Sustainable Fishing Vessel Development by Prioritising Stakeholders Engagement in Indonesian Small-Scale Fisheries

By

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Abstract

The attempts to achieve the sustainability of fisheries sector are affected by the existence of the fishing fleets as the principal tool for fishing activities. This thesis reports on research to develop a holistic methodology for ensuring that fishing vessels working in Indonesian waters are themselves sustainable, accordingly it can support the achievement of sustainability of Indonesian fisheries sector.

A sustainable fishing vessel can be simply defined as a vessel that fulfils the requirements of the three pillars of sustainability regarding the social, economic and environmental aspects throughout its life cycle. Based on the requirements for the sustainable fishing vessels, and by considering the conditions of most fishing communities in Indonesia, this research project is aimed at proposing an appropriate approach and method to the design of fishing vessels for specific fishing communities, in order to ensure that the implementation of the three pillar of sustainability are considered during the design process.

The proposed approach to design a sustainable fishing vessel for a specific fishing community has been developed and tested through a case study in a selected fishing community. An 18 meters length multi-purpose fishing vessel has been designed for fishing community in East Java, Indonesia. In order to increase the acceptability of the proposed vessel, local fishers' requirements concerning the new design have been elicited. The aesthetic characteristics of traditional fishing vessels and current fishing practices have been adopted and adapted. Furthermore, in order to ensure that the proposed vessel fulfils the requirement for a sustainable fishing vessel, the technologies that can be applied on-board have been assessed in terms of their social acceptability, economic viability and their potential negative impact to the environment.

The results of Focus Group Discussions to have local fishers' views and feedback regarding the proposed design, showed excellent responses from the local fishers. The results show that the initial approach by carefully considering local fishers requirements and conditions without ignoring the potential improvement in the future is the appropriate approach to design fishing vessels for specific fishing communities in Indonesia.

For Warma and Andra

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List of Abbreviations and Symbols

Abbreviations:

AC = Alternating Current
AHP = Analytical Hierarchy Process
BKI = Biro Klasifikasi Indonesia (the Indonesian Classification Bureau)
BOBP = Bay of Bengal Programme
CSW = Chilled Sea Water
CUNO = Cubic Number
DANIDA = Danish International Development Agency
DC = Direct Current
FADs = Fish Aggregating Devices
FAO = Food and Agriculture Organisation
FGDs = Focus Group Discussions
FMAs = Indonesian Fisheries Management Areas
FRP = Fibre Reinforced Plastic
FSM = Free Surface Moment
GA = General Arrangement
GDP = Gross Domestic Product
GHG = Greenhouse Gas
GPS = Global Positioning Systems
GT = Gross Tonnage
IEEZ = the Indonesian Exclusive Economic Zone
LCA = Life Cycle Assessment
LCI = Life Cycle Inventory
LCIA = Life Cycle Impact Assessment
LPG = Liquefied Petroleum Gas
MDGs = Millennium Development Goals
MMAF = Ministry of Marine Affairs and Fisheries
MSY = Maximum Sustainable Yield
MCDM = Multi-Criteria Decision Making
RFLP = Regional Fisheries Livelihoods Programme for South and Southeast Asia
RSW = Refrigerated Sea Water
SDGs = Sustainable Developments Goals

SFIA = Sea Fish Industry Authority

TAC = Total Allowable Catch

UN = United Nations

WCED = World Commission on Environment and Development

Symbols:

B_B = Breadth of basis vessels

B_D = Breadth of design vessels

D_B = Depth of basis vessels

D_D = Depth of design vessels

f = Inflation rate

Fb_B = Freeboard of basis vessels

FV = Future value

GZ = Righting lever

L_B = Length of basis vessels

L_D = Length of design vessels

PV = Present value

NPV = Net present value

$PV\,(B)$ = Present value of benefit

$PV\,(C)$ = Present value of cost

t = year

T_B = Draught of basis vessels

T_D = Draught of design vessels

W = pairwise comparison matrix

Declaration

Except where references are made to the works of others, I declare that the contents of this thesis are my original research work.

Chapter 1. Introduction

1.1 Background

The fisheries sector, which provides employment for millions of people and sustains the livelihood of another hundred million people globally, has a significant role in ensuring food supply security and is an economic driver for many countries worldwide. The existence of this sector particularly in relation to the welfare of current and future generations is believed to be in a perilous situation if little or no effort is made to manage the exploitation of the fish stock in a sustainable way (FAO, 1995).

Indonesia, where the fisheries sector has likewise become the principal source of revenue for a large number of coastal communities is presently confronted by similar challenges related to the fisheries sector. The numerous challenges faced by local fishers related to fish stocks and moreover to their fishing vessels have raised concerns in connection with how the Indonesian fisheries sector might survive in the future and continue to provide benefits, not only for current generations but also for future generations.

As the largest archipelagic country in the world, Indonesia has enormous potential in relation to their fisheries sector. The country which is located in Southeast Asia, as seen in Figure 1.1, is bordered by Malaysia and Singapore to the north, Papua New Guinea to the east and Australia to the south, and consists of approximately 17,499 islands, of which 4,038 have not yet been named. These vast numbers of islands collectively have approximately 99,093 km of coast line and are surrounded by 284,210.9 km^2 of territorial waters, in addition to 2,981,211 km^2 of the Indonesian Exclusive Economic Zone (IEEZ)(MMAF, 2014b). Indonesian waters include the second largest coral reef in the world covering approximately 18% of the world's total area related to coral reefs. As a part of the coral "triangle" that stretches from the South China Sea to the Timor and Solomon Seas, Indonesia's coral reef is considered to be the most diverse coral reef in the world in terms of biodiversity (Worldfishing, 2014) and it is therefore, a perfect habitat for a wide spectrum of marine life including an enormous variety of fish.

Figure 1.1 Map of Indonesia
(source: https://www.google.co.uk/maps)

The extensive seas around Indonesia provides far-reaching benefits for the country, both from renewable and non-renewable resources. The potential advantages from non-renewable resources, come from, for instance, petroleum and natural gas, while the potential benefits from renewable resources include tidal energy, wind energy, ocean thermal energy conversion, mangrove, coral reef and, moreover, fish resources (MMAF, 2010). Among these potential resources, fish resources have been exploited for extensive periods of time spanning centuries and have been supplying a considerable amount of benefits for Indonesia, especially on behalf of the coastal communities.

The production of the capture fisheries in Indonesia over the last few decades, demonstrates the potential of this sector to be a prime mover in relation to Indonesian national development. According to the Food and Agriculture Organisation (FAO) of the United Nations, Indonesia is one of the foremost nations in the world with regards to capture fisheries. In 2014, the country was placed second behind China regarding total production per year (FAO, 2016). In addition to benefitting the nation in terms of economy by contributing to the national Gross Domestic Product (GDP), this vast fish production also influences the food supply security for the Indonesian people. In their report in 2014, the FAO identified that Indonesia is among many countries worldwide that consume fish, in order to obtain more than 50% of their animal protein needs (FAO, 2014).

Notwithstanding the substantial national production generated by the capture fisheries, the average annual production by individual fishers is in fact relatively low. Data from the Indonesian Ministry of Marine Affairs and Fisheries (MMAF) in 2014 demonstrated that the average annual production provided by individual fishers in Indonesia was only 2.3 tonnes (MMAF, 2014b). This is significantly different when compared to fishers in Europe and in North America who, on average, can catch approximately 24 and 18 tonnes annually individually (FAO, 2010). The significant national fish production in contrast to the low productivity from individual fishers' explained the enormous number of people engaged in this sector and also revealed that most fishers in Indonesia are principally engaged in small-scale fisheries.

In fact, there are substantial numbers of fishers who depend on the fisheries sector for their livelihood. Based on *the Indonesia Marines and Fisheries in Figures 2014*, there were in the region of 2.7 million fishers along the Indonesian coastline (MMAF, 2014b). The vast potential in fish resources coupled with the relatively low skill requirement to be a fisher in conjunction with challenges in finding a suitable job onshore are the main reasons for the significant numbers of people, coastal communities in particular, relying on fishing for their living. If on-shore fish workers involved in this sector are included, the total number of people engaged in this sector in Indonesia will be significantly higher. In 2012, there were nearly 12 million fishers and fish workers involved in the fisheries sector in areas such as harvesting, processing catches and other related supporting activities (Malau, 2012).

Concerning the level of productivity of the Indonesian fishers, the MMAF in their strategic plan for 2010 - 2014 stated that one of the main reasons for the low productivity of the fishers in most fishing communities in Indonesia is due to the condition of their current fishing vessels. The Indonesian fishing fleet is dominated by small fishing vessels up to 3 GT (MMAF, 2010). The weaknesses of the current fishing boats according to MMAF are, among others, fishing trips that are of a short duration typically of only one day or less and a low level of technology installed on-board.

Conversely, the operational costs of the boats have been increasing recently, in particular the cost of fuel, as a result of the increase in the fuel price nationally. This that influences the duration and the distances that fishers can undertake to travel during their fishing trips, due to limitations in finance to cover the operational cost. The low individual fishers' production and the increasing operating costs have been responsible for reducing the fishers' profit (MMAF, 2010).

The problems on the fishing vessels are exacerbated by the condition of the fish stocks in most of the traditional fishing grounds in Indonesia. Given that the fishers operate small fishing vessels with a relatively low level of technology on board and fish over a short period of time, which is only a day or less, their regular fishing grounds are quite close to the coastline and their community base. In many fishing communities, fishers normally only go fishing out to a distance less than 3 miles or a maximum of 12 miles from the shoreline. Hence, the enormous numbers of fishing boats that operate in these limited fishing grounds have increased the pressure on this area of water and its resources, and furthermore, have ultimately led to overfishing in many traditional fishing grounds. It should be noted that nearly all of the fishing grounds in Indonesia have experienced over-exploitation and fully-exploited states (Heazle and Butcher, 2007; Patlis, 2007; Ainsworth *et al.*, 2008; MMAF, 2011a; MMAF, 2014b).

These aforementioned circumstances are believed to be among the reasons for the poverty that most fishers and their fishing communities in Indonesia have been confronted by (MMAF, 2010; Zamroni and Yamao, 2011; Wekke and Cahaya, 2015).

Based on the above description, the fisheries sector clearly has a very significant role to play regarding the development of Indonesia, given that it may well ensure food supply security for the public, principally for those at a lower economic level, as fish remains affordable for them. Moreover, it could become the solution for poverty alleviation for almost 12 million fishers and fish workers along the extensive Indonesia coastline. However, the fishers continue to be confronted with many problems, as mentioned previously, and which might endanger the continuity of this sector being the main livelihood of the coastal communities as well being one of the contributors relating to Indonesia's GDP.

As stated in The Code of Conduct for Responsible Fisheries, FAO (1995, p4);

> *"Fisheries management should promote the maintenance of the quality, diversity and availability of fishery resources in sufficient quantities for present and future generations in the context of food security, poverty alleviation and sustainable development"*

Therefore, well-structured attempts to overcome the aforementioned problems should be conducted by the Indonesian government, working with all stakeholders in fisheries; otherwise, the fisheries sector in Indonesia may collapse and endanger the livelihood of the millions of people that engage directly and occasionally in the fisheries sector.

In order to ensure the continuity of the fisheries sector in Indonesia in the future, several aspects that support the achievement of a sustainable condition within this sector need to be developed. One of the many aspects which plays a significant part in supporting the sustainable development of the fisheries sector in Indonesia is the existence of the Indonesian fishing fleet. As the main tool for fishing activities in capture fisheries, the state of the fishing vessels will affect the productivity of the fishers and thus, the potential profit that they can obtain. At the same time, it can influence how sustainable the fishing practices are, which are employed to catch the fish, so as to ensure the sustainability of the fish stocks. For that reason, it is very important to develop fishing vessels that can support the sustainability of the fisheries sector in Indonesia.

The Indonesian government has established many programmes to aid in the development of the Indonesian fishing fleet in the last few decades. However, before 2010, the government's efforts to improve the national fleet were mostly limited goal programmes related to the application of specific technology for traditional fishing boats, for instance by granting fishing gear, fish storage boxes or outboard engines to groups of traditional fishers. Although the government's assistance was only partial, the advantages of these programmes were quite significant in relation to the fishers' productivity. For instance, the motorisation of traditional fishing vessels that started at the beginning of the 1970s, usurped sails and oars as the main method of propulsion for the vessels and as a result boosted the productivity of local fishers (Suadi, 2006; Rosyid, 2015).

Given that the high demand load on the artisanal fisheries is considered to be one of the principal reasons for the depletion of fish stocks in many traditional fishing grounds, the Indonesian government established policies to reduce the demands on the exploitation of fishing grounds that are close to the coastlines by encouraging fishers to fish further into the Indonesian Economic Exclusive Zones (EEZs) potentially up to 200 miles from the shoreline. For that purpose, massive programmes for restructuring the Indonesian fleet were introduced by the Indonesian government in 2010 - 2014. These policies were implemented by offering 30 Gross Tonnage (GT) fishing vessels for collective use by groups of fishers in every province, in the form of a grant. A number of them were built with FRP and equipped with more modern technology, such as Fish Finders, Global Positioning System (GPS) and solar panel systems.

Until the end of the programmes, 878 fishing vessels (out of a target of 1000 fishing vessels) had been built and granted to fishing communities in more than 200 districts in Indonesia. Most of the boats have a capacity of 30 Gross Tonnage (GT), as planned at the beginning of the programme. However, in 2012, the government decided to differ funding for some of the planned 30GT vessels to build smaller vessels of 5GT to 20GT for fishing communities in the eastern regions of Indonesia, as a number of local fishers had refused to use the 30GT fishing boats and, moreover, argued that the larger vessels were not suitable for their fishing grounds (Sutianto, 2012).

Similar to the eastern part of Indonesia, in many cases, fishers in various other fishing communities refused to operate these granted vessels for several reasons. The fishers have stated that they are reluctant to use the boats due to their design, the inappropriate technology applied on-board and the construction quality of the vessels. The relatively high and so unaffordable operational costs, and the perceived low competency of the local fishers' in operating these fishing vessels are also among the issues that affect the fishers' acceptance of the boats (Grahadyarini, 2013). Hence, regardless of the successes claimed by the government that 90.61% of the 735 fishing vessels that have been brought into operation from 2010 to 2013 have been performing well, and that they have significantly increased production (KAPI, 2015), there were still several challenges that needed to be considered and solved before operating a similar programme again.

Therefore, there is great concern from many parties including the fishers' association, various NGOs and the Indonesian Parliament, relating to the plan of the new Indonesian Cabinet of 2014-2019 to build 4,000 fishing vessels of sizes from 5GT to 40GT, mostly of up to 20GT, by 2016 (Ernis, 2015; Idris, 2015; Purukan, 2015). They recommend that the MMAF needs to consider and learn profoundly from the experience of numerous perceived to be unsuccessful cases in previous programmes. The apparent lack of success related to the programmes implemented by the Indonesian government to develop new fishing vessels in countless country-wide fishing communities, reveals that many complex aspects and issues need to be considered when introducing new designs and incorporating new technologies for specific fishing communities in the country.

To develop fishing vessels suitable for, and acceptable by, specific fishing communities will always be a challenge. Making an identical design of a specific size for the entire country will not work given that each fishing community has its own characteristics related to their deeply established fishing practices, geological conditions, local economy, and so forth. Gulbrandsen (1988), who was employed for twenty-five years by the FAO in fishing boat design and construction in Asia, Africa and the Pacific recognised that in general, the problems encountered when introducing newly designed fishing vessels and innovative alternative technology related to the technological aspects, the economic feasibility, and in particular the fishers' acceptance. He argued that the risks regarding unsuccessful development in fisheries are always high, including improvement of the fishing vessels; however, there is the possibility of avoiding expensive mistakes by applying the correct methods (Gulbrandsen, 1988).

Recommendations made by the FAO in Voluntary Guidelines for Securing Sustainable Small-scale Fisheries (2015) included the proposal that all nations should promote improvements in technology and activities to support responsible fisheries by strengthening the contributions made by research and the education sector, as well as the relevant industries and NGOs. This research project therefore intends to develop a family of sustainable fishing vessels that can support the future sustainability of the fisheries sector in Indonesia. This study has attempted to identify the many diverse aspect that should be considered when designing and manufacturing fishing vessels that will be accepted by specific fishing communities. Furthermore, alternative methods regarding how to develop fishing vessels that can support the sustainability of the fisheries sector have been proposed, and any obstacles that could inhibit efforts to develop such vessels, including any strategy to surmount the obstacles, have been identified. As an example of the suggested approach, a case study has been conducted in order to develop fishing vessel for selected fishing community in Indonesia.

1.2 Aims, Objectives and Research Questions

The aim of this research project is to develop a procedure for designing sustainable fishing vessels for specific fishing community in Indonesia. Based on the rationale outlined earlier, the specific objectives of this research project are as follow:

1 To identify the characteristics and needs of fishers and their fishing communities that most influence the development of sustainable fishing vessels in Indonesia.
2 To identify the design requirements and concerns that needs to be considered when developing a sustainable fishing vessel for Indonesia.
3 To identify both the established and the newest global technologies that are applicable for fishing vessels in Indonesia.

4 To assess the possible technology to be incorporated and applied in Indonesian fishing vessels taking account of societal, economic and environmental issues.
5 To design a proposed fishing vessel for selected fishing community as a case study, in order to create a procedure to aid in the development of sustainable fishing vessels.
6 To identify the actual and potential obstacles in introducing new vessels and technology and to propose the necessary strategies required to make a sustainable fishing vessel possible and acceptable to the fishers.

According to the aim and objectives stated above, the research questions that need to be addressed in this research project are:

1 What is the status, level of knowledge, and type of qualifications of local fishers and others in their fishing communities, and what are their preferences and requirements related to fishing vessels in Indonesia?
2 What are the design requirements and other aspects that need to be considered in order to design sustainable fishing vessels?
3 What are the latest and the established technologies found on boats in world-wide service that could be applied or adopted in some way to fishing vessels in Indonesia?
4 What are the most appropriate technologies that can be applied on-board fishing vessels in Indonesia which fulfil the requirements concerning the social, economic and environmental aspects?
5 What are the obstacles that need to be overcome and the strategies required in order to develop fishing vessels that are sustainable in Indonesia?

1.3 Research Methodology in General

The following description is an overview of the methodology of this research project. A more detailed methodology will be explained at the beginning of each chapter of the thesis.

In order to respond to the above research questions, this research project consists of six separate stages of activities, as illustrated by the flow chart in Figure 1.2:

1 Initial activities include preparing for the fieldwork to elicit local fishers' views related to fisheries and fishing vessels. These initial activities consisted of identifying possible technologies that could be applied to fishing vessels in

Indonesia, as well as studying the current national and international regulations and policies related to fisheries and fishing vessels.

2 Conduct surveys in three selected fishing communities in Indonesia, in order to capture the existing conditions regarding local fishing vessels and to elicit fishers' views related to fishing vessels and the fisheries sector.
3 Identify the fishers' preferences for alternative technologies based on the survey results and to assess these alternative technologies for their economic viability and their potential negative impact on the environment.
4 Identify the design requirements pertaining to designing fishing vessels for specific fishing communities in Indonesia, including the mission profiles and the local identity on existing local fishing boats that needs to be considered.
5 Designing the proposed fishing vessel for targeted fishing community
6 Conclude the propose procedure to develop sustainable fishing vessels in Indonesia.

The discovery of the newest technologies stage was intended to identify the established and state-of-the-art technologies utilised worldwide on fishing vessels that could be applied in Indonesia. A list of technologies from fisheries based across the world was obtained from journals, magazines, websites and others resources. Subsequently, based on these available alternative technologies, potential technologies have been selected to be possibly applied on fishing vessels in Indonesia. In order to select possible technologies, potential alternative technologies have been ranked, taking account of the current conditions of local fishing communities and of other factors that could influence fishers' decisions when selecting the technologies.

The study that was conducted on the Indonesian legislation and current government policy was aimed to gain an understanding of the current state of Indonesian legislation related to both fishing vessels and the fisheries. The result of this study has been used as input for preparing the interviews, in order to attain overviews regarding the fishers' concerns and awareness of legislation that is related to fisheries and their fishing vessels. The Indonesian Government's policy related to fisheries and fishing vessels has also been studied, with the aim of acquiring an overview about how these policies will influence the development of sustainable fishing vessels in Indonesia in the future. Given that the Indonesian fisheries are part of the international market, a study into international regulations concerning fisheries and fishing vessels was also conducted, so as to understand any international issues related to fishing vessels.

