rate lessens at the period of $\pm$ 16 weeks and tend to become constant afterwards.
- The use of laminated bamboo as alternative material for fishing vessel building is potential for developing innovative green industry and promoting sustainable environment.

One of the primary contribution drawn from this research programme so far is the results of the analysis on the strength and durability of laminated Ori and Betung bamboos in the seawater environment as an alternative material for fishing vessel construction. Elaboration on the advantages and drawbacks of laminated bamboo slats is expected to enrich scientific and practical knowledge in fishing vessel building, through the revelation of distinctive production method as well as the economic considerations.

## 7. Concluding remarks and future work

After the systematic gap analysis and initial research as shown above, the following conclusions have been made for the on-going SUVESIN project.

As coastal communities are living on the small islands in Indonesia, they require logistics from the larger islands. Large modern ships are not appropriate to provide logistics for such small islands. These large ships are not able to provide service to the small islands for many reasons, with a major reason being their size. These islands are very small and the water around them is very shallow, which makes the operation of large vessels almost impossible. Therefore, all the loads are on small traditional boats' shoulders. These small boats currently meet the small islands' needs by carrying cargo to them. Moreover, local people do not easily accept new designs, so they are stuck with their

traditional boats. They believe that new boat designs may bring bad luck. These cultural beliefs, of course, have an effect on design requirements for the present project and research.

Most traditional boats are made from solid wood. However, a scarcity of wood is increasingly becoming a real problem in Indonesia. If any solution is sought, it is obvious that in the near future the construction of new traditional boats would be in trouble. The use of a sustainable and locally available material could replace the use of wood in traditional boats. Bamboo shows its high potential among all alternative materials. Bamboo is a fast-growing material, and there is a vast amount of bamboo grown in Indonesia, which deserved a further research on its application in the boat building industry.

A preliminary study on the utilisation of laminated bamboo as an alternative material for construction of fishing vessel by the method of cold press planking system (CPPS) has been conducted. The results of the analysis on the strength and durability of laminated Ori and Betung bamboos in the seawater environment as an alternative material for fishing vessel construction could be confirmed. Elaboration on the advantages and drawbacks of laminated bamboo slats is expected to enrich scientific and practical knowledge in fishing vessel building, through the revelation of distinctive production method as well as the economic considerations.

The outcome of this research project is to develop a new design concept which will be made freely available to all interested stakeholders in Indonesia, including designers, boatyards as well as local fisherman who build their own boats. This will accelerate the industry take up. In the long term these new vessel designs are expected to improve the fishing operations which will result in safer and more efficient transportation. Without a doubt, in the long term this will have a positive impact on the economic development and social welfare of the country. The framework of this project will be delivered to the Indonesian partner institution in order for them to apply the design, construction and operations framework to other vessel types.

The realisation of ambitious aim of this project will depend on the successful engagement with the entire local stakeholders. Therefore, in this project utmost importance will be given to attract our stakeholders though continuously utilising public engagement events and dissemination activities. Newsletters will be published periodically to disseminate project findings throughout the project lifetime. We will be publishing freely available reports for all interested stakeholders through our webpage and we will aim to collect feedback. We will utilise social media to engage with the public and we will trigger discussions through our social networks. Moreover, the findings of this project will also be converted into training materials, which will be delivered to small vessel operators to improve their understanding of the behaviour of their vessel considering different operational conditions. Specific attention will also be paid to increase operator's safety culture. After the completion of the project the impact will be closely monitored through measuring the industry uptake. In order to achieve this, in the short term the stakeholders will be interviewed to capture their views on the potential impact of this project. Moreover, the number of members in our social networks and the number of visits to our webpage will be monitored through Google analytics. In the long term the measure of impact will be a reduced number of accidents, increased productivity in fisheries, less fatalities, increase in passenger satisfaction, and increased levels of operability such as able to operate in rough seas without being exposed to high risks.

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