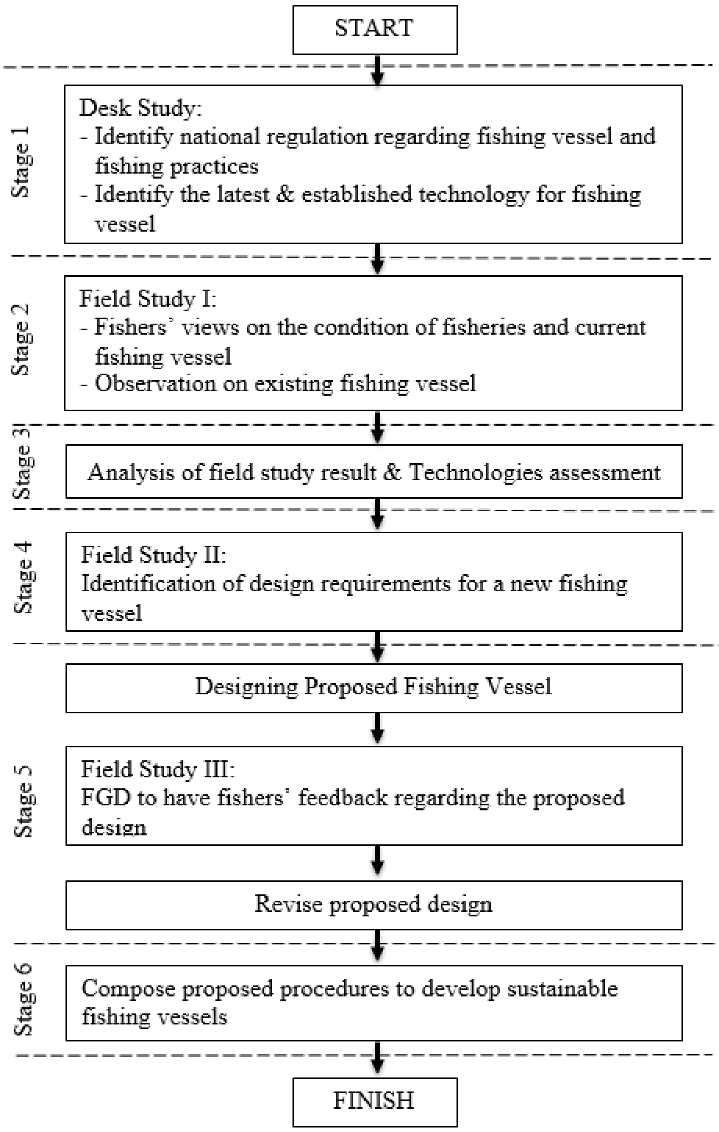


Figure 1.2 Flowchart of research project activities

The second stage of the research dealt with the fishers' requirements, their status and qualifications and their perspective on fishing vessels as a whole. In addition, it examined the sustainability of fisheries in their operating region. Concerning the alternative technologies that might possibly be incorporated on local fishing vessels, the fishers' preferences related to several established alternative technologies were identified as well. A survey on existing fishing boats in selected fishing communities was also performed in order to identify existing technologies on-board and the possibility of employing the new technologies.

The third stage of the research is concerned with the assessment of both the existing and of the established alternative technologies for fishing vessels regarding their social, economic and environmental aspects. There are four main groups of technologies that have been assessed during this stage: the construction materials for the vessels, the main engines, the fish preservation systems and the electricity sources.

In terms of the social aspect, the fishers' preferences in relation to the technologies have been identified. The reasons for their approval or rejection in connection with each technology, and of any obstacles regarding the social aspects that inhibit the implementation of the alternative technologies, have been recognised during this stage based on the results from the field study in the second stage. In terms of the economic aspect, a cost analysis for each of the four groups of technologies has been undertaken. The costs of the initial investment and of operating the technologies during the life cycles of the vessels have been identified. Concerning the environmental aspect, a Life Cycle Assessment (LCA) of the selected groups of technologies was undertaken in order to compare the negative impact of each existing and alternative technology.

The last three stages of the research project provide a case study on how a fishing vessel, which could support the achievement of sustainability in the fisheries sector, should be designed based on the concept of sustainable development. The design requirements and considerations that reflect the three pillars of sustainability (namely social, economic and environmental) have been identified and applied. The case study focused on the design of fishing vessel for selected fishing community in Indonesia. The outcome of the fifth stage was the design of fishing vessels which took account of local fishers' requirements and moreover, applied technologies that have been assessed for their economic viability and potential impact on the environment. This project is intended to inform the Indonesian government, and related stakeholders in the fisheries sector, of issues regarding the development of sustainable fishing vessels in Indonesia, therefore the outcome obtained from the last stage also included the guidelines and strategies for the future development of sustainable fishing vessels for use in Indonesia.

1.4 Structure of the Thesis

This thesis is divided into the following ten chapters. A list of reference and appendixes that support the chapters are presented at the end of this thesis.

This first chapter has introduced the Indonesian fisheries in general and formulates the challenges faced by fishers related to the fisheries and their fishing vessels, followed by the aim, objectives, research question and methodology of the research in general.

Chapter Two describes how the concept of sustainable development was introduced worldwide and has affected all aspects of development, including the fisheries sector, in conjunction with the national and international regulations that encourage the implementation of this concept. The existing conditions regarding Indonesian fishing vessels in general as one of the potential challenges to implement sustainable development in the Indonesian fisheries sector have also been discussed

Chapter Three defines the concept of sustainable fishing vessels and its implementation. The development of fishing vessels in various parts of the world have been reviewed, followed by the design requirements related to developing sustainable fishing vessels. Concerning the condition of Indonesian fishers and their fishing vessels, the relevant step to design such vessels has been identified.

Chapter Four describes how the survey was conducted in selected fishing communities in Indonesia. The general description regarding selected fishing communities and the methodologies that have been applied to obtain the information from the field study have also been presented.

Chapter Five explores the state of the art and established technology on fishing vessels across the world, which includes technology related to construction materials, powering, fish preservation, electrical sources, fishing aids and electronic devices. Moreover, technologies that possible be applied in fishing vessels in Indonesia have been identified.

Chapter Six reviews the current condition of Indonesian fishers and their fishing vessels. The result of the interviews of local fishers, boatyards and other related stakeholders about their views concerning the existing condition of the fisheries sector and fishing vessels in their region have been reviewed. The identification of the current condition of local fishing vessels in selected fishing communities, including existing technologies applied on-board and the challenges faced by local fishers regarding their fishing vessels have also been presented.

Chapter Seven examines the alternative technologies that might possibly be applied on fishing vessels in Indonesia. Fishers' preferences regarding alternative technologies for their fishing vessels have been reviewed in detail, followed by the result of the assessment of the alternative technologies pertaining to the economic aspects by means of cost analysis, and of environmental impact by using Life Cycle Assessment (LCA).

The decision making process to identify selected technologies for Indonesian fishing vessels based on the results obtained from the fishers' preferences, cost analysis and LCA have been presented, including its results.

Chapter Eight explores how the local fishing vessels have become the identity of local fishing communities and moreover have evolved as being part of their culture. The local fishers' views related to how important is the aesthetic aspects in their fishing vessels have been elicited.

Chapter Nine explains the process of designing the proposed fishing vessels for selected fishing communities in Indonesia and how the results acquired from previous chapters have been used during this design process. Each stage of the design process has been presented and supported by design drawings related to the proposed fishing vessels.

Chapter Ten recommends the procedure to develop sustainable fishing vessels for Indonesia. Furthermore, the obstacles that inhibit the development of sustainable fishing vessels in Indonesia and the strategy required to overcome these particular obstacles have been identified. The possibility of applying similar methods to develop sustainable fishing vessels for other fishing communities across the world is discussed in this chapter. The conclusions for the entire project and suggested potential research for the future regarding the development of fishing vessels for Indonesia have also been discussed.

Chapter 2. Sustainable Development in Fisheries and its Challenges for Indonesian Fishing Fleet

2.1 Introduction

The rapid growth of the world's population is believed to be the principal factor for the over-exploitation of numerous natural resources. The massive development of industrialisation indicates that there is an increasing demand from the global population in order to fulfil their subsistence needs, which therefore places enormous pressures on many natural resources, both renewable and non-renewable ones. Obviously, the over-exploitation of resources could endanger the preservation of limited natural resources and furthermore, could threaten the sustainability of these resources and their benefits, not only for current generations, but also for future generations. The increasing concern related to the sustainability of natural resources has prompted countries worldwide, through many international organisations, to focus more on the preservation of natural resources and their rate of exploitation by implementing more robust international policies, legislation and recommendations regarding how the world should manage its natural resources and subsequently benefit from them responsibly.

Concerning the worldwide fisheries sector, the following chapter reviews how international legislation has been developed, with the aim of covering all of the challenges that have been raised in this sector related to sustainable development. Pertaining to the Indonesian fisheries, how the Indonesian government manages this sector through the approval and implementation of numerous policies and regulations, and furthermore, how it affects the development of the fisheries sector, including its impact on the existence of the Indonesian fishing fleet, are also explored in this chapter.

2.2 Sustainable Development in World Fisheries

2.2.1 Concept of sustainable development

It was in Stockholm in 1972, when the United Nations (UN) held the first global conference related to the environment, which illustrated concerns with regards to the economic development potentially associated with adverse environmental degradation as a primary global issue. This conference considered the requirements of common principles as guidance for societies in exploiting natural resources that could ensure the preservation and improvement of the human natural environment (UNEP, 1972).

By 1983, the United Nations established an independent commission known as the World Commission on Environment and Development (WCED) that was assigned to formulate '*A global agenda for change*'. This was as a response to growing international unease concerning the sustainability of natural resources and how these resources could possibly be used to benefit human beings completely without endangering the sustainability of the resources themselves. In 1987, the WCED presented their report, titled '*Our Common Future*', and which introduced the concept of sustainable development followed by several strategies required in order to achieve this particular goal (Brundtland *et al.*, 1987).

The WCED report, more well known as the Brundtland report, in accordance with the name of the commission's chairman, noticeably exposed the interaction of economic growth, the environment and human beings throughout development, in order to attain societies' essential needs, and furthermore, how one aspect could influence other aspects during the process. The commission insisted on the need for sustainable development in a manner which could fulfil the necessities of current generations, whilst at the same time ensure that future generations could be able to accomplish their needs without any exceptions (Brundtland *et al.*, 1987).

Based on the Brundtland report, sustainable development could be achieved by integrating the implementation of three main aspects, also recognised as the three pillars of sustainability: namely social, economic and environmental aspects. Similar to the concept of "pillars", these three aspects should be implemented at the same level of importance and be similar in relative weight so that they are able to support sustainable development. This report outlined a number of important strategies that should be employed in order to achieve sustainable development, among others are by protecting and improving natural resources; reorienting technology and managing the risk related to its implementation; and by integrating economic and environmental aspects in decision making.

After the Brundtland report, many international initiatives were conducted that aimed to promote sustainable development in all aspects of human life. In order to have more quantitative and definitive time-scale targets related to global sustainable development, the States' leader established the Millennium Development Goals (MDGs) during the UN summit in New York, in 2000. The principal points of the MDGs are associated with the eradication of poverty, improved education, equity issues, health issues, and environmental sustainability (UN, 2000). The concept of the Green Economy, which is "*one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities*", has been introduced by the United Nations Environment Programme (UNEP) in 2008, as one of the main method to accomplish sustainable development (UNEP, 2012).

The MDGs have been completed in 2015, and as the successor, the 2030 Agenda was launched in 2015. This Agenda is the new action plan for the world to engage in up to 2030, so as to achieve the realisation of new global Sustainable Developments Goals (SDGs). The SDGs consists of 17 goals *inter alia:*

> *"To end poverty in all its form universally; end hunger, achieve food security and improved nutrition; and also to conserve and sustain actions regarding the use of the oceans, seas and marine resources for sustainable development"* (UN, 2015).

2.2.2 Implementation of sustainable development in the world's fisheries

One of the new global sustainable developments goals contained in the 2030 Agenda is with reference to "*the conservation and sustainable use of the oceans, seas and marine resources for sustainable development*" (UN, 2015). The inclusion of this point demonstrates how important this sector is for human beings. However, the decline in fish stocks in many global fishing grounds was becoming a wake-up call for the world, especially of concern to the coastal states, on how they should manage and exploit these resources if they want to continue to benefit from this specific sector. In addition to the concern related to how many fish stocks can be safely exploited annually, the protection of the marine environment itself has also become a pressing issue. The characteristics of the fish species, including the pattern of their life cycle, such as the spawning and migration phases and all the important 'food chain' are significantly affected by their environment.

Marine resources, fish in particular, have been exploited by people from time immemorial. Fish remains one of the main sources of nutrition for many humans; while fishing has become the foremost livelihood for coastal communities in many countries (FAO, 1995). The high demand placed on fish products worldwide has encouraged coastal states to dramatically increase the quantity of their modern fishing fleets and moreover, their fishing industries. Unfortunately many coastal nations, in contrast with their intense efforts to exploit resources, have fewer capabilities in order to be able to manage their fish resources appropriately (FAO, 1995).

These circumstances have led to the overfishing and depletion of fish stocks in waters adjacent to many countries, and this adverse trend has continued to increase. The trends in relation to fish stocks worldwide can be illustrated in Figure 2.1. It show that in 2013, only 10.9% of the fish stock is still potential for additional exploitation, the remaining of it, approximately 58.1% of fish stock is fully fished, which is mean there no room to increase the total production, and about 31.4% of the stock is in the condition of unsustainable level or overfished (FAO, 2016).

The need for better fisheries management that more concern on the environmental issues, as promoted in the concept of sustainable development, have encouraged the Food and Agriculture Organisation (FAO) to conduct many initiatives in order to ensure the sustainability of fisheries resources, including the adoption of the *Code of Conduct for Responsible Fisheries* in 1995. This Code provides the guidelines for State members in conducting activities related to the preservation, management and development of their fisheries sectors (FAO, 1995).

Concerning the availability of fish stock and the preservation of marine environment, the Code recommended coastal nations to promote more responsible fishing practices by operating fishing vessels that are installed with more environmentally-friendly technologies including the appropriate fishing gears, less energy-intensive equipment and technologies that have a minimal negative impact on the environment.

According to the Code, other important features that need to be improved by coastal states is the involvement of all related fisheries stakeholders, in particular the fishers themselves. Special attention has been devoted to the existence of the great many indigenous fishing communities, especially in developing countries, who rely on the fisheries sector for their livelihood. Most of them are involved in small-scale fisheries and have been trapped in poverty, lack access to education, and lack access to health and financial support. It is believed that this situation has led indirectly to largely irresponsible fisheries practices (FAO, 1995; FAO, 2015d).

It is worth noting that some of the recommendations made by the Code that are related to fishers, particularly indigenous fishers, suggest that nations should carefully consider the existence of indigenous fishing communities when they plan and settle on any policies related to managing the fish resources. It is including the transfer and implementation of new technology to the local fishing communities and the enactment of new regulations that are principally related to the exploitation of fish resources.

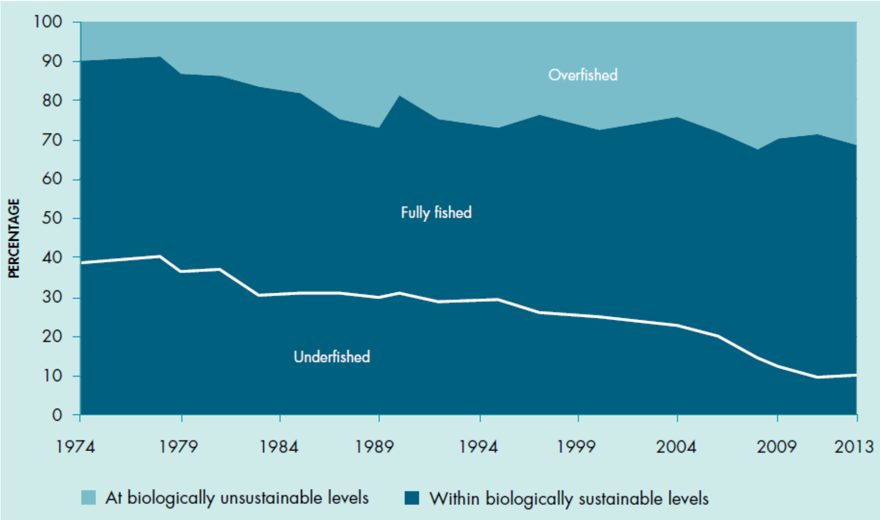


Figure 2.1 Global trends in the state of the world's marine fish stock, 1974 – 2013 (FAO, 2016)

States also need to promote the health and safety in their entire fishing fleet, and additionally, to take into account fishers' awareness and knowledge pertaining to health and safety on-board vessels. The Code believed that the empowerment of local fishers and their communities by providing people with a better education and by improving their professional competencies on fishing practices are the most appropriate ways to develop their personal role in achieving responsible fisheries (FAO, 1995).

The important to involve the small-scale fisheries is emphasised in the FAO document titled '*Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication'.* The Guidelines were adopted as there was a contrast between the potential contribution of small-scale fisheries to sustainable development with their current condition, especially in developing countries, that mostly feel vulnerable and marginalised, and moreover, have less access to development (FAO, 2015d).

A number of points from the Guidelines that need to be highlighted including that every decision maker should ensure that small-scale fishing communities are involved in every decision making process that impacts on local or traditional fishery resources and their environment; and that any effort related to small-scale fisheries should respect the local culture by:

> " *Recognising and respecting existing forms of organisation, traditional and local knowledge and the practices of small-scale fishing communities, including indigenous peoples and ethnic minorities*" (FAO, 2015d, p2)

Furthermore, concerning the implementation of Code of Conduct for Responsible Fisheries and based on the concept of the Green Economy, the Blue Growth Initiative (BGI) was introduced by FAO in 2014. This Initiative aims at '*restoring the potential of the oceans and wetlands by introducing responsible and sustainable approaches to reconcile economic growth and food security together with the conservation of aquatic resources' (FAO, 2015a).*

Based on the above description, the UN and many international bodies via a partnership have built a foothold and guidelines for countries across the world in order to benefit from their natural resources, including marine resources in a responsible manner and to ensure that these resources will be available not only for current but also for future generations.

2.3 Sustainable Development in Indonesian Fisheries and Fishing Vessels

2.3.1 Concept of sustainable development embodied in Indonesian development policy

As with other developing countries, Indonesia is confronted by enormous challenges in managing the exploitation of its natural resources with the aim of gaining optimal gains from the resources, whilst simultaneously ensuring that the natural resources are preserved for the future generations. Concerns about the potential benefits from the natural resources was the reason for the inclusion of Article 33(3) in Chapter XIV, regarding the National Economy and Social Welfare, of the 1945 Constitution of the Republic of Indonesia (KBRI, 2006), which states:

> *"(3) The land, the waters and the natural resources within shall be under the powers of the State and shall be used to the greatest benefit of the people".*

Based on the growing insistence regarding enhanced national development, which is more equitable and more concerned about the environment, a new article was added in this chapter. Consequently, Article 33(4) was the result of the fourth amendment to the 1945 Indonesian Constitution that was enacted in 2002 (KBRI, 2006) and which states:

> *"(4) The organisation of the national economy shall be conducted on the basis of economic democracy upholding the principles of togetherness, efficiency with justice, continuity, environmental perspective, self-sufficiency, and keeping a balance in the progress and unity of the national economy".*

Furthermore, these two articles have become one of the legal supports for the implementation of sustainable development in every feature of national development in Indonesia.

In order to have some guidance for the development processes, the Indonesian government established the National Development Plan applicable for a particular period of time. The latest plan is the National Long-term Development Plan for 2005–2025. The vision of the plan for 2005–2025 is to achieve an Indonesia that is independent, developed, just and prosperous. It will be attained through eight missions, and among these missions are ones including the accomplishment of Indonesia as an archipelagic nation which is strong, developed, self-reliant and based on national interest. The success indicators for this mission are, among others, the establishment of an integrated marine economy that employs marine resources in a sustainable manner (President_RI, 2007).

According to this development plan, Indonesian marine development is directed to apply sustainable development in a manner that fully considers human resources, economic, environmental, social, and cultural, in addition to national defence and security. Furthermore, it will take into account the implementation of relevant beneficial technology. The strategies to be applied in order to accomplish this mission are: 1) to promote insight and maritime culture in society by educating people to facilitate their awareness concerning the marine sector and also by preserving local cultural values related to the marine environment by revitalising indigenous laws and local knowledge in marine management; 2) to improve the competences of human resources in the marine sector; 3) to reduce the impact of coastal disasters and pollution at sea; and 4) to increase the prosperity of coastal communities (President_RI, 2007).

In line with the implementation of the eight missions connected to national development, the Indonesian government introduced what are known of as the three pillars of Indonesian national development in 2004, specifically *pro-growth, pro-poor and pro-jobs*. Subsequently, these three pillars were supplemented by a further pillar known of as the *pro-environment* in 2007 (Dhewanthi, 2012). The mission that was established and the four pillars of national development indicated the implementation of sustainable development that the Indonesian government attempted to fulfil with regards to national development.

Despite the relative well organised development plan, a number of challenges remain in relation to the implementation of policies and plans that had been established previously. According to Chapter 2 of the 2005–2025 long-term national development plan with reference to the general condition of Indonesia, notwithstanding the benefits that are to be gained from the exploitation of natural resources, exploitation practices in many sectors are still unsustainable and very often ignore the conservation of the environment. The government, according to this document, believed that the circumstances pertaining to natural resources in a few sectors had become very worrying in the context of their preservations. Furthermore, the existence of indigenous people who are significantly dependent on local natural resources for their livelihood and who in fact have local knowledge related to the responsible exploitation of natural resources remains unrecognised.

2.3.2 The potential and challenges involved in developing sustainable Indonesian fisheries

As briefly described in previous chapter, Indonesia fisheries have significant potential to be exploited for the benefit of the society, however there are still numerous challenges in order to ensure that the sector is harnessed responsible and sustainably. This sub-section describes more detail about the potential and challenges involved in developing Indonesian fisheries that are more sustainable.

Before the reform era began in Indonesia in 1998, the government's focus on national developments was related more to the terrestrial sectors rather than to the sea areas, although two-third of Indonesian territorial is the sea. The new Indonesian government after the reform era demonstrated an increasing attention related to the potential benefits that could be attained from the marine sector, especially fisheries, and furthermore, as to how this sector could play a role in the nation's development (MMAF, 2014a).

In contrast to the small amount of government attention that was given prior to the reform era, the industrial sector had been putting their interests first and have been exploiting the marine sector, particularly the fish resources located in Indonesian waters for a few decades (Patlis, 2007). This exploitation is demonstrated by the continuous increases in the production of the Indonesian fisheries. Data from *the Indonesian Marine and Fisheries in Figures 2014* demonstrate that the total production of the Indonesian marine capture fisheries was 5.78 million tonnes in 2014, which had increased significantly from 3.72 million tonnes in 1998 when the reform era was started (Suadi, 2006; MMAF, 2014b; BPS, 2015).

This significant growth due to the exploitation of the fish resources that has been undertaken across the entire Indonesian waters and with the most aggressive exploitation being undertaken in the western parts of Indonesia (Bailey, 1988; Mous *et al.*, 2005; Patlis, 2007; Muawanah *et al.*, 2012). Unfortunately, the overfishing conditions have also spread across the entire Indonesian waters. As illustrated in Table 2.1, there are only four out of the eleven of Fisheries Management Areas (FMAs) that still have the potential to be exploited further. The depletion has not only been experienced by the western parts of Indonesia where the population is more dense (Kusumastanto, 1996; Patlis, 2007), but also, by the eastern parts of the country where there are less fishers. The movement of fishers from the western parts of Indonesia to the eastern area has tended to have an influence on the abundance of fish stocks in eastern parts of Indonesia as well (Ainsworth *et al.*, 2008).

The Fisheries Management Areas (FMAs) in Table 2.1 are the zoning of fishing grounds that divided the Indonesian waters into eleven areas (MMAF, 2009), as shown Figure 2.2. In order to manage the fish stocks, Indonesian government also has introduced a Maximum Sustainable Yield (MSY) level for Indonesian fish resources. This is the maximum amount of fish that can be annually exploited in Indonesian waters, both nationally and for each FMAs, with the intention of allowing this resource to naturally regenerate, grow safe stock and ensure its availability in the future.

According to the latest official data obtained from the MMAF in 2011, based on input from the Committee for National Fishery Stock Assessment, the total MSY of fish resources was approximately 6.5 million tonnes nationally (MMAF, 2011a). Along with this total nation-wide MSY, MMAF also established the individual MSY for each FMA, as identified in Table 2.1.

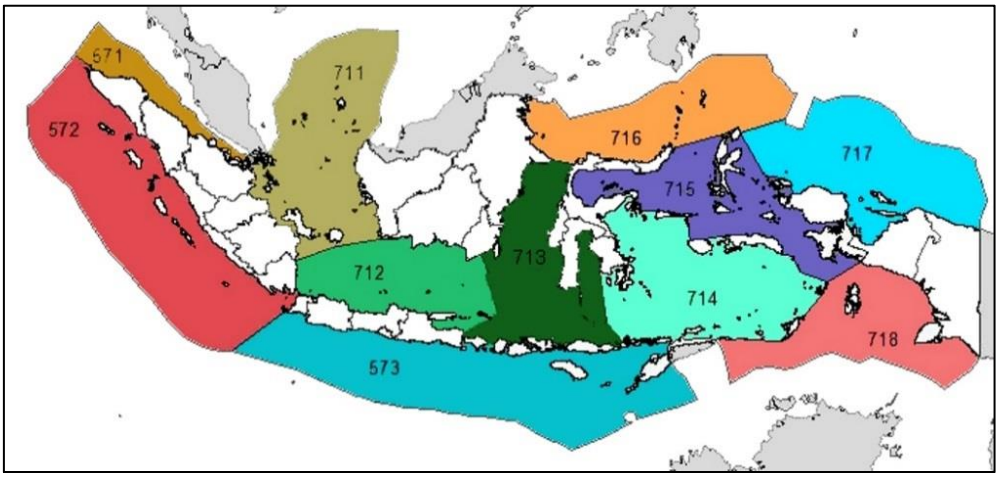


Figure 2.2 Indonesian Fisheries Management Areas (FMAs)
(Sources: http://www.eafm-indonesia.net/profil_perikanan/)

Table 2.1 Status of fish stocks in each Indonesian FMAs (in thousands tonnes) and total production in 2013
(Compiled from (MMAF, 2011a) and (MMAF, 2014c))

	Fisheries Management Areas										
	571	572	573	711	712	713	714	715	716	717	718
MSY	276	565	492	1,059	837	930	278	596	334	299	856
80% MSY	220	452	393	847	669	744	222	476	267	239	684
Production	496	633	464	623	919	688	519	505	301	143	416

Note : Over-fished Fully-fished Under-fished

Concerning the sustainability of fish stocks in the FMAs in the future, the Indonesian government by means of the MMAF has introduced defined Total Allowable Catches (TACs) additionally, and which was set at 80% of the MSY (Mous *et al.*, 2005; Megawanto, 2015). However, Indonesia has not yet applied the concept of an individual TAC for single vessels that has been implemented in many other coastal states in order to control the total catch per unit vessel annually (Megawanto, 2015).

In addition to the enormous exploitation of fish resources, another possible reason for the decline in fish stocks in Indonesian waters is a decrease in the quality of the marine environment, which ultimately damages the habitat of the fish. Among the reason is the employment of non-environmentally-friendly fishing technology, such as using fishing gears that damage the seabed together with its ecosystems. The ban on some types of fishing gears established by the Indonesian government, for example the ban of trawl in 1980 and seine nets in 2015, apparently failed to protect and rehabilitate the marine environment, since the lack of fishers' awareness and low of regulation enforcement (Yusuf, 2015).

The reduced amount of fish stocks available in traditional fishing grounds has forced most local fishers in many fishing communities to fish further from their more common fishing grounds, and thus over longer round-trip durations. However, with vessels of a similar capacity and without any improvement to the technology incorporated on-board, the income that the fishers can obtain from one fishing trip has not significantly increased, seeing as they expend more costs to operate the vessels, especially since there are an increase in the fuel price nationally.

In addition to the increasing operational costs, fishing for longer periods and further afield can result in an escalation in the potential for risks that the fishers are confronted by during extended fishing periods and operations. With the existing physical conditions of local fishing vessels and the relatively low level of fishers' awareness in connection with safety at work, the increase in risks during their work could endanger fishers' lives. There are no official data related to fishing vessels accidents in Indonesia (Suwardjo *et al.*, 2010); however, The People's Coalition for Fisheries Justice (KIARA) noted that the number of fishers who died at sea in one year is quite high. KIARA claimed that in 2012 there were 186 fishers who died at sea, as many as 225 in 2013 and 210 people in 2014 (Grahadyarini, 2015).

It is also worth noting that the increasing demand for certified fish products has also raised another challenge for Indonesian fishers. Thus, public concern, in the international market in particular, regarding the source of any fish products that they consume and in relation to the sustainability of the fish resources for future generations, moreover, the health and safety work environment during fishing operations, have all increased the demand for eco-label fish products (Potts and Haward, 2007). As traditional fishers, many features of their fishing practices together with their fishing vessels themselves need to be adjusted in order to fulfil the requirements of eco-labelling products, thus generating more challenges for the fishers.

2.3.3 Current state of Indonesian fishing vessels

The existence of fishing vessels in Indonesia is believed have begun a very long time ago when very old communities along the coast lines attempted to reap benefits from the sea. Since that time, the configuration and size of fishing vessels have continuously evolved (Samodra, 2009).

The various types of fish resources, besides the specific characteristics of each local fishing ground and the fishing communities, are the main reason that nearly every region in Indonesia has its own distinctive fishing vessel. The boats were developed by local fishing communities as the obvious solution to any problems related to their fishing practices, and commonly based on the historically acquired local knowledge and resources available in their particular environment. Therefore, in the numerous fishing communities, their fishing vessels have also become their local identity, as seen in Figure 2.3 (Rosyid and Johnson, 2005; Samodra, 2009)

Figure 2.3 Traditional fishing vessels in East Java, Indonesia
(Photo by the Author)

The high rate of growth of the Indonesian population that directly increases the demand in fish for human consumption has led to an increasing demand on fishing vessels for exploiting the fish resources in Indonesian waters in the last few decades. Shortly after the period of motorisation of the traditional fishing vessels in the mid-1960s and the introduction of active bulk fishing gear, such as trawl nets in 1966 and purse seine in the early 1970s, the numbers of fishing vessels in Indonesian waters has increased significantly. There were about 283,913 fishing boat units in Indonesian waters in 1968 with only 2.01% of them installing motors to replace sails and oars (BAPPENAS, 1974). The numbers of vessels continued to grow significantly and reached 643,100 units in 2014 with roughly 73% of these vessels utilising motors for powering (MMAF, 2014b). However approximately 88% of this vessels in 2014 were small boats up to 3GT (MMAF, 2014b)

Although the numbers of fishing vessels that use motors for powering have increased considerably, the level of technology that is included on-board is still one of the main problems for most of fishing vessels in Indonesia (MMAF, 2010). In term of main engine, most of these fishing boats have installed second hand truck engines or other general purpose non-marine-use engines that quite often cause difficulties in their reliability and life span. The improper of fish preservation systems on-board have affected the quality of fish landed. Moreover, the problem on the availability of wood as the main construction material for the boats that forced local boatyards to employ lower quality of wood have reduced the quality and life span of the vessels. Additionally, the electronic device to assist fishing activities are very rarely employed in these fishing vessels.

This situation has affected the profit the fishers can earn and have limited the fishing grounds; therefore, only a small number of vessels can operate within the Indonesian Exclusive Economic Zone (IEEZ) (MMAF, 2010). Nevertheless, it should be noted that the relatively small numbers of national flag fishing vessels that operate in the IEEZ area essentially offer an opportunity for foreign fishing vessels, which are commonly larger than local fishing vessels and are often equipped with more modern technology to illegally exploit fish stocks that are within the IEEZ.

Based on the aforementioned description regarding the current physical condition of fishing vessels, there is significant apprehension regarding the sustainability of the current fishing boats themselves and furthermore, how the fishing fleet can support the sustainability of fish resources, with the purpose of establishing the long-term sustainability of the fisheries sector in Indonesia. Therefore, the enormous challenge for the Indonesian fisheries is to discover appropriately designed fishing vessels with correct environmentally-friendly technologies incorporated on board. Consequently, this could fulfil both the actual and latent requirements of the local fishers, in addition to adapting to current conditions within the fisheries; whilst at the same time providing the capabilities necessary in order to meet the obligations with respect to future conditions.

2.4 Concluding Remarks

Sustainable development requires the implementation of the three pillars of sustainability: social, economic, and environmental in order to ensure that the development can achieve the needs of society both for current and future generations. Concerning the fisheries sector, this concept involves the implementation of responsible fishing practices to ensure the sustainability of fish resources and to achieve the preservation of the marine environment. Moreover, it needs the comprehensive participations from key stakeholders in fisheries, in particular the fishers, throughout the development, from the planning stages to implementation.

With regard to Indonesian fisheries, the fish resources of the extensive water area of this archipelagic country have been providing huge benefits including providing significant protein resources for society, and job opportunities for huge numbers of people along the Indonesian coastal line.

Notwithstanding some measures from the Indonesian government in order to ensure the sustainable development of the fisheries sector (for instance, by organising a development plan related to marine resources exploitation, and by establishing some management policies including Fisheries Management Areas), the implementation of sustainable development in Indonesian fisheries still has many weaknesses. The bias in policy from the government toward exploitation rather than conservation, low enforcement of the regulations and the lack of fishers' awareness concerning the sustainability of fisheries are among the reasons for the difficulties in applying sustainable development in Indonesian fisheries.

Another challenge to the sustainable development of Indonesian fisheries is the poor condition of current Indonesian fishing fleet. The application of non-environmental-friendly technology on-board, in addition to the lack of fishers awareness related to responsible fishing practices, have caused improper practices for the exploitation of fish resources. These conditions have led to the decline of fish stocks and the decrease of marine environment quality in many fishing grounds throughout Indonesia that threatening the sustainability of the fisheries sector in the future.

For that reason, in order to encourage the implementation of sustainable development in Indonesia fisheries the measures to promote responsible fishing practices need to be established continuously. One element of this effort is to develop sustainable fishing vessels that provide a simultaneous solution for the social issues, the economic issues and the environmental issues associated with the operation of fishing fleets in Indonesian waters.

Chapter 3. Sustainable Fishing Vessels: from Concept to Design Requirements

3.1 Introduction

The gradual decline in fish stocks, the potential decrease in quality regarding the marine environment, and moreover, the relative poverty that confronts most fishers and their local communities are among the various challenges that the global fisheries sector has to actively manage and reverse in order to ensure the sustainability of this sector. Concerning the sustainable development of the fisheries, the fishing vessel, as one of the fundamental tools, has a significant influence on the sustainability of the sector; consequently, the design and operation of the fishing boats should support the implementation of the three pillars of sustainability. Therefore, in order to ensure that the fishing vessels can support attempts to achieve sustainability within the fisheries sector, it is important to understand the features of these fishing vessels and to identify the methods required to develop them.

In this chapter, the concept of a sustainable fishing vessel is defined, in addition to examining how it is related to the implementation of and compatibility with the three pillars of sustainability. Based on this concept and the experiences of many countries that have been endeavouring to develop their fishing fleets, including several projects undertaken by the Indonesian government, the design requirements and any deliberations and trade-offs required to develop sustainable fishing vessels will be identified. Concerning the development of fishing vessels for Indonesia, the methods required to design sustainable fishing vessels that consider the specific characteristics of fishers and their local fishing communities in Indonesia will be proposed.

3.2 The Concept of Sustainable Fishing Vessels

The principal concept of sustainable development is the fullest possible consideration of the three pillars of sustainability: economic, societal and environmental, within the development process itself (Brundtland *et al.*, 1987). In order to justify the achievement of sustainable development, it requires clear and unambiguous criteria, including performance indicators, which can be used to assess the level of success in the implementation of the three pillars in the development process. Concerning the fisheries sector, the FAO suggest several criteria and indicators that can be used to measure to what extent sustainable development has been accomplished. For instance, in terms of social aspects, the criteria can be with regards to the safety of the fishing vessels and its associated indicator could be the percentages in relation to the loss of life and boats in a year (Garcia, 1996). According to the FAO, these criteria and associated indicators have been established to ensure the following aspects are achieved in the fisheries sector; specifically: 1) the fulfilment of human needs for all generations, 2) socially acceptable conditions, 3) the preservation of the environment, including its organisms, 4) the use of appropriate technology, and 5) economically viable exploitation, (Garcia, 1996).

Based on the suggestions of the FAO related to the criteria for sustainability assessment, the sustainability of the fishing vessels could also be assessed by selecting the appropriate criteria and indicators. Utne (2008) applied 7 criteria to assess the sustainability of Norwegian fishing vessels, based on the objectives of Norway’s sustainable fisheries management. These attributes, including risk of accidents, profitability, employment, fish quality, catch capacity, greenhouse (GHG) emissions and bycatch (Utne, 2008a). Each of these criteria could basically be classified into elements of the three pillars: risk of accidents and employment, as a part of the social aspect; profitability and fish quality, as the economic dimension; whereas the environment feature is reflected in the catch capacity, GHG emissions and bycatch fish rate (Utne, 2008b).

Crilly and Esteban (2013) compared the impact of social, environmental and economic aspects of both small and large-scale fishing fleets in the United Kingdom’s North Sea cod fishing sector, in order to determine which size of fishing fleet is the more sustainable in this particular area. Regarding this specific assessment, several criteria including GHG emissions, employment, subsidies, discard rate and productivity had been applied in order to obtain a more sustainable fishing fleet.

Given the above description, similar criteria could be used as guidance in order to develop fishing vessels that are designed to facilitate sustainable operations. These criteria, which reflect the implementation of the three pillars of sustainability, could be applied when identifying the requirements and considerations in order to design a sustainable fishing vessel. For instance, concerning the criteria related to social concerns regarding the safety of the fishing vessels, sustainable fishing vessels should be designed with particular attention paid to health and safety, by providing sufficient safety equipment on-board. Hence, this could minimise the risk and consequences of accidents and loss of life at sea due to all operational and environmental conditions.

By considering the aforementioned idea related to the concept of vessels that can support the achievement of the sustainability of the fisheries sector, a sustainable fishing vessel could be simply defined, as a vessel that reflects the consideration and implementation of the three pillars of sustainability throughout its life cycle, from construction through to eventual disposal of the vessel. Specifically, the characteristics of the vessel can be identified as potential solutions for any issues related to the environment, as well as social and economic aspects within the fisheries sector.

Firstly, concerning environmental issues, the vessel should have a minimum negative impact on the natural environment, not only regarding the impact from the operation of the vessel, but also the impact from manufacturing the vessel, its through life maintenance and its eventual scrapping. For instance, the building of the vessels should use environmentally-friendly fabrication methods and construction materials. Moreover, the technology employed on board should minimise the degradation of the quality of the environment, by having minimum emissions, minimum water pollution, and be energy efficient. In addition, the selected fishing gear applied on board should reduce the likelihood of the unintended catch of non-target species and avoid damage to the environment caused by the way the fishing gear is operated.

Secondly, with regard to social concerns, the sustainable fishing vessel should be able to fulfil the requirements of the fishers and their fishing communities. The design of the vessel therefore should consider the characteristics of local fishers, who will operate the vessels. It is very important that the local fishers have no obstacles to operating and maintaining the vessels; hence, it needs to bear in mind the local fishers' competencies in undertaking their fishing practices, their skills related to operating fishing boats, and also their capability to economically maintain and repair the craft. Furthermore, the design and construction of the vessel, including the selection of technologies to be applied on board, need to take into account the fishers' economic background, given that it will relate to their capability to cover the initial investment cost and the operational and maintenance costs. An additional aspect that is a social concern regarding fishing vessels is related to health and safety in the work environment. Sustainable fishing vessels should have an appropriate health and safety working environment on board, seeing as fishing activities have become one of the most dangerous occupations globally. At last, it should consider aspects of style relating to the local culture that reflects fishing vessel features and fishing practices that have evolved over many generations and often embody community identity.

Finally, with respect to economic issues, the operation of sustainable fishing vessels should be able to offer a reasonable profit to the fishers on a permanent basis. In order to achieve a reasonable profit, besides the volume and proper value of the catches, the fishing cost should also be sensible and affordable for local fishers. This fishing cost includes the cost of operating, maintaining and repairing the vessel and the equipment, as well as the initial cost of constructing and outfitting it.

3.3 Global Fishing Vessel Development

Fishing vessels around the world have evolved and been developed over many centuries; from ancient rafts made of bundles of reeds or papyrus (Ward, 2006) powered by sail and oars, through to the complicated vessel made of modern construction material, such as steel, aluminium alloy or composite materials (Valdemarsen, 2001), powered by a modern diesel engines and equipped with complicated and computerised fishing equipment (Borgstrom, 2015; FAO, 2015b; Icelandic_Fisheries, 2015).

The increasing number of fishing vessels worldwide and the development of many types and forms of vessel is principally affected by the significant increase in society's demand for marine protein, particularly fish, and the potential profit that can be obtained from the fisheries sector. Improvements in fishing technologies and the adoption of numerous inventions in diverse ship technologies in fishing boats has boosted the development and efficiency of fishing vessels, especially in developed countries. The success of specific technologies in fishing vessels in some countries result in their application, possibly with some modification, in other countries. This has led to fishing vessels worldwide having designs which are closely similar if not identical and constructed in a similar manner too. If there are any differences, it is mostly associated with their fishing gear and fishing methods (Borgstrom, 2015),

However, this idea of fishing vessel designs that are similar is most applicable to large commercial fishing vessels. For traditional artisanal fishing vessels, in particular in developing countries, the idea of an identical design nationally, let alone worldwide, would not be successful. The case of the Oregon Dory design is an example of how the concept of developing the 'ideal' fishing vessel that would be able to work locally all over the world was not a satisfactory idea. The Oregon Dory was a fishing vessel powered by a 30kW petrol engine from a car, and which was disseminated across the Pacific Ocean in the early 1970s. The anticipated spread of this type of fishing boat throughout the Pacific Ocean islands was motivated by the thought that '*What works in*

Oregon must work everywhere else'. However, this eventually proved to be a quite incorrect assumption both from an economic and a technical standpoint (Gulbrandsen, 1988).

In fact, the presumption of an improvement of fishing vessels by implementing a range of new technologies does not always work for many reasons, particularly in developing countries. Various attempts to improve the quality and performance of fishing fleets have been undertaken in many coastal nations. There have been several examples of fishing fleets that have been developed in global context. Some of these have succeeded in having a positive impact on specific fisheries, however a number of them ended up failing. In some cases these resulted in creating new, often unanticipated, challenges for individual local fishing communities, or even worse, endangered the sustainability of the fisheries sector itself (Gulbrandsen, 1988; Kurien and Achari, 1990).

For this reason, many factors should be considered before introducing a new design or new technology for individual fishing communities. In order to understand what factors need to be considered and evaluated, several lessons could be learned from programmes that have been conducted by the FAO in a number of developing countries. One FAO programme, which started in 1979, was a small-scale fisheries project under the Bay of Bengal Programme (BOBP). This FAO's programme was primarily related to identifying and introducing appropriate technology to be applied in traditional fishing boats operating from coastal communities around the Bay of Bengal: Bangladesh, India, Malaysia, Sri Lanka and Thailand (BOBP, 1980; Gulbrandsen, 1986; Pajot, 1993). Another project also under the supervision of the FAO was the Regional Fisheries Livelihoods Programme for South and Southeast Asia (RFLP), which was conducted from 2009 to 2013. The RFLP was established with the purpose of enhancing the livelihood of small-scale fishing communities in Cambodia, Indonesia, the Philippines, Sri Lanka, Timor-Leste and Vietnam, while simultaneously enhancing the awareness of local fishers in implementing more responsible fishing practices (FAO, 2015c).

One of the findings during these FAO programmes was connected to how the affordability of the new technology frequently became an obstacle to its potential implementation. For instance, measures to implement alternative construction materials were inhibited by the high first cost of implementing alternative materials, which local fishers could not afford. According to the FAO's project, many fishing communities on the east coast of India experienced challenges in obtaining certain types of wood of the required quality for the hull construction of the traditional fishing boat, moreover, the price of wood continued to rise each year. Under the supervision of BOBP, several potential alternative materials were evaluated. However, wood is still the least expensive material and local fishers have difficulty in affording the initial cost of alternative materials, such as FRP and aluminium. Therefore, the recommendation of the project was to apply the closest alternative material, which is laminated wood, and also of guaranteeing timber supply in the future by developing improved forest planting management (BOBP, 1980). It is worth noting that quite similar recommendations were suggested during the RLFP project in Timor-Leste in 2012, which tried to introduce FRP as a substitute for wood as the primary hull construction material for local fishing boats. In addition to this, it tried to develop a sustainable forest sector with the purpose of ensuring the supply of materials to local boatyards. The project also recommended that the government of Timor-Leste seeks to educate local fishers in ways to improve their maintenance and restoration skills, in order to have wooden fishing boats with a longer life span (Tsujimura *et al.*, 2012).

Finance, in addition to various technical aspects, also became a reason for the lack of acceptance of the new fishing boat designs that were developed during the RLFP project in Cambodia. Concerned with the safety of the 12 metre undecked wooden fishing boat that was commonly used in Cambodia, in 2010 the FAO under the RLFP project introduced a newly designed fishing boat, which was judged to be more stable and safe, in contrast to the existing local design. Local boatyards, however, discovered that the newly proposed design was more expensive to construct and therefore, too expensive for local fishers. Moreover, local fishers ascertained that the proposed boats were too heavy compared to their traditional ones after a 12 month fishing trial. Hence, the local fishers had difficulties in handling the boat in shallow water, where the traditional boats commonly operated. For these reasons, the proposed design was considered to be less acceptable for local fishers in Cambodia (Needham *et al.*, 2013).

Ensuring the availability of a supply chain for spare parts (specific machinery and equipment) and consumables (fuel, oil, batteries, etc.) to operate the technology properly is another aspect that needs to be thought about when introducing new technology to specific fishing communities. The lack of kerosene, for instance, for the motorised canoes in India during the BOBP project in 1982, which aimed to establish the outboard motor for use in traditional canoes on the west coast of India, resulted in the motorised fishing boats undertaking less fishing trips in contrast to the canoes that did not have a motor on-board. Moreover, the cost of operating the motorised canoes meant that there was no significant difference in the profit acquired by using a motor to propel the canoe, in comparison to the profit obtained by using a canoe with oars and a sail. However, it was observed that the local fishers did gain some advantages from the motorised canoe, as they did not need to row the boat for 2-3 hours a day to go to their traditional fishing ground, and therefore saved more time on fishing trips. Nevertheless, limitations in the fuel supply have influenced local fishers' acceptance of the new vessel (Gulbrandsen, 1984).

A good example that is related to introducing new design and technology into fishing communities was the project that was undertaken in Western Samoa in the final years of the 1970s by FAO/DANIDA. Five boats with varied designs were developed and tested by local fishers before it was decided which boat would be built on a relatively large numbers. In contrast to the initial predictions, the local fishers preferred the 8.5m plywood-catamaran design powered by a 25hp out-board petrol engine, compared to the single-hull boat powered by an inboard diesel engine. The shallow waters around most of their home ports was believed to be the main reason for local fishers' preference for catamaran boats. In its development, this catamaran fishing boat, locally known as *Alia*, was built with aluminium at the end of 1970s and became popular with the fishers in this particular region (Gulbrandsen and Overa, 1977; Gulbrandsen, 1988; Chapman, 1998).

Based on an observation of a number of projects that were conducted by the FAO in many developing countries, Gulbrandsen (1988) identified several points that needed to be considered when developing fishing vessels or when introducing new technology in fishing communities: 1) that there is no single identical design that can be applied to entire fishing communities, 2) the new proposed fishing boat must be field tested by several fishers over a long period of time prior to it being built in greater numbers, 3) the application of new alternative technologies must be assessed carefully, 4) the design and technologies that succeed in industrial countries are mostly irrelevant in developing countries, 5) the traditional fishing boat must not be underestimated.

3.4 Steps to Design Sustainable Fishing Vessels for Indonesia

With regard to the development of fishing vessels in Indonesia, when introducing a new design for specific fishing communities, it is also essential to organise the steps that are required to design the vessels, from identifying the mission profile of the vessels to drawing in detail the final design. Additionally, arranging a proper well-thought out procedure is essential for designing fishing vessels in Indonesia, seeing as most current fishing vessels are very traditional fishing boats that have never passed through a design process in a formalised conventional way.

In fact, traditional fishing vessels have never been designed. Instead, they have evolved in '*a technological version of natural selection*' and have been developed from experiences over many centuries, as practical solutions to the numerous problems faced by local fishers and their fishing communities, until the final design was accepted by local fishers as the optimum solution for local dilemmas in their specific fishing practices (Birmingham and Sampson, 2001). The local conditions that influenced the evolution of the vessels, including the availability and characteristics of local resources consisted of the fish stocks, timber, etc.; the geographical features of the home port and their traditional fishing grounds, and moreover, the knowledge and skill that the local fishers and local boat builders have collectively evolved.

However, in order to have better designed fishing vessels in Indonesia in the future, an appropriate formalised method of fishing vessel design with a more structured and systematic design process is required. For this reason, the concept of the design spiral for fishing vessels prepared by Fyson (1985) has been applied and adapted for this study taking account of the characteristics of fishing communities in Indonesia and the implementation of sustainable development as is applies to the vessels.

Figure 3.1 demonstrates the adapted design spiral in order to design sustainable fishing vessels for specific fishing communities in Indonesia. This new design spiral, which represents a process of iterative approximations and refinement until a final practical solution is reached, has incorporated several issues concerning the social, economic and environmental aspects potentially confronted by fishers during the full life cycle of their fishing vessels. The italic and bold texts in several stages of this adapted design spiral explains in which stages the three pillars of sustainability are thoroughly assessed and deliberated. The main objective when taking into account the implementation of the three pillars in various stages of the spiral design is to ensure that the fishing vessel that is designed using this particular method can fulfil the requirements for sustainable fishing vessels.

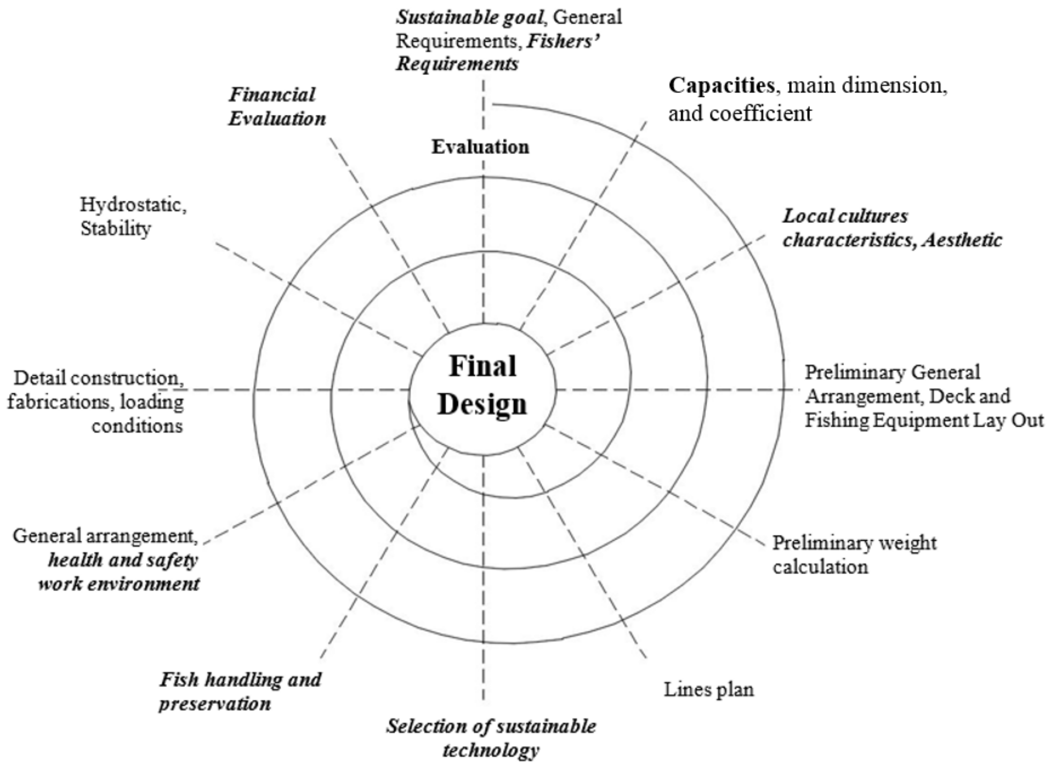


Figure 3.1 Adapted design spiral for sustainable fishing vessels

The design activities that need to be conducted for each stage of the design spiral according to Figure 3.1 can be described as follows:

1. *Sustainable goal, fishers' requirements and other general requirements,*
   At the first stage of the design process related to the sustainable fishing vessel, it is important to define and underline the goal of the design process, which identifies the target final outcomes of the process in term of sustainability. The first step in connection with achieving the sustainable goal regarding fishing vessel design is to ensure that the design requirements are in line with the full range of the local fishers' needs. Therefore, a personal approach is required with local fishers, with the aim of eliciting their requirements related to the design of fishing vessels.

2. *Capacities, main dimensions and coefficients,*
   As soon as the design requirements are available, the expected carrying capacities of the new design can be identified, in conjunction with the main dimensions and shape coefficient of the new design. The main dimensions, capacities and coefficients of the new design can be obtained by using a number of existing fishing vessels as comparators, or as the basis vessels. These comparators or basis vessels can be selected from the local fishing vessels that have operated in traditional fishing grounds and have been accepted by local fishers.

3. *Local culture characteristics and aesthetics*
   This stage of the design process attempts to identify the visual style and characteristics of local fishing vessels that have a connection with local culture and therefore need to be retained in the new design, in order to increase local fishers' approval of the new design. These attributes comprise specific features of the boats, typical ornaments that decorate the vessels and other aesthetic aspects of the vessels.

4. *Preliminary General Arrangement, Deck and Fishing Equipment Lay Out*
   Based on the selected main dimensions, the initial general arrangement of the vessel is planned. Along the profile view of the vessel, the position of engine room, fish hold, the accommodation for crew and storage for fishing gear are arranged. From the plan view, the area required for accommodation and working spaces, consisting of the area for setting and hauling the fishing gear, for handling and storing catches, etc. are arranged; thus, the initial lay out of the deck is sketched. Fishers' requirements concerning working areas, the position of accommodation and the storage of fishing equipment are used as guidance for this stage.

5. Preliminary weight calculations
   Preliminary weight calculations are conducted, in order to predict how much displacement is required for the new vessel in order to cover its designed payload or deadweight. The displacement prediction will be required in order to generate the lines plan that will be designed in the next stage. This preliminary weight calculation is the best weight estimation pertaining to the vessel's structure, main engine and general equipment, fishing gear, crew and their luggage, consumables and maximum anticipated fish catches.

   Concerning the weight of the vessel's structure, the selected construction material for the new design is decided in these stages. However, since the construction materials also affect the sustainability of the fishing vessels, its selection should be undertaken via a through-life sustainability assessment. The local fishers' preference related to construction material has to be one of the primary concerns in this assessment.

6. Lines plan
   Based on the selected main dimensions, preliminary weight calculation, the result of the study into the aesthetics of local fishing vessels and moreover, the

preliminary general arrangement, the lines plan of the new vessel can be generated. One of the main considerations of the lines plan design is how the proposed hull shape relates to the existing traditional hull shapes. For instance, the inclination of the sheer line in the existing traditional fishing vessels could be adapted and applied in the new design.

7. Selection of sustainable technology on-board

   The selection of technologies in this stage, including the selection of the main engine, auxiliary engine and other technologies that will be installed on-board, should remember the sustainable goal that was established earlier. For this reason, the selection of technologies for the new design need to be assessed concerning their social, economic and environmental aspects.

8. Fish Handling and preservation

   Fish handling and catch preservation are essential for fishing vessels. Ensuring the quality of the catch during fishing trips until they are landed is imperative, in order to maintain the value of the fish. The method of fish handling on board will be influenced by the type of fish being targeted, the fishing method and type of fishing gear, while the method of fish preservation will be affected by the length of fishing duration, volume of catch, and the fishers' preferences.

9. General arrangement, health and safety work environment

   Based on the results from the previous stages, specifically the initial lines plan, preliminary general arrangement and the technologies selected, the revised general arrangement can be designed. Aspects related to the visual aesthetics of the design remain one of the main concerns, given that it will influence the acceptability to the fishers of the new design; furthermore, local features that could possibly be applied can be adapted in the new design. Moreover, given that a healthy and safe working environment has become crucial regarding sustainable fishing vessels, this aspect needs to be carefully considered during the design of the vessel.

10. Detailed construction, fabrication, loading conditions

    Based on the revised general arrangement, lines plan and selected construction materials, the structure of the vessels can be designed in some detail. The identification of the structure's scantling will follow meticulous rules appropriate to the selected construction materials. When the detailed construction has been identified, a more complete weight calculation can be obtained.

11. Hydrostatic and stability

    In order to ensure the safe operation of the vessel, the stability of the new design is to be confirmed by assessing the stability of the vessel in all loading conditions that the fishers may be experience during the vessel's operations. Various loading scenarios can be listed and analysed, including extreme conditions that create unusual risks in connection with the stability of the vessel, as well as the regular operations, and standard such as conditions when leaving and returning home to port.

12. Economic assessment

    An economic assessment is conducted on the new design, in order to understand the costs relating to its construction and outfit. Furthermore, an analysis of the profit that it is possible to earn from the vessel during its life cycle also needs to be examined. Certainly, this profit should consider the expenses due to operational costs, maintenance and repair of the vessels, whilst also taking into account the depreciation costs.

13. Evaluation

    The evaluation stages of the design spiral aims at verifying the results of the design related to the mission profile of the vessel and the sustainable goals set initially. The next cycles of the design process aims to review and refine the design until it converges on a viable result that successfully meets all the design requirements.

3.5 Design Requirement for Sustainable Fishing Vessels

The preliminary stages of the design process in the design spiral of the sustainable fishing vessel, requires the identification of fishers' requirements and other additional general requirements, which are necessary for the entire design process. Therefore, it is essential to organise the design requirements at the initial stage of the design process. The ideal design requirements are the guiding principles that enable the designer to develop vessels of appropriate size and configurations, in accordance with the various mission profiles. Hence, the success in relation to developing these fishing vessels will be determined by the accuracy of identifying the fundamental design requirements of the vessels.

The above generic description of the development of fishing vessels in many countries demonstrates that there are many factors which should be deliberated when designing vessels for specific fishing communities. The examples discussed earlier confirm that the social aspect, especially acceptance by the fisher, is a significant factor that needs to be considered over when introducing a new ship design or even new technology, in addition to the more fundamental and obvious technical and economic aspects. This illustrates that each fishing community often has its own specific intrinsic requirements that need to be fulfilled and that these will affect the local fishers' acceptance of the design of the boats and the technologies applied on-board. The fishers' acceptance, based on the FAO's experience of the development of fishing vessels, was partly affected by their economic background or by their competencies in operating the technologies on-board. For this reason, these two matters related to the fishers' economic background and skills need to be established as part of the vessels design requirements.

Based on the FAO's programmes on fishing vessel development in the 1970s and 1980s, Fyson (1985) and Gulbrandsen (1988), who are two experts that worked for the FAO on the development of fishing vessels, identified a list of factors that affect the

Table 3.1 List of factors affecting the design of fishing vessels
(Fyson, 1985; Gulbrandsen, 1988; FAO, 2015b)

No	Fyson (1985)	Gulbrandsen (1988)	FAO (2015)
1	Fish species available to be caught, quantity of fish liable to be caught, radius of trip, expected catch rate	Fish Resources, distance to fishing grounds	The species, location, abundance and dispersion of the fish resources
2	Fishing gear & methods	Fishing gear	Fishing gear and methods
3	Geographical characteristics of the fishing area	Size limitation, beaching, shallow draft, number of crew and accommodation	Geographical and climatic characteristics of the fishing area
4	Seaworthiness of the vessel and crew safety	-	Seaworthiness of the vessel and safety of the crew
5	Laws and regulations applicable to fishing vessel design	-	Laws and regulations applicable to fishing vessel design, construction and equipment
6	Choice of construction material	Available materials	Choice and availability of construction materials
7	Handling and stowage of the catch	Catch preservation	Handling, processing and stowage of catch
8	Economics (Profitable, Affordable building costs)	- Markets - Available engines & fuel	Availability of finance, economic viability
9	-	- Skills for building and maintenance - Crew's skill	Availability of boatbuilding and fishing skills
10	-	- Needs of fishing community - Social traditions	

design of fishing boats. Table 3.1 compares the lists prepared by these two experts, in addition to the list that was later formulated by the FAO (2015).

Table 3.1 allows a comparison of the three lists of factors. In terms of the technical aspects of the vessel there are practically no differences, however, due to increasing concern in relation to social and environmental issues, these factors affecting the design of fishing vessels have been expanded. The incorporation of the fishers' skill, the needs of the local fishing community and their social traditions are factors affecting the design of the vessels and illustrate that social factors can influence the success of introducing a new design and new technology in fishing communities.

In fact, according to the FAO, introducing a completely new design and technology into local fishing communities without first undertaking an in-depth study concerning the needs of the local fishers, their common fishing practices and their existing traditional local fishing vessels could seriously affect the success of the programmes (Gulbrandsen, 1988). The interaction of the local communities with their fishing vessels over many years means that the vessels are not only mechanisms for earning a profit but they also represent the local identity of the individual fishing communities as a cultural artefact (Rosyid and Johnson, 2005). Additionally, in many fishing communities, their traditional fishing vessels have become part of local culture related to their belief in the 'goddess of the sea' or other kinds of superstitions which affect their mental attitudes and sense of well-being in the context of the dangers and uncertainties in fishing activities. This is illustrated in Figure 3.2, a ritual called "Petik Laut", when the local

(a) (b)

Figure 3.2 The ritual of local fishers called "Petik Laut" in Muncar, East Java
a) Traditional boats are decorated more attractively to bring the offers to the sea (http://beritadaerah.co.id/2013/11/19/tradisi-petik-laut-muncar-banyuwangi-jawa-timur/); b) a miniature of a local fishing boat full of local crops given as an offering (source: http://dotcomcell.com/BANYUWANGIONLINE/PETIKLAUT/)

fishers throw offerings into the sea to express their gratitude for what they obtain from the sea (Nugroho, 2012). Therefore, to replace the traditional fishing boat with a newly designed vessel requires more understanding and sensitivity of the connections between traditional fishing vessels and local fishing communities, and their cultured beliefs.

In addition to social concerns, there are also increasing concerns associated with environmental issues, and which will affect to some degree the design of fishing vessels. According to Table 3.1, the factors affecting the design of the fishing vessels have been expanded by considering more detailed aspects of the resources. These consist of the species of fish, the fish habitats, and also the abundance and distribution of fish resources. The details related to the availability of fish resources need to be taken into account in the design requirements of the fishing vessels, in order to ensure that the operation of the vessels never endangers the sustainability of the resources.

From the above discussions it is clear that the factors affecting fishing vessel design have become more complex. They are not only associated with conventional small vessel design requirements, which only consider the technical, functional and economic aspects of the vessels, but are also related to the social and environmental aspects of the vessels.

Based on earlier illustrations related to developing fishing vessels concerned with responding to changes of the particular constraints when developing such vessels**,** the more complex inter-connected design requirements in relation to designing sustainable fishing vessels have been identified, and are presented in Table 3.2. The requirements and considerations are divided into four related groups namely environmental, social, economic, and technical.

Each group contains several factors that should be considered when designing sustainable fishing vessels. Although the identified design requirements have been classified into four groups, the requirements within the four groups are in fact inter-connected. For instance, conditions related to the species of fish that are allowed to be caught as given in the ‘environmental’ group will have a connection with the choice of fishing method given in the ‘economic’ group, and with the on-board choices concerning fish handling and preservation as given in the’ technical’ group.

The ‘environmental’ group contains the requirements and considerations in order to ensure the sustainability of fish resources and the preservation of the marine environment. In addition to considering the fishers' requirements about fish targets, it is essential to be aware of any local or national regulations that control the amount and types of fish that can be caught in targeted fishing grounds. Furthermore, the design should also bear in mind any regulations that control the implementation of any devices on-board with the intention of preventing pollution to the sea.

It is clearly crucial to take into account the social aspects of the fishing vessel when developing new boats for specific fishing communities, as it will affect the acceptability of a new design. Therefore, the 'social' group in the design requirements contains factors concerned with the attitude, conditions and characteristics of the fishers and their fishing communities. By considering this group of design requirements, the design is expected to suit the local fishers' requirements and preferences, and to minimise human factors' difficulties when operating the vessels, seeing as it is designed according to their skills. Furthermore, so as to increase the connection between a new design and

Table 3.2 Design requirements intended for a sustainable fishing vessel

	Design Requirements
Environmental	• Size and species of fish allowed to be caught • Size and type of fishing gear allowed to be operated • Fishing capacity, Individual Fishing Quotas (IFQs) • Allocation of fishing grounds based on the size of the vessel • Regulations related to marine pollution
Social	• Fishers' requirements and preferences • Fishers' competencies • Local culture and practices • Aesthetic • Organisation or management of crews • Health and safety environment • Fishers' awareness and views related to environment, social and economic issues • Regulations related to health and safety, regulations related to fishers/seafarers
Economic	• Mission profile: - Method of fishing - Fishing capacity - Size of the crews - Duration of fishing trip - Distance to fishing ground • Ownership & financing structure • Fishers' economic background • Market and supply chain support
Technical	• Geographical characteristics • Construction material • Fish handling and preservation systems • Powering and propulsion system • Others supporting technology on board • Technical support for installed equipment • Regulation related to the structure of the vessel

local fishers, this group of design requirements also considers local culture and aesthetics traditionally embedded in their fishing vessels, when designing the vessel. The local culture could be simply the ornaments that decorate the vessels, or it could incorporate the hierarchy or organisation of the crew that in some cases will affect the arrangement of accommodation on board. For instance, in some communities, the skipper, who is occasionally the owner of the vessel, would be in the same room with other crew, while in other communities, the captain would have his own room or area on-board. Further social issues of concern to local fishers and their fishing community are the hazards that the fishers encounter when fishing; therefore, the health and safety issues needs to be prioritised when designing the vessel.

The factors associated with the economic viability of the vessel are categorised in the ‘economic’ group. This group of requirements need to be reflected upon, with the aim of ensuring that the new design can provide the fishers with a reasonable profit. Additionally, the appropriate mission profile will improve the potential productivity of the vessel and subsequently increase the fishers’ profit. However, when the establishing mission profile of the vessel, in addition to maximising the potential profit that the vessel could achieve, the new design needs to understand the limitations of the mission profile. For instance, the fishers’ economic background frequently limits the operational cost of the vessel, which eventually hampers the duration and distance of fishing trip. There may also be regulations that restrict the operation of the vessel, such as fishing ground limitations or restrictions on fish targets. Additional requirements that need to be considered in the ‘economic’ group are the availability of a market for the fish, and the accessibility of a supply chain for fuel, spare-parts and servicing for the on-board technologies. An insufficient availability of these elements could reduce the economic viability of the new design.

The last group is the ‘technical’ group, which contains a number of common requirements to achieve an enhanced performance from the fishing vessel as a reliable and safe craft. During the identification of these requirements, the other groups of requirements also must be taken into account, in order to make sure that there is no conflict related to the requirements.

3.6 Concluding Remarks

A sustainable fishing vessel could be defined as being a fishing vessel that has solutions for various issues related to social, economic and environmental aspects, as a consequence of the intended operations of the vessels to exploit the fish resources, in conjunction with the impact of the initial manufacturing and the eventual disposal of the vessel.

The experience of the FAO in relation to the development of fishing vessels in many countries around the world revealed that in addition to the many technical and economic factors that are involved, new fishing vessels that are successful in the long term are influenced by how the design and associated technology fit with the characteristics of local fishers, seeing as every fishing community is unique. Moreover, it should minimise the potential negative impact of the vessels' operations on the fish stocks and the marine environment.

Sustainable fishing vessels can only be developed if the design process considers each design requirement in the context of managing potential challenges related to the three pillars of sustainability along the full life cycle of the vessel.

Most fishing vessels in Indonesia are traditional fishing vessels that have never gone through any form of conventional design process; instead they have evolved over many generations in order to overcome the numerous challenges faced by local fishers. In addition to more complex design requirements for the development of sustainable fishing vessels for Indonesian fisheries in the future, a proper design method is required for such vessels. For that reason, the adapted design spiral that considers and incorporates the implementation of the three pillars of sustainability has been identified in this chapter.

Chapter 4. Eliciting Fishers' Views and the Current Conditions of Traditional Fishing Vessels

4.1 Introduction

As described in Chapter 3, one group of factors affecting the design of the sustainable fishing vessels is the social aspects related to the introduction of a new design of fishing vessel. Included among the factors in this group are fishers' views that are related to the operational environment including their immediate community and the local economy; fishers' technical requirements and preferences; also fishers' experience and competencies.

In order to obtain complete and comprehensive descriptions in support of the social issues that correlate with and affect in some way the development of fishing vessels in specific fishing communities, the appropriate practical method that is to be applied is by collecting and compiling relevant information and opinions from local fishers and related stakeholders in the fisheries sector. Local fisheries stakeholders, the fishers themselves in particular, are clearly an important source of input regarding the rational development of fishing vessels. This is due to the fact that their collective experiences, observations, preferences, and also their expectations related to fishing vessels and the fisheries sector are highly significant when developing sustainable fishing vessels for specific fishing communities.

In addition to understanding the complex social issues of importance to the development of fishing boats, it is also essential to recognise the current condition of the existing traditional fishing fleet and the many problems that are faced by local fishers related to the day to day and future operation of the vessels. Furthermore, having an understanding of the physical characteristics and attributes of traditional fishing vessels could be the starting point, and a bench-mark, for developing new fishing vessels that are acceptable to the local fishers and their communities.

For this reason a field study was undertaken concerned primarily with social issues in selected fishing communities in Indonesia. This was performed in order to identify and understand the relative importance of the many social issues that must be considered when developing sustainable fishing vessels in general and when designing a vessel for a specific fishing community in Indonesia.

In this chapter, the methods that were applied in order to elicit the information from local stakeholders will be detailed, together with a brief description of each of the selected fishing communities including the respondents. Kinds of information that were obtained from this field study and of how the outcomes will be used in the next stage of the project will be described.

4.2 Field Study: Engaging with Local Stakeholders

Involving local people is clearly the best approach to identifying actual and latent problems and to explore possible solutions to overcome these problems faced by a community. The collective knowledge and experiences of the community members are crucial with regards to any effort that made to find feasible solutions for the complex issues which communities are confronted with (Corburn, 2002).

The field study was undertaken in three selected fishing communities in Indonesia, in order to identify the spectrum of social issues that could affect the development of sustainable fishing vessels and in addition to have an overview of the condition of existing traditional fishing boats in Indonesia.

The methods that were applied to collect information from local stakeholders in the fisheries sector were in-depth interviews, Focus Group Discussions (FGDs), and field observation in the selected fishing communities. These activities were undertaken on three separate occasions during the three years of the project.

Given that the outcome of the field study was used as input for the design of the sustainable fishing vessels, the objectives of this field study are as follows:

1. To identify the local fishers' views concerning the existing condition of the overall fisheries sector in their region, particularly associated with the future sustainability of this sector.
2. To understand local fishers' awareness regarding regulations, health and safety in the working environment, and marine pollution prevention measures on board.
3. To understand the level of current technologies installed in traditional fishing boats.
4. To identify local fishers' responses to potential new, alternative technologies that can possibly be applied in their current fishing boats.
5. To identify local fishers' requirements regarding the characteristic and detail of the new designs of the fishing vessels.
6. To collect fishers' feedback related to the proposed designs of fishing vessels.

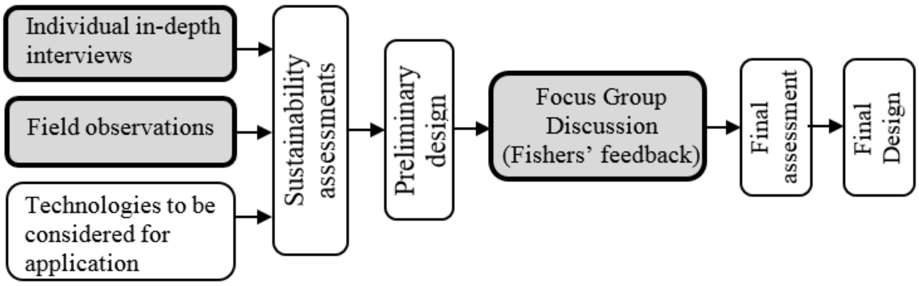


Figure 4.1 Outcomes of the field study as input for designing the sustainable fishing vessel

The results of the field work was analysed and evaluated, establishing how these outcomes influence decisions made during every stage of the design process. Figure 4.1 demonstrates how the results from the field study were used.

The results of the in-depth interviews, the focus group discussions and the field observations in conjunction with the analyses and discussions of these outcomes are presented in several chapters of the thesis, as follows:

1. The fishers' views on the subject of the overall condition of the fisheries sector in their geographical region and furthermore the current conditions of local fishing vessels themselves are presented in Chapter 6, followed by an identification of the potential impact of these results on the design process for the proposed fishing vessels.
2. The fishers' preferences related to established alternative technologies that can possibly be employed in their fishing vessels are described in Chapter 7, together with an assessment of the alternative technologies in economic and environmental terms.
3. The aesthetic and local culture that is embedded in traditional fishing boats in three selected fishing communities are discussed in Chapter 8, in conjunction with a discussion on how these particular aspects will and do influence the design of fishing vessels.
4. The fishers' requirements in association with the design of the new fishing vessel are deliberated in Chapter 9 together with the design of the proposed fishing vessel for selected fishing community.

4.3 Selected Fishing Communities

In order to provide a broad overview regarding the conditions of both the fisheries sector and the current fishing vessels in Indonesia, three fishing communities were selected for the field study. Two fishing communities are located in the province of East

Java, these being representative of fisheries in the western region of Indonesia, while the other fishing community is located in Maluku province, this being representative of the fisheries in the eastern part of Indonesia.

The reason for selecting the fishing community in the Maluku Islands, in addition to two fishing communities on Java Island, is to have a wider perspective concerning the relative conditions of the fisheries sector and traditional fishing vessels in these quite different areas of Indonesia. This is partly due to the fact that Java Island with the largest population in Indonesia is considered to be experiencing increased levels of development and to have a greater infrastructure compared to other islands in Indonesia, especially compared to the eastern region of Indonesia. Therefore, resources in the eastern areas of Indonesia are relatively less explored and developed (Mous *et al.*, 2005; USAID, 2013). The national problems with regards to infrastructure and logistics, for example, have affected development in many ways in Indonesia, including the fisheries sector. Therefore, in order to understand how these different conditions will affect the development of sustainable fishing vessels across Indonesia, one fishing community in the eastern provinces of Indonesia had been selected for inclusion in the field study.

The two fishing communities in the province of East Java are Brondong and Muncar, while the fishing community in the Maluku Province is known as Latuhalat, as can be seen in Figure 4.2. These three fishing communities are the focus for the field study because they have been recognised as being at the centre of the capture fisheries in

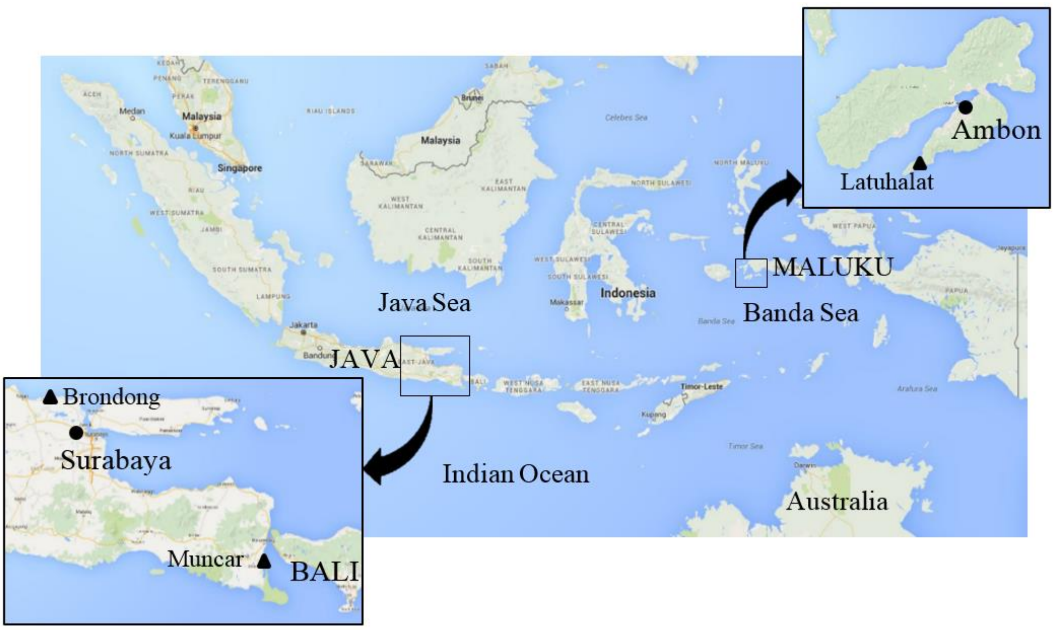


Figure 4.2 Fishing communities in Indonesia selected for the field study
(Adapted from https://www.google.co.uk/maps/)

Indonesia. Furthermore, each of the three of them undertake relatively different fishing practices, including the type of fishing method employed, the typical length of fishing trips, and the constraints imposed in different Indonesian Fisheries Management Areas (FMAs). The other important reason is the existence of an extensive range of fishing fleets that are operated in these communities, from small fishing boats that are less than 3GT, often with outriggers, up to large fishing vessels which are more than 30GT. These diverse circumstances will provide a comprehensive picture of the current condition of the Indonesian fisheries and of the fishing fleets in particular.

The first fishing community that was selected, Brondong Village, is located approximately 70kms northwest of Surabaya city, the capital city of East Java Province. This village is situated next to the Java Sea on the north of Java Island, which is included in Fisheries Management Area (FMA) 712. A positive factor related to the fisheries sector in this region is the accessibility of Brondong fishing port, shown in Figure 4.3, and the existence of numerous fish product manufacturer that process most of the fish landed in this area. Brondong fishing port is classified as a type “B” fishing port, meaning that the depth of water in the port is at least 3 metres, and it is able to cater for more than 75 individual 30GT size fishing boats in its docks at any one time (MMAF, 2012).

The second fishing community, Muncar Village, is located on the most eastern part of Java Island, approximately 210kms east of Surabaya City. The waterfront of this village faces the Bali Strait, separating Java Island and Bali Island, and is included in FMA 573, which is part of the Indian Ocean to the south of Java Island. Muncar is also well-

(a) (b)

Figure 4.3 View of Brondong Fishing Port
a) Aerial view of Brondong fishing port (mapcarta.com/Java); b) Preparations being undertaken at Brondong fishing port for a fishing trip (Photo by the Author).

(a) (b)

Figure 4.4 View of Muncar Fishing Port
a) Aerial view of Muncar fishing port (mapcarta.com/Java); b) Fish landed at Muncar fishing port (Photo courtesy of Prof. Birmingham).

known as one of the centres for the canned sardine industry, supported by good accessibility to Muncar fishing port, as revealed in Figure 5.3. Muncar fishing port is categorised as a type “C” fishing port. The standard for this type of fishing port is that it must have a depth of water of at least 2 metres, and that its docks are able to cater for a minimum of 30 individual 10GT fishing boats (MMAF, 2012).

The final fishing community in connection with this field study, Latuhalat village, is located at the tip of the south western part of Ambon Island, one of the principal islands in Maluku Province. This village is roughly 25km to the south and west of Ambon City, the capital city of Maluku Province. The northern part of Latuhalat faces Ambon Bay, which is relatively shallow, while its southern part faces the Banda Sea, a deep sea,

(a) (b)

Figure 4.5 Eri fishing port close to Latuhalat village
a) Aerial view of Eri fishing port (mapcarta.com/Maluku); b) A Latuhalat fishing boat anchored at Eri fishing port (Photo by the Author).

which is part of FMA 714. In order to facilitate this fishery, a type “D” fishing port has been established at Eri village, which is approximately 1.5 nautical miles from Latuhalat village in Ambon Bay, as depicted in Figure 4.5. This type of fishing port has a water depth of at least one metre and is able to manage a minimum of 15 individual 5GT size fishing boats. In addition to this small fishing port, local fishers can also land their catches at Ambon National Fishing Port, which is roughly 7 nautical miles from the village that close to cold storages for frozen fish industries.

4.4 Methodology for Collecting Data

In order to obtain all of the required information related to the existing conditions of the fisheries sectors and of the fishing boats in the three selected fishing communities, including any challenges faced by local fishers, three data collection methods were undertaken. The methods employed were in-depth interviews, field observations and focus group discussions. The following sub-sections explore how each of these three methods were conducted throughout the field study.

4.4.1 In-depth interviews

In order to elicit people’s knowledge, experiences and also their perspectives concerning problems in their local society and its environment, there are several methods that can be used. In order to elicit information, the “interview” approach is frequently applied, as it has several advantages in terms of facilitating and controlling the progressive process of information elicitation. Additionally, interviews allow for complex questions to be elaborated and so minimise bias or respondents’ possible incorrect interpretation of the questions (Schutt, 2015)

The depth of information gathered from the interview can be controlled by means of how the questions are prepared and asked throughout the interview process. A structured interview is a type of interview method in which a list of questions are prepared and the interviewer only asks the certain questions in the prepared. In contrast the semi-structured interview, also known as the in-depth interview, is a more flexible interview conducted in more informal manner, which enables the interviewer to further explore and clarify the respondents’ responses to obtain a greater understanding of the issues. Furthermore, the questions devised for the in-depth interview method are often open-ended and the interviewer will prepare follow-up questions depending on the respondents’ responses and reactions (Schutt, 1996; Greenbaum, 2000).

The gradual emergence of trust between the interviewer and the respondent is an additional advantage of the in-depth interview; hence, further information can be elicited from respondents, even regarding more sensitive issues (Hamilton *et al.*, 2011). Therefore, this method enables the interviewer to have an enhanced understanding that will provide more comprehensive and relevant information to explain any findings acquired during the interview (Gaskell, 2000).

For this project in-depth interviews were undertaken in two separate sessions. The first set of interviews, which were undertaken in each of the three selected fishing communities from August – October 2013, were associated with the identification of the fishers' perspectives relative to the current condition of their local fisheries sector and the fishing boats in their individual fishing communities. The interviews also explored their preferences in relation to alternative technologies that could be incorporated in their fishing vessels.

The second session of interviews was performed solely in the Muncar fishing community on November 2014. These were more specific, so as to elicit fishers' requirements regarding the features of the expected design of the new fishing vessel. Consequently, these fishers' requirements were subsequently used as preliminary input for the design of the proposed sustainable fishing vessel.

The material obtained from the first session of interviews could be conveniently classified into a number of categories as follows:

1. Respondent' background, such as name, age, level of education, position on board a vessel, and years of experience.
2. General information regarding the respondent' existing fishing boat, including the main dimensions, capacity, number of crew, fishing grounds, fuel consumption, and duration of fishing trip.
3. Technologies incorporated on existing fishing boats together with any problems faced by respondents with regards to each particular technology.
4. Health and safety practices on board, including the availability of safety equipment on respondents' fishing boats
5. The form of prevention of marine pollution as a result of fishing activities on board.
6. Respondents' responses and preferences regarding the possibilities of employing alternative technologies for their fishing boats. In order to identify the alternative technologies that may be applied on local fishing vessels, a study was conducted on

both the established and state-of-the-art technology on fishing vessels, with the outcomes presented in Chapter 5.

7. Respondents' understanding of the official regulations related to all aepects of fishing practices and the consequences of violating such regulations.
8. Respondents' observations concerning any changes that have occurred in their local fisheries sectors over the last few years and their opinions in relation to the sustainability of this sector, including whether younger generations are interested in becoming fishers.

Since the objective of the second session of interview is to obtain the input for designing the proposed fishing vessel, therefore the second set of interview elicited local fishers' requirement regarding:

1. The expected mission profiles of the proposed fishing vessel
2. The anticipated general arrangement especially deck lay out
3. The confirmation of local fishers' preferences regarding technologies applied on board
4. Information about traditional features that need to be retained on board the new fishing vessel.

Details of the interview questions and an example of the fishers' responses from the first session of interviews are given in *Appendix A-2*.

During the interviews concerning the fishers' preferences on alternative technologies, several alternative technologies that could to be applied in local fishing vessels were introduced to respondents. In order to assist the respondents in their understanding of the new alternative technologies, a simple flyer consisting of images and brief explanation of the alternative technologies was prepared and presented to the respondents. The sample of this particular flyer as an interview aid can be seen in *Appendix A-3*.

Issues that emerge in one community are generally a common concern amongst many members of that community, therefore a greater number of respondents does not necessarily result in an enhanced understanding (Gaskell, 2000). Furthermore, typically each in-depth interview took one hour or more, and results in large number of pages of interview transcribe that then need to be analysed. For that reason, it is recommended that the number of respondents participating in in-depth interviews undertaken by a single researcher should be between 15 to 25 respondents (Gaskell, 2000; Crouch and McKenzie, 2006)

The process of the recruitment of the candidates followed the so-called “snowball” method that utilises the respondents’ own network in order to recruit other potential candidates to then participate in the interviews (Biernacki and Waldorf, 1981; Patrick *et al.*, 1998; Noy, 2008). The respondents were initially recruited by local contacts who in the first place explained the purpose of the interview and then asked whether or not an individual might be interested in participating. The local contacts in Muncar and Brondong were students and alumni of the Surabaya State Shipbuilding Polytechnic, where the author is employed as a member of the academic staff. While in Ambon, the local contacts were students of the Department of Naval Architecture at the University of Pattimura in Ambon. Furthermore, the first few respondents in Brondong and Muncar were relatives and neighbours of the local contacts. While in Latuhalat, the first few respondents were acquaintances of the local contacts from their previous projects. Thus, from these first group of respondents, the information about the next potential candidates were obtained. In addition to respondents who were the actual fishers, furthers initial contacts were conducted by the author, particularly for harbour masters and fisheries officers, for who a more formal approach was required.

For the first session of interviews a total 89 of respondents were interviewed. Of these 68 respondents were local fishers and 21 respondents other stakeholders in the fisheries sector from the three selected fishing communities. The related stakeholders that were involved in the interviews are shown in Table 4.1.

For the second set of interviews specifically concerning the development of the design requirements, ten respondents were recruited for the in-depth interviews. All ten

Table 4.1 Number of respondents for the first session of interviews

Group Number	Respondents	Total
1	Fishers in Brondong	28
2	Fishers in Muncar	25
3	Fishers in Latuhalat	15
4	Boat builders	6
5	Harbour masters	2
6	Fisheries officers	5
7	Ice makers	2
8	Engine supplier	1
9	Fish traders	5
	Total Respondents =	89

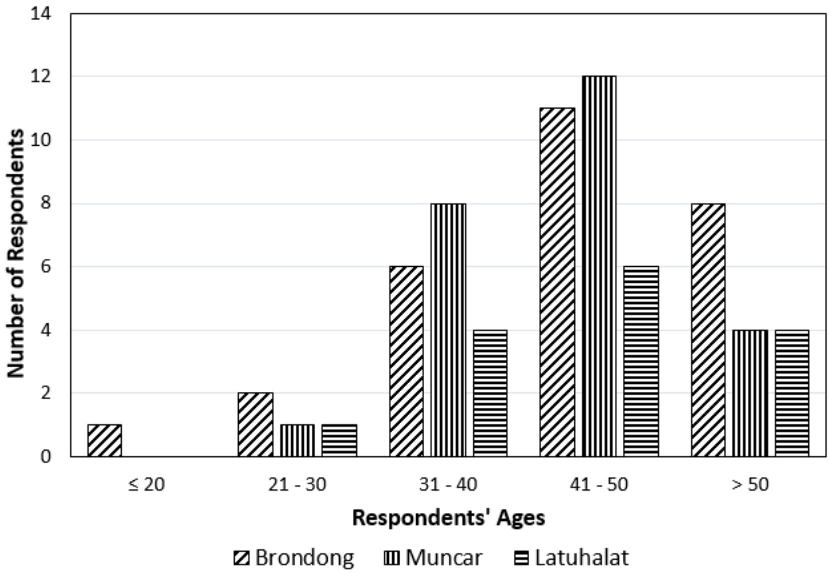


Figure 4.6 Distribution of respondents in three fishing communities based on their age

respondents were selected from the list of respondents in Muncar who had been involved previously in the first period of interviews.

In order to provide a general description of the respondents involved in the first interviews, the bar charts in Figure 4.6 and Figure 4.7 show the basic characteristics of the respondents. Figure 4.6 demonstrates the distribution of respondents in the three fishing communities based on their ages and Figure 4.7 based on their role on the vessels.

The highest number of respondents is in the 41 – 50 years old age group. Furthermore, as the goal of the interview was to elicit the fishers' views relative to the condition of

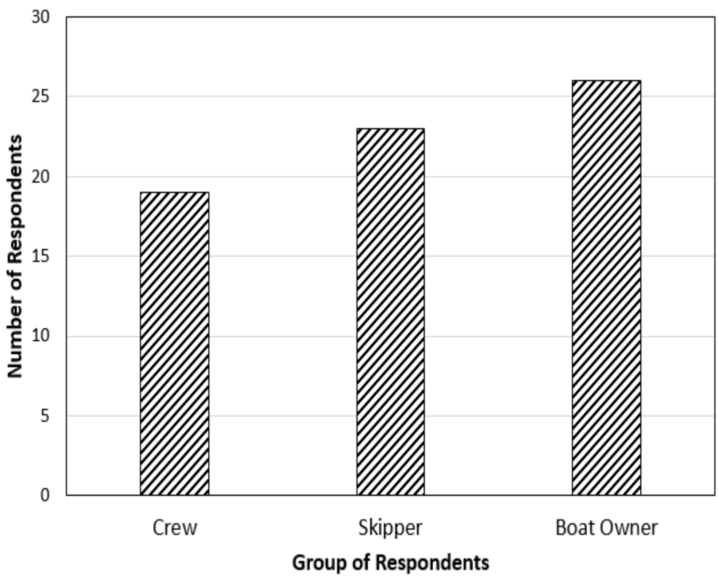


Figure 4.7 Distribution of all the respondents based on their position on the fishing vessels

(a) (b)

Figure 4.8 The interviews occurred at the respondents' request
a) on respondents' boats (Photo by the Author); b) or at respondents' houses (Photo by the Author).

the fisheries sector in their area, and of any changes, over the last few years, it is reasonable to assume that with the highest percentage of respondents in this age range, the responses were expected to be reasonably complete and reliable, as these respondents were able to offer more comprehensive longer term perspectives based on their extensive experience.

At the opening stage of each of the interviews, a description of the interview and of the entire project was explained in detail and the respondents' consent obtained. The interviews lasted for approximately one hour on average however a number of interviews took more than one and a half hour, due to the detail responses to the questions.

Most of the interviews occurred in the respondents' houses, either during the daytime or at night. However, as shown Figure 4.8, a considerable number of the interviews were actually undertaken on the respondents' boats when the fishers were preparing for their fishing trip or when undertaking maintenance of some form of their boats.

4.4.2 Focus Group Discussion (FGD)

FGD is a type of in-depth interview method that involves groups of people that have similar interests in one or a number of related issues. Since the interviewer acts more as a moderator, FGD enables a free dialogue among participants to develop in an informal setting (Wilkinson, 2004). Furthermore, with between six to eight participants (Gaskell, 2000), or even less for a mini-FGD (Greenbaum, 2000), discussions during the FGD can be more efficient, productive and constructive. Moreover, with the intention of encouraging and attracting participants to be actively involved in FGD, moderators can use several tools or techniques in order to assist with the development of the discussions, such as photographs, drawings, or even a role play (Gaskell, 2000).

As demonstrated by various FAO and Indonesian government programmes regarding the development of fishing vessels, the challenge of designing fishing vessels suitable to operate effectively in specific fishing communities, is related to how to ensure that the design fulfils the actual and latent needs and preferences of the local fishers. Then in order to ensure that the proposed design is highly acceptable for the targeted fishing community, further discussions need to be conducted with local fishers of the proposed fishing vessel design, once completed to a level where it can be evaluated. Therefore, in this study, Focus Group Discussions (FGDs) aimed at gathering local fishers' assessments, comments and input related to the proposed design was carried out in both the Muncar and the Brondong fishing communities.

The FGD in Muncar, which was carried out at one of the participant's houses, involved 17 participants in total, divided into three groups, each comprised of 5 or 6 local fishers and boat builders. With regards to Brondong, the discussion was undertaken at the fishers' union office, and involved only one group of 8 local fishers. The main FGDs concerning the proposed fishing vessel were conducted in Muncar, because that is where the fishing vessel is being targeted to be operated. The similar FGD in Brondong was undertaken in order to have an overview of whether the proposed designs, that had essentially been targeted for Muncar could be accepted by local fishers in Brondong. However, FGD was not conducted in Latuhalat since the characteristic of fishing vessels and the technologies applied on-board in this fishing community are significantly different compared to Muncar and Brondong. Therefore the probability of the proposed design to be refused is higher.

When considering the probable educational background of most of the fishers in the selected fishing communities, it was believed that the presentation of formal conventional design drawings such as a lines plan and a general arrangement drawing during the FGDs would not help the participants to have a genuine understanding of the proposed design. Therefore, based on the lines plan and general arrangement of the proposed initial design, solid physical model of the fishing boats, constructed with a scale of 1:40, were prepared to assist and provide the participants in the FGDs with a good visual assessment of the proposed design. By using the scale models, participants

Figure 4.9 The 3D design and models were used during the FGD in Brondong
(Photos by the Author)

could visually observe and assess many aspects of the proposed design from various angles.

Furthermore, three dimensional (3D) drawings of the proposed vessels (created using design software called SketchUp Pro) were presented during the discussion. These 3D drawings were presented to the FGD participants to provide more complete images relating to the inside of the accommodation and the wheelhouse, so that fishers could visualise the view that the skipper will have from the wheelhouse to the working deck and also all around the vessel. Moreover, by using 3D visualisation of the design, the examples of the proposed designs with surfaces rendered with a number of different colours and ornamentation can be presented in order to help the FGD participants fully imagine the design. Figure 4.9 illustrates how the 3D design and models were used during the FGD in Brondong.

In addition to using the scale model mock-ups and 3D drawings as discussion aids, the many aspects of the current fishing boats could also be used as tools and comparators in

Figure 4.10 Further discussion at the waterfront during the FGD in Brondong

order to assist with understanding the local fishers' preferences and challenges. Figure 4.10 illustrates the further discussions that took place with the FGD participants in Brondong concerning the new type of hull, originally from the distant region of Kalimantan Island, which has become more acceptable to the local fishers.

4.4.3 Field observations

In addition to the considerable body of information elicited by interviewing the many local fishers and related stakeholders, many direct observations were undertaken by the researcher to the traditional fishing vessels in selected fishing communities, with the aim of obtaining a greater understanding about the condition of traditional fishing boats, and, moreover, of the local fishers and their fishing communities.

Observation of the local fishing vessels not only provided a very tangible description of the current technologies that local fishers employ to support their fishing practices, but also allowed the researcher to understand the common operational practices routinely used by local fishers, and also to analyse the implications of any possible alternatives regarding future improvements.

In this case, observations of traditional fishing boats were focused on the shape of the boats, the technologies applied on board, the health and safety at work environment on board, specific features only found in local boats, and also on the ornaments that create the unique identity to the local boats.

Observations were also undertaken on numerous other activities in the local fishing ports and local boatyards to support findings revealed during analysis of the respondents' responses, for example on the local maintenance and repair activities.

4.5 Data Documentation and Analysis

With regards to the documentation of the data that has been acquired from the field study, the individual interviews and the FGD were all initially recorded and then subsequently transcribed verbatim. Moreover, the photographs taken during the field observations of the existing traditional fishing boats and the local environment have also been documented.

Software used for applications in the field of qualitative analysis, known as Nvivo, has been employed in order to store all of the collected data. This software enables data to be stored in many forms: text, audio, audio-visual, images, etc. Additionally, the software can also support the analysis stage, seeing as it can be used for grouping and coding the collected data based on pre-defined similar issues or classifications, for making connections between the groups, and for exploring the entire data via simple queries (Richards, 1999; Bazeley and Richards, 2000; QSR, 2016).

Analysing the data from the qualitative research, such as the in-depth interview, helps to elicit the essential features of what the participants actually thought concerning the various issues discussed during the interviews (Schutt, 2015).

The images from the photographs, just as in the interviews and other sources of information, can also provide valuable information for the researcher (Prosser and Schwartz, 1998). Therefore, in addition to the analysis on the responses to the in-depth interviews, the photographs taken from the associated field observations were also analysed and linked with the respondents' responses in order to support any essential findings related to various issues in the research questions.

Analyses of the respondents' responses from the first stage of the interviews were used to answer the research question concerning the fishers' perspectives related to the current condition of their fishing boats and of the fisheries sector in their region. Respondents' preferences, in association with the potential alternative technologies that can possibly be applied on their fishing vessels were scored by means of the Likert Scale and then used to discover sustainable technologies, as discussed in Chapter 7.

Analyses of respondents' responses from the second stage of the interviews were used to answer the research questions concerning the fishers' requirements in relation to the proposed new design for fishing vessels.

4.6 Concluding Remarks

In order to have relevant and comprehensive inputs concerning the social aspects related to designing a sustainable fishing vessel for a specific fishing community in Indonesia, field studies have been conducted in three selected fishing communities. There were two fishing communities in East Java Province, namely Brondong and Muncar, and one fishing community in Maluku Province, known as Latuhalat.

The groups of related stakeholders, in particular local fishers, were involved so as to share their views regarding the conditions of the fisheries sector in their areas, including the condition of their existing fishing vessels. Small groups of local fishers were also involved in providing feedback for the final design of the proposed fishing vessel. Additionally, the in-depth interviews and Focus Group Discussion methods have been employed to elicit the relevant information from selected respondents.

Furthermore, observations have been conducted on existing fishing boats in selected communities, in order to obtain a greater understanding regarding the condition of local vessels in term of technologies employed on-board, detailed profiles and the specific local identity of the vessels.

Chapter 5. Potential Alternative Technologies for Indonesian Fishing Vessels

5.1 Introduction

It is obvious that the enormous increase in fish capture production globally has been enabled and influenced by the tremendous development in the different modern technologies that are employed on fishing vessels. Several inventions related to powering boats, better fishing gear and their associated equipment, and also various electronic devices to assist in fishing operations are among the improvements that have enhanced the effectiveness and efficiency of fishing vessels (Valdemarsen, 2001).

This development has caused extreme concern in the Food and Agriculture Organisation (FAO) regarding the consequences of the development and transfer of such technology to developing countries. The FAO’s concerns are particularly associated with the capability of developing countries to apply the new technologies appropriately and responsibly, in order to support the implementation of responsible fishing practices (FAO, 1995). For that reason, the FAO in their Code of Conduct for Responsible Fisheries suggest that coastal states should clearly recognise the specific conditions and requirements of their fishing communities related to fishing technologies (FAO, 1995).

Based on the recommendations in the Code of Conduct for Responsible Fisheries and also in order to answer the research questions on the subject of the latest and the established technologies currently available on fishing boats worldwide, which could be applied or adopted in some way to fishing vessels in Indonesia, the identification and selection of alternative potential technologies has been undertaken in this study. Furthermore, since the final outcome of this study is also in the form of the design of sustainable fishing boats for selected fishing community in Indonesia, the results obtained from this stage are also used as an input for the rational selection of technologies to be employed for the proposed design.

In this chapter, both the current established and the state-of-the-art technologies available for fishing vessels and small craft globally are identified and discussed. Subsequently, based on these discussions, the potential technologies that could possibly be employed to advantage in fishing vessels in Indonesia are selected from among the alternative technologies. The criteria that are used for selecting the appropriate technologies and the result of this selection process are presented in this chapter.

5.2 Existing Technology in World Fisheries and Its Development

By considering the various problems that most fishers in Indonesia are confronted with regarding the technologies that are incorporated in their fishing boats, the identification of the potential technologies was divided into five groups, namely: 1) construction material for the hull; 2) main engine; 3) fish preservation system; 4) electricity sources; and 5) electronic and navigation devices.

5.2.1 Construction material

The need to have lighter, stronger, and more durable construction materials for small craft has led to the development of several construction materials as substitution for wood, which has for centuries has been the principal material for small craft. However, among the few choices that are available, there is no single material that could provide the greatest benefit for the all sizes and types of fishing vessels. Each material has its particular strengths and weaknesses related to construction, and therefore, need to be considered during the design process (Fyson, 1985).

A. Wood

Among the materials used to construct fishing boats, many types of wood have been employed over the centuries. The simple dugout canoes and the sewn-plank boats are examples of the earliest boat building methods that employed wood to construct these ancient boats (McGrail, 2002; Ward, 2006). The development in building methods, including fastening/joining technology and the availability of a wide variety of wood has made the employment of wood as a construction material for small craft still exist nowadays. However, since there is wide variety of wood species that can be used, it is important to consider the mechanical and physical properties of the wood, such as its strength and durability, in addition to its availability locally, when selecting the proper type of wood for any part of the boat (Birmingham, 2005; FAO/ILO/IMO, 2012).

B. Wood-adhesive laminates

The implementation of adhesive as a jointing/bonding agent for wood structures and also as a coating material in the boatbuilding industries since the 1960s has altered the physical nature of the application of wood as a construction material. In this method, wood is a component of a composite material that produces wood-adhesive laminates, which utilises all the positive aspects of wood, while simultaneously managing its weaknesses (Gougeon, 2005). In addition to the introduction of chemical preservatives for wood, the implementation of adhesive technology has been one of the solutions for the growing shortage of good quality and the expensive of timber. Thus, both technologies enable the boat builder to employ relatively fast growing wood or less expensive poorer quality wood for their boats and can extend the life span of the boat (Birmingham, 2005; Gougeon, 2005).

A wood-adhesive laminate is one type of composite material, which principally is a derivative material that combines the excellent properties of two or more basic materials and results in a new material with better properties, both physically and mechanically, if compared to the basic material (Brigante, 2014).

C. Fibre Reinforced Plastic (FRP)

Although the concept of composite materials has been known for centuries, the vast development and extensive application of this type of material started in the 1930s after fibreglass and resin polyester were invented and combined as a reliable composite material (Marsh, 2006).

The introduction of composite material for watercraft has delivered other alternatives regarding lighter materials. Fibre Reinforced Plastic (FRP), which is conventionally composed of polyester resin as the bulk matrix and fibreglass as its reinforcement, is a relatively light and strong material for small craft. Hence, it can result in vessels which have hulls that are lighter in weight compared with wood. This allows for an increased payload and a decrease in fuel consumption with respect to the vessels (Fyson, 1985).

The continuous developments related to this type of composite material, both for the matrix element and for the reinforcement component, have resulted in several alternative composites with respective advantages. The invention of stronger fibres, compared to the previous basic fibreglass material, such as *carbon* fibre and *aromatic polyamide* (aramid) fibre have enabled the production of superior structures, which also weigh less (Marsh, 2006; Brigante, 2014), however, their cost is high and so they tend to be reserved for specialised applications.

Conversely, increased demand for renewable and environmental friendly materials has encouraged the invention and development of matrix composite materials produced from renewable resources. The success of the Canadian boat builder, Campion Marine Inc., in constructing two composite boats that were based on a *bio-resin* made from soybean and corn, demonstrates potential improvements in this material that will respond to environmental concerns (McAfee, 2009).

D. Sandwich laminate

The requirements of lighter larger FRP boats with good stiffness were also the primary reason for the development of the sandwich laminate method in composite materials. The application of balsa wood, honeycomb or expanded polymer foam as a core material that is then covered on both side by FRP laminate enables a lighter structure to be obtained that has superior strength and stiffness properties, principally in terms of bending resistance (Karlsson and TomasÅström, 1997).

E. Ferro-cement

An alternative composite material for the construction of small craft is Ferro-cement. The matrix of this composite is made of a mixture of cement and sand, which is internally reinforced by several layers of steel wire meshes (BOBP, 1980). The combination of these basic components has resulted in a durable material that is adaptable in terms of the geometric shape of boats. However, its high weight to volume ratio means that it is not viable for small fishing vessels of less than 15 metres in length. Moreover its poor resistance to impact loads has made this construction material less attractive compared to other composite materials for boats (Hyman, 1988; Riley and Turner, 1995).

F. Aluminium alloy

Aluminium alloy is another light construction material that can increase the vessels carrying capacity and reduce the power required to propel a boat (Fyson, 1985; Gulbrandsen, 2012). Moreover, alloying aluminium with 2.5% - 5.5% magnesium, can produce a marine grade of aluminium alloy that has superior resistance to seawater corrosion (Fyson, 1985). An additional benefit of aluminium alloy as a construction material is that it can be formed reasonably easily, particularly for a chine hull with developed surfaces. In addition only simple hand tools are required for cutting the material, it is therefore possible to build and repair aluminium fishing boats in small boatyards with relatively simple facilities (Fyson, 1985).

G. Steel

A further construction material for use in vessels is steel. Steel has proven to be a strong and long-lasting material for many type of vessels and is dominant as a construction material for larger ships. Its application for smaller vessels, principally for boats under 12 metres in length is not practicable, given that its advantages are diminished owing to its weight compared to the other alternative materials (Eyres, 1984; Fyson, 1985). However, for boats above 12 metres in length, or over 15 metres for use in tropical water when considering the corrosion that can gradually reduce the thickness of the plates, the employment of steel as a construction material remains beneficial, in particular for boats with a simple shaped hull (Eyres, 1984; Fyson, 1985).

H. High Density Polyethylene (HDPE)

A highly promising new construction material for fishing vessels is a thermoplastic material called High Density Polyethylene (HDPE)**.** The characteristics of the thermoplastic material enables the mass-production of the boats with more complex hull shapes by using the rotation moulding method (Nelson, 2001). It is therefore relatively inexpensive in contrast to other construction materials. There is a limitation, however, on the maximum length of the boats using this building method. Nevertheless, the development of plastic welding has enabled the construction of larger HDPE boats. The advantages of this type of material are its durability, outstanding impact resistance, and as it is thermoplastic, it can be 100% recycled (DutchWorkBoats, 2016).

5.2.2 Main engines

During an earlier period in the fisheries industry, wind energy extracted with sails was the main energy utilised to propel fishing vessels. In the late 1800s, the coal-fired steam engine became an alternative in some parts of the world that made fishing vessels more powerful and easier to operate, principally because this technology did not require the presence of a favourable wind as with the previous technology (Tyedmers, 2004; Fisk, 2010). Later, the internal combustion engine fuelled by fossil fuel, specifically oil, completely replaced the use of wind energy and the coal-fired steam engine in the early 1900s (Tyedmers, 2004; Crowley, 2012). Nowadays several types of propulsion systems are used for fishing vessels and other small crafts worldwide:

A. Combustion engine run on diesel fuel or petrol fuel

More than a hundred years later, the internal combustion engine remains the principal choice for powering fishing vessels in the fisheries sectors worldwide (Tyedmers, 2004; Fisk, 2010). Many developments in combustion engine technology have, over time, produced more reliable and fuel efficient engines. For instance, the development of the turbo-charged diesel engine that uses an engine driven compressor to supply and input more air mechanically enables the engine to consume less fuel compared to the usual naturally aspirated diesel engine (Wilson, 1999). Conversely, the development of direct fuel injection in petrol combustion engines, which inject high compression fuel into the combustion chamber, has also increased the fuel efficiency of the petrol engine (Wilson, 1999).

B. Combustion engine run on LPG

The fundamental technology employed in combustion engines to produce power involves the presence of mixed gases in the combustion chamber. This enables the use of several types of gas as alternatives, reducing or replacing the use of diesel or petrol (Goldsworthy, 2012). This alternative technology that has become extensively used in vehicles in recent decades, and subsequently implemented in fishing vessels worldwide is the petrol engine modified to use Liquefied Petroleum Gas (LPG) (Murillo *et al.*, 2005; Goldsworthy, 2012), or diesel engine that operates on dual fuel (Bi-fuel)**,** such as diesel and LPG (Saleh, 2008; Ashok *et al.*, 2015). As an alternative fuel LPG offers numerous advantages, including reducing the operational cost for powering (Murillo *et al.*, 2003).

C. Electric propulsion

A simple electric propulsion system is an electric drive motor on-board that is powered by numerous batteries (Fisk, 2010). The electricity, which is stored in the batteries, could be from a variety of sources, which include electricity from a land grid or from a renewable source, such as solar panels or a wind turbine that are mounted on-board (Johnson, 2011; Alfonsín *et al.*, 2014). Another environmentally sound supply to the batteries can be centralised larger solar panels or a wind turbine onshore (Sterling and Goldsworthy, 2007). Recent developments in battery technology such as the lithium ion battery have enabled greater and longer storage of charge and a superior life cycle

(Baudry *et al.*, 1997; Iwahori *et al.*, 2000). This has increased the potential application of electric propulsion to include fishing boats (Johnson, 2011).

D. Hybrid-electric propulsion

For fishing vessels that operate for a longer trip durations, the number of batteries that would need to be provided on-board for electric propulsion will be considerable (Fisk, 2010). Hence, in order to maintain the supply of electricity to the electric drive motor and to reduce the number of batteries on-board a diesel electric generator can be installed, in order to recharge the batteries continuously (Johnson, 2011). In addition to the benefit of longer operational, hybrid-electric propulsion system enables flexibility in relation to the engine room layout as the diesel electric generator supplies the electricity to the drive motor through a power cable system, and it can be positioned anywhere on-board; therefore, there is more space for other needs, such as for fish holds (Crowley, 2012).

It is also worth pointing out that a state-of-the-art and promising technology for supplying electricity continuously to the electrical drive motor in vessels is the fuel cell that is fuelled by hydrogen (Fisk, 2010; Alfonsín *et al.*, 2014).

E. Wind Power

In contrast to several of the advanced and complex technologies that could be applied to propel vessels, the revisited idea to utilise the natural environment by using available wind energy to assist the main propulsion has resulted in innovative alternative technologies, such as the kite sail that have been developed from the concept of the conventional sail (Johnson, 2011). Kite sail, has been introduced in recent years to drive large cargo ships, is a sail that adopt the concept of huge kite to tow the ship. Its higher altitude enables this system to respond to greater wind speeds, which eventually results in high towing traction for the ship. Moreover, this technology requires less space on the main deck in contrast to the conventional sail technology (Naaijen and Koster, 2007).

For fishing vessels, the employment of conventional sail to assist the main propulsion potentially reduce the fuel consumptions and eventually reduce the operational cost of the vessels. The research conducted by Samples (1983) on 14 meters and 19 meter length commercial fishing vessels in Hawaiian waters found approximately 36% reduction of fuel consumption (Samples, 1983).

5.2.3 Electrical resources

Electricity sources in fishing vessels are required in order to supply electricity to a variety of equipment on board, including lighting, pumping systems, fish preservation systems and various electronic devices, such as radio communication. Therefore, the selection of electrical sources will be affected by the total amount of power that is required for powering at any one time all of the electrical equipment.

A. Batteries

Fishing boats that require relatively small amounts of electric power for their lighting and electronic devices mostly bring on-board a small number of batteries to supply this equipment. In order to generate the electricity that can be stored in the batteries, in addition to the conventional method by recharging batteries through power from the land grid, the application of renewable energy to supply the electricity is quite common recently. These include solar cells that harness solar energy using the *photovoltaic* effect (Hu and White, 1983)**,** and wind generators, which catch the wind energy by means of the rotors to drive the generator that produces the electric power (Wang *et al.*, 2009)**.**

Furthermore, more advanced solar cell developments have resulted in thin film solar panels that can be more flexible in their application and positioning on board (Yachting-World, 2015). Conversely, a reasonably similar system to the wind generator has been applied as well to the hydro generator, which harnesses seawater energy with the aim of generating the electricity, principally for sailing boats using sails (Street, 2011; Yachting-World, 2015).

B. Fuel Cells

An advanced invention in electricity generators that potentially could be applied on board is fuel cell technology that is fuelled by hydrogen. The profusion of hydrogen in nature, which can be produced from renewable resources and its zero impact on the environment are the main reason for the development of hydrogen fuel cells to generate electricity (Momirlan and Veziroglu, 2005; Edwards *et al.*, 2008). However, there are a number of drawbacks that need to be considered, including the method for storing the hydrogen on-board and the huge cost of producing the hydrogen. Therefore the potential large scale application of this technology in fishing boats worldwide, as has been undertaken in Iceland, is still far from a reality (Edwards *et al.*, 2008; Fisk, 2010)

C. Electric AC (Alternating Current) generators

For fishing vessels that need larger supply of electricity, the electrical generator driven by a combustion engine is currently the most appropriate choice (Anderson, 2014)**.** There are many choices on the market with a wide range of power outputs so the fishers can match their needs on board to the appropriate available generator in the market. Moreover the options regarding fuel are also a factor that requires consideration, given that there are electrical generators that run either on diesel, petrol or LPG available in the market.

5.2.4 Fish preservation

The economic benefit that can be obtained by the fishers primarily depends on the quality of their catches. Therefore, it is important to ensure that the caught fish stays fresh up to and including entering the market (Shawyer and Pizzali, 2003; Thanasansakorn, 2008). One method to keep the fish fresh is by decreasing the temperature of the fish to below a certain temperature and subsequently maintaining this level for the rest of the fishing trip and entry to the market (Shawyer and Pizzali, 2003).

In general, there are two types of methods for fish preservation in a cold state based on the temperature to be maintained. The chilled method keeps the fish at a temperature around the melting point of ice (0˚C), while the frozen method maintains the fish at a very low temperature, which is typically from -18˚C to -30˚C (Shawyer and Pizzali, 2003; Ruiz, 2012). The appropriate method depends on the fish species and how long the fish will be stored in the fish hold. The chilled method is suitable for fish that will be stored in the fish hold for a few days up to maximum of a month (Shawyer and Pizzali, 2003), while the frozen method is appropriate for high value fish and they can be stored for more than a year (Shawyer and Pizzali, 2003). The following methods are commonly employed for fish preservations in fishing vessels:

A. Block ice

Among the chilled methods, block ice is considered to be the most common preservation system that is used by fishers in a large number of countries (Shawyer and Pizzali, 2003). The size of the ice block enables easy transportation and storage of the ice, whilst at the same time ensuring a slow melting rate of the ice block itself. Given that the ice is stored in a simple block shape, for applying to the surfaces of the fish this block ice must be crushed into small pieces. However, as the ice block is crushed by a machine or often manually by hammer, small pieces of ice are produced with sharp edges that can physically damage the fish (Kauffeld *et al.*, 2010). A further disadvantage of block ice for fish preservation is in the large amount of block ice that has to be carried in the fish hold during the trip. As the block ice cannot normally be produced on-board, fishers need to take a sufficient quantity of block ice for the entire fishing trip. Considering the melting rate of the ice, the quantity of block ice is even higher for a fishing fleet in tropical waters (Soeharmono, 2008).

The problem of excessive ice in the fish hold, particularly when there are smaller catches obtained in a trip, can be overcome by using ice that can be produced on-board according to demand (Shawyer and Pizzali, 2003). These on-board systems include flake ice machine, slurry ice machine, Chilled Sea Water (CSW) and Refrigerated Sea Water (RSW).

B. Flake Ice and Slurry Ice

Flake ice is produced in small amounts, 2 – 3 mm thick with an irregular flat shape. Because it is small in size, it can be used directly in the fish hold from the ice flake machine (Piñeiro *et al.*, 2004). In general, this machine has a deep-frozen metal cylinder spinning slowly in a tank filled with fresh water or sea water. The sea water freezes on the surface of the cylinder, and subsequently releases as small pieces of ice. While slurry ice is a mixture of crystal ice and seawater in a particular composition. The composition of slurry ice varies depending on its utilisation, which commonly contains 25-30% of crystal ice. This composition permits the slurry ice to be pumped; therefore it is easier to transfer into the fish boxes or fish holds (Piñeiro *et al.*, 2004).

C. Chilled Sea Water

Chilled Sea Water (CSW) is a relatively simple system for fish preservation on-board. The cooling medium is obtained by cooling sea water in the fish hold to below a certain level by constantly adding small amounts of ice. In order to ensure that the temperature is constant and uniform a pumping system or a compressed air system is applied (Shawyer and Pizzali, 2003). A reasonably similar method, the Refrigerated Sea Water (RSW) uses a refrigeration system to chill the sea water in the fish hold. For overall efficiency, before the seawater is refrigerated, ice is added into the seawater at the pre-cooling stage (Shawyer and Pizzali, 2003).

D. Frozen Method

Certain types of fish, especially commercially valuable fish such as tuna, can be stored for a longer period of time, in order to achieve a wide distribution that could include international markets. For that reason, the frozen method is applied. This method requires the initial process to reduce the temperature of the fish to between -18˚C to -30˚C and then keeps the fish frozen in cold storage on-board. In contrast to previous preservation systems, a frozen method is a physically fixed system which is attached to the fish hold and requires both higher capital and operational costs. It also requires high skilled operators to operate and maintain the system (Shawyer and Pizzali, 2003).

5.2.5 Electronic and navigation devices

The demands for greater efficiencies in fishing activities has encouraged the invention and development of many electronic devices that can help fishers to undertake their fishing activities more effectively and efficiently. The implementation of these types and forms of devices has increased the productivity of vessels within the planned fishing periods and has also improved the safety of the fishing trip itself. These electronic and navigation devices include:

A. Sonar

Following the successful military application of Sonar, which stands for *Sound Navigation and Ranging*, the adaptation of this technology for other sectors has, since the early 1950s, encouraged countless important inventions and developments based on this “sound in water” technology (SIMRAD, 2003), and many of these developments have helped fishers.

The Echo sounder is one of the applications of Sonar technology, and allows the detection of the surface of the seabed together with any objects between the seabed and the water surface, which includes schools of fish. The fish finder, which applies the same method as the echo sounder, enables fishers to detect the presence of fish in the area below their fishing vessels (Burgess, 1966; Pike, 1992; SIMRAD, 2003)

Ensuring that the nets open correctly under the water and avoiding nets from becoming snagged or stuck on the seabed are some of the difficulties that fishers face when operating trawl, seine nets or purse seines. In order to help fishers to manage and control their nets during such operations, net instruments that are adapted from Sonar technology, can be attached to the nets. These instruments include a depth sensor for checking the distance of the bottom of the net relative to the seabed (SIMRAD, 2003) and door distance sensors which are employed for identifying the distance between the otter boards on trawl nets (SCANMAR, 2016b).

The same basic technology can be used to detect and estimate the amount of fish that are trapped in the cod-end of trawl or seine nets; thus it helps fishers to decide when they should haul in the nets. This device, which is called a catch sensor**,** or catch indicator, is attached to the trawl doors or at the mouth of the cod-end (SCANMAR, 2016a).

B. Radar

An additional electronic device that is frequently installed in fishing vessels is Radar. This device is primarily used for navigation purposes. It helps the skipper to navigate his vessel, especially during conditions of poor visibility, and to avoid collisions (Pike, 1992). Recent developments in radar enable the wider application of this device in fishing activities. Fishers that operate purse seine can use radar to detect the position and the circular shape of their nets by using special reflective floats attached to the float lines (FURUNO, 2008). The same technology is also used to detect and track sea birds, which can indicate the possible presence of schools of fish. Therefore, the function of Radar is not only for navigation purposes but also to act as a form of fish finder (FURUNO, 2016).

C. Global Positioning System (GPS)

A further navigation device, the Global Positioning System (GPS), uses radio signals from satellites in order to detect the latitude and longitude position of the receiving devices on the earth. By installing this device on board, the position of the boat can be easily identified. Furthermore the positions of locations related to fisheries, such as landing ports, specific fishing grounds, fish aggregated devices and so forth, can be saved in the devices, so the vessels can be navigated easily toward the selected target location (RFLP, 2012). Advanced developments in these devices have resulted in simple and compact units, with one recent device consisting of both GPS and a sonar fish finder combined (GARMIN, 2016).

5.3 Possible Technologies to Be Applied on Indonesian Fishing Vessels

Based on the above descriptions regarding both established and state-of-the-art technologies that are applied in fishing vessels and small crafts globally, and by considering the current conditions of the Indonesian fishers in particular, it is impossible for many reasons to employ all the alternative technologies in Indonesia, especially the advanced and state-of-the-art technologies. Each fishing community in Indonesia has its own challenges and obstacles, which tend to inhibit the implementation of some of these alternative technologies. Therefore it is important to recognise and to match the correct potential technologies with the local fishers' requirements and circumstances.

For this reason, an initial evaluation of the alternative technologies has been undertaken. In this section, the possible technologies that could be employed for fishing vessels in Indonesia are identified based on specific criteria. All of the alternative technologies in the four groups, namely hull construction material, main engine, electricity sources, and fish preservation, are listed and scored based on the following criteria: capital cost, operational cost, current acceptability, and viability.

The criteria for capital cost is related to the budget that will be required by the fishers for procuring the technology, while the criteria for operational cost is associated with the expenses that the fishers will incur for the operation of the technology. Within these criteria, the higher the score means the more relatively affordable that the technology is for the fishers. The criteria for current acceptability is related to the existing application of the technology in fishing vessels in Indonesia. The scoring for this criteria is based on the degree to which each technology has been adopted in fishing vessels in Indonesia. The score will be high in this criterion if the technologies have already been applied extensively. The last criterion namely, viability, is related to the operational viability and production viability of the technology. Operational viability is associated with how complicated is employment of the technology for the fishers, while production viability is related to the capability of local boatyards to install, maintain, and repair the alternative technology. Regarding the viability criteria, the more complicated the technology is the lower score it is given.

These four criteria were selected based on the initial observations made in the chosen local fishing communities and from a few references (Gulbrandsen, 1988; Samodra, 2009). They therefore reflect the obstacles which often are found to be constraints for the implementation of new technologies for fishing vessels in Indonesia. In order to numerically score each technology, specifically for the criteria of cost and acceptability, the scoring is based on many references to the related technology, for instance from references about the cost for procurement of the technologies. Furthermore, the informed judgement of the author was used to score the viability of the alternative technologies.

In order to score each technology, a simple numerical value on a 1-10 scale is used for each criterion. The descriptions of each numerical score are as follows: 1) very poor; 2) poor; 3) significantly below fair; 4) below fair; 5) fair; 6) above fair; 7) significantly above fair; 8) good; 9) very good; 10) excellent. Technologies that are considered possible to be applied in fishing vessels in Indonesia are those that have over a minimum total score of 20, and have a score over a minimum 5 in the viability criteria. It needs to be stressed that the scoring for the possibility of the alternative technologies being applied for fishing in Indonesia is only for the small fishing vessel that are the most widely operated in Indonesia. It is not related to the larger commercial industrial-scale fishing vessels. These will have different considerations regarding the application of alternative technologies.

5.3.1 Construction materials

Table 5.1 shows the scoring for the alternative construction materials. The results explain that FRP and wood laminates are the most feasible alternative materials to be applied for fishing vessels in Indonesia. Based on this table, it is not feasible to apply the four other alternative materials in current conditions in Indonesia. However, the

Table 5.1 Alternative construction materials with potential to be employed for fishing vessels in Indonesia

No	Technologies	Scoring				
		Initial Cost	Operational Cost	Current Acceptability	Viability	Total
1.	Wood laminates	8	7	3	7	25
2.	FRP	6	8	5	5	24
3.	Aluminium alloy	3	7	1	2	13
4.	Steel	4	5	1	3	13
5.	Ferro-cement	6	7	1	4	18
6.	HDPE	7	8	1	1	17

Table 5.2 Alternative main engines with potential to be employed for fishing vessels in Indonesia

No	Technologies	Scoring				
		Initial Cost	Operational Cost	Current acceptability	Viability	Total
1.	Inboard diesel marine-engine	7	8	5	8	28
2.	Engine run on LPG	7	8	3	8	26
3.	Hybrid diesel-electric (diesel generator + batteries + electric drive motor)	4	9	2	7	22
4.	Electric drive motor powered by batteries	4	9	2	7	22
5.	Electric drive motor powered by hydrogen fuel cell	1	1	1	1	4
6.	Engine + Sail	7	9	4	8	28
7.	Engine + Towing kite	1	9	1	1	12

potential employment of both steel and aluminium were still considered in this study for specific reasons, seeing as Indonesia has massive potential in mineral resources including iron ore and bauxite. In order to gain some benefit from these potential indigenous resources, the government has attempted to promote, encourage and increase the downstream industries that harness the national production of steel and aluminium manufactures and goods (NERACA, 2014). Therefore, the possibility of employing these two materials on fishing vessels in the three selected communities was discussed with local fishers during the in-depth interviews.

5.3.2 Main engines

Table 5.2 shows the selection of main engines that are possible to be employed in Indonesian fishing boats. Based on the total score, the most feasible types of main engine that can be applied are inboard marine engines running on diesel fuel, engines running on LPG, and engines that are assisted by sails. For the electric drive motor arrangement that is powered by an on-board electricity generator and also for a simple electric drive motor that is powered by batteries, their high initial costs for procuring the equipment are the main obstacles for the implementation of this technology in Indonesia, unless the procurement is financially supported by the Indonesian government.

Table 5.3 Alternative electricity sources with potential to be employed for fishing vessels in Indonesia

No	Technologies	Scoring				
		Initial Cost	Operational Cost	Current acceptability	Viability	Total
1.	Batteries + Solar cell	8	9	5	8	34
2.	Batteries + Wind turbine	8	9	1	8	28
3.	Electricity generator run on LPG	8	8	3	8	26
4.	Hydrogen fuel cell	1	1	1	1	4

5.3.3 Electricity sources

According to Table 5.3, there are three possible alternatives that could be applied regarding the on-board electricity sources in the fishing vessels. The first two alternatives use batteries to store the electricity, which are supplied by either of two alternative environmental friendly technologies: solar cells and wind turbines. While the third possible alternative is an electricity generator that runs on LPG. Currently, the hydrogen fuel cell is not feasible to be applied in the small fishing vessels in Indonesia, given that to produce the hydrogen fuel is very costly.

5.3.4 Fish preservations

Regarding the alternative technology for the preservation if fish on-board, as can be observed in Table 5.4, providing a machine that can produce ice as and when it is required is one of the possible alternatives to be employed for small fishing vessels in Indonesia. More recently, freezers are regularly employed on fishing vessels in Indonesia, particularly for fishing vessels that catch tuna and go fishing for more than a month. The problem with RSW is that the chilled sea water is not appropriate for all types of fish; several fish require relatively dry conditions in the fish hold, so as to maintain the quality of the fish. Fishers that need to apply chilled sea water tend to

Table 5.4 Alternative fish preservation systems with potential to be employed for fishing vessels in Indonesia

No	Technologies	Scoring				
		Initial Cost	Operational Cost	Current acceptability	Viability	Total
1.	Flake/slurry ice machine on-board	7	7	2	7	23
2.	Freezer	4	4	5	7	20
3.	Refrigerated Sea Water	4	4	2	7	17

employ simple sea water with ice added and thus, do not need a refrigerated system on-board.

5.4 Concluding Remarks

The enormous improvements in technology, for example regarding fishing gear, fishing aids and the technologies related to the vessel itself, have boosted the productivity of the fisheries sector worldwide over the last few decades. Although various developments in fishing technologies, and the improvements in small craft technology in general, have supported improvements in the fisheries sector, not all of the established and state-of-the-art technologies in fishing vessels can be adopted successfully in every coastal state worldwide. Even in one coastal state the requirement for technology to be successful could be quite different among each of the many fishing communities. Thus many aspects, including human factors, need to be considered prior to applying any of the alternative technologies to specific fishing communities. These include the cost of implementing the technology, the level of complexity of the technology in relationship with the local fishers' competencies, and the acceptability of the technologies related to fishers' preferences.

Based on these criteria, the alternative technologies that can possibly be applied with some measure of confidence in fishing vessels in Indonesia have been selected, as seen in Table 5.5. These selected technologies were subsequently assessed in terms of social implications by discussing each of them with local fishers during the in-depth interviews.

Table 5.5 Alternative technologies that possible to be applied for fishing vessels in Indonesia

No	Group of Technologies	Possible technologies to be applied
1	Construction materials	• Wood laminates • FRP • Steel • Aluminium alloy
2	Main engines	• Inboard diesel marine-engine • Engine run on LPG • Hybrid electric + diesel • Electric drive motor powered by battery
3	Electricity sources	• Batteries + solar cell • Batteries + wind turbine • Electric generator run on LPG
4	Fish preservations	• Ice machine on-board • Freezer

Chapter 6. Fishers' Responses Concerning the Sustainability of Fisheries and Technologies in Traditional Fishing Vessels

6.1 Introduction

The field study in order to elicit local fishers' views concerning the condition of current fisheries sector in their regions and their existing fishing vessels have been conducted in three selected fishing communities.

In this chapter, the respondents' responses during the first interview sessions will be presented and the implications for the design of the proposed fishing vessels will be discussed. The discussion in particular will focus on the following significant issues: 1) the fishers' perspectives on the sustainability of fisheries in their region; 2) the fishers' awareness of the regulations; 3) the fishers' views on preventing marine pollution and creating a safe working environment; and 4) the existing technology in traditional fishing vessels in conjunction with the problems that are frequently encountered.

Quotations taken directly from the respondents' opinions are presented in order to support the discussions; however for ethical reasons the survey results are presented anonymous with the individual identity of each of the respondents coded. The identifying letters 'B.F' stand for Brondong's fishers, 'M.F' identifies Muncar's fishers, whilst 'L.F' stands for Latuhalat's fishers. The number following the letters signifies the order of the respondents' interview in their overall group.

6.2 General Characteristics of Local Fishers

By observing daily activities in these three communities, as shown in Figure 6.1, it can be noted that fishing is the primary economic activity in these three communities and involves an enormous number of people. According to data from the local Marine Affairs and Fisheries Agency, there were 12,840 fishers registered in the Brondong fishing harbour in 2012 (MAFA_Brondong, 2012). In the same year, 13,123 fishers were registered in the Muncar fishing harbour (MAFA_Muncar, 2012). With regards to Latuhalat, although the number of fishers in this community was only approximately 10% of the total number of fishers in Brondong or Muncar, it still remains the highest concentration of fishers in Ambon Island (Kurniasari and Yuliaty, 2014).

(a) (b)

Figure 6.1 Fish landing activities in Brondong fishing port
a) Fish landed are put into bamboo baskets (Photo by the Author); b) A very crowded wharf in Brondong fishing port (Photo by the Author)

In addition to the large numbers of actual fishers in these locations, as they are engaged in artisanal or small-scale fisheries, almost all of the family members are involved, from the actual fishing activities to post-harvesting. This can be seen in Figure 6.2 which illustrates how local women are involved in post-harvesting activities

Based on the respondents' answers, it was revealed that local fishers often start their job as a fisher at a young age, mostly just after finishing primary school at 12 years old. Even some of the respondents said that they dropped out of their primary school and followed their fathers become a fisher. The difficulties in their economy dissuaded them from continuing their studies to a higher level, and the easy access to becoming a fisher has lured young people to become involved in fisheries sector at young ages.

(a) (b)

Figure 6.2 Women's activities in the fisheries sector
a) Fish sorting in Brondong fishing port (Photo by the Author); b) Dried fish processing in Muncar (Photo from http://www.antarajatim.com/)

Figure 6.3 The condition of some fishers' houses in Muncar with access directly to their moored boats
(Photo by the Author)

The competencies of local fishers in fishing practices were obtained from their elders, and their skills were mostly improved through the actual experiences gained by joining several types of fishing boats with different types of fishing gear.

Moreover, according to the interviews and observations undertaken in the local communities, as illustrated in Figure 6.3, poverty is still the main problem that is faced by most local fishers. The largest proportion of the fishers in each of the three selected fishing communities are crew members. The income of each fisher is determined on the monetary value of their catch from each trip undertaken, after being reduced by operational costs and a portion to the boat owners. The rest of the profit will be shared among the crew and with the skipper, who will get the highest percentage. According to respondents, because there are a large number of crew on-board and the unpredictable catches, the share portion for each individual is quite small.

6.3 Fishers' Views and Concerns on the Sustainability of Fisheries in Their Region

The respondents in each of the three fishing communities all agreed that the establishment of new fishing methods, as well as the general improvement of technology in their fishing vessels, are the main reason for the massive increase in their fish production in the last few decades. Superior fishing gear enables the local fishers to catch more fish in a given period of time, while the introduction of engines to propel their boats and ice for fish preservation allows the fishers to fish for longer periods and further afield than before.

"In the 1970s, the fishing boat in Brondong was still very traditional and propelled by paddle and sail. Diesel engines of about 12hp were established

around 1982, but only for powering the boats. At that time, we were still hauling the net line by hand. Then a diesel engine that rotated the line hauler was introduced about two years later by a few local fishers" (Respondent B.F.19).

The improvements in fishing technology subsequently motivated many fishers to increase their profits by increasing their catches per trip, often by unintentionally catching more fish than they could physically carry on-board. In the past, there were even cases where fishers discarded their excess catches back into the sea as they were unable to actually load the caught fish onto their boats. One of the respondents explained:

> *"2007 – 2009 was the peak of sardine production in Muncar. However, because the catch was much more than the capacity of the fish hold, fishers often threw away their excess catches into the sea. Conversely, fish manufacturers and fish markets could not accept all the fishers' catches; so the fish was thrown away along the shore line. Perhaps that past condition is the reason that sardines have disappeared over the last 5 years in the Bali Strait"* (Respondent M.F.14).

The financial motivation to increase catches meant an increase in the size of fishing gear and boats. Thus, the capacity of the fish holds in the vessels of the three fishing communities increased significantly in order to cover the hoped for growth in fish catches. In Muncar for instance, the as-designed capacity of the fish holds increased considerably from approximately 2 tonnes in vessels of the past to more than 40 tonnes in the new construction of recent times. Moreover, fishers also tend to operate the active type of fishing gear, in contrast to the passive ones like gillnets, in order to increase the catching rate.

The above conditions have placed a huge pressure on the sustainability of the fish stocks in each of the three fishing communities, especially on Java Island, and all the local fishers recognised the adverse changes that are taking place in their common fishing grounds. The respondents' opinions revealed changes occurring in the fish stocks in their fishing areas over the last few decades, as stated below:

> *"In the past, there were more fish compared to now and we could get a lot of fish only a few miles from shore in only one day. Therefore, we did not require any ice or salt for fish preservation in the past"* (Respondent B.F.02).

> *"There is no change in the shape of the boats, only their size has become much bigger. In the past, we only went fishing for less than one day. We left the port at 2am and landed our catches before 1pm on the same day. There were a lot of fish around here before, and we could even catch the fish by hand"* (Respondent B.F.19).

The decline in fish stocks also has influenced the ordering of new fishing boats from the local boatyards. Consequently, the number of new fishing boats being built in local boatyards has dropped significantly. One boatyard owner in Brondong said that when fish production was booming in the past, his boatyard would construct approximately 15 boats a year; now in the last few years it only builds 2 or 3 boats of the same size in one year. According to respondents, even in Muncar, no new fishing boats had been built in the last 6 years, with only re-planking or others form of structural repairs of old boats being undertaken.

Slightly different responses were heard in Latuhalat concerning the fish stocks in their traditional fishing grounds. Most respondents claimed that although there was a change in the fish stocks in local fishing grounds, the grounds remain in good condition, as stated below:

> *"In the 1990s, we fished quite close to the beach, but now we go further. The fish stock has been declining, but it is not significant"* (Respondent L.F.07).

> *"The fish stock is still a lot, but we need to have Fish Aggregating Devices (FADs), because we cannot compete with other fishers that have FADs"* (Respondent L.F.09).

These responses confirm the independent findings of several scholars regarding the conditions of fish stocks in the three selected fishing communities (Buchary, 2010; Fauzi and Anna, 2012; Sasongko *et al.*, 2014). It also corresponds with the status of Indonesian Fisheries Management Area (FMA) 573, FMA 712 and FMA 714, which cover the three fishing communities, according to Ministry Decree KEP45/MEN/2011 which is related to the estimation of potential fish resources in the Indonesian FMAs (MMAF, 2011a).

The local fishers actually understand what the reasons are behind the depletion of the fish stocks in their areas. The respondents argue that the increasing number and size of fishing boats and the use of active and destructive fishing methods are the main reasons for the reductions in the fish stocks, in addition to the pollution by the solid waste that enters the in-shore water is a further cause of fish depletion. The respondents argued that:

> *"The operation of seine nets should be banned (by the Government), although this gear doesn't have any otter board (like trawlers), however the dimension of its bottom line is very large and it could still destroy even the large coral reefs"* (Respondent B.F.09).

"There is change in fish stock and it is not as widespread as before. Perhaps one of the reasons was the condition of the coastal area a few years ago; which was contaminated by waste from fish manufacturers along the coastline in Muncar." (Respondent M.F.14).

One respondent stated that in addition to the massive exploitation of the resources and the increase in pollution along the shore line, the ignorance or disobedience of local fishers with respect to the regulations related to fishing gear is also a further reason for the reduction in the abundance of fish in their traditional fishing ground. He stated that:

"Most fishers here never follow any advice from local fisheries officers or local government. For instance, there are regulations about the mesh size, but most fishers disregard those rules. In the past, small fish would be discarded at sea, but nowadays all catches, including small fish (juvenile fish) will be landed since all fish have a value, as even small ones are also accepted by manufacturers. It is because the government is less stringent (on the enforcement of regulations). Nowadays, the fish have diminished, because most fishers infringe the rules and harm the sea" (Respondent B.F.12).

In fact, it is relatively easy to find local fishers drying their juvenile fish catches and other less valued catches around the fishing harbour before they deliver them into the local fish flour manufacturers, as seen in Figure 6.4.

In contrast to the problems concerning fish resources in the future, from the human resources aspect, all respondents agreed that there is no foreseeable problem associated with the future generations of fishers in those three selected fishing communities. It is important to note that the interest of young people in becoming a fisher in those three fishing communities remains high for numerous reasons. According to the respondents, one of the main reasons is due to the fact that to be a fisher does not need an education,

Figure 6.4 Juvenile fish landed and dried for fish flour manufacturing in Brondong (Photo by the Author).

which has been the main obstacle in preventing local young people from obtaining relatively better jobs.

This fact is actually in contrast to what most fishers typically wish for their sons in the future. According to the respondents, many fishers prefer their sons to look for jobs onshore rather than to be a fisher. The high risk, unpredictable financial results and particularly the level of relative poverty are among the reasons why fishers do not agree with their children following in their footsteps and becoming fishers.

Based on the various discussions, the availability of fish stocks in the local fishing grounds that are close to the coastline is the foremost problem faced by local fishers. Consequently, local fishers need to fish further out and for longer periods than they have previously done. Unfortunately, their traditional fishing boats were not designed or equipped for these distances and sea condition encountered, which are understandably quite different. As stated by one of the respondents referred to earlier, there have been no changes regarding the geometrical shape of their boats, only changes in relation to the overall size of the boats, which have become larger geosims of the earlier boats, as shown in Figure 6.5.

A consequence of the challenge of designing new fishing vessels that can be operated in a sustainable manner in these communities is that the design should consider all aspect of the potential operational scenario of new fishing trips, including total distances and the duration of the fishing trips. Furthermore, it is important to recalculate the need for

Figure 6.5 Similar shape and proportions of the main dimensions of a large and a small boat in Muncar
(Photo by the Author).

increased or even decreased fish hold capacity, as according to respondents, it is now quite rare that they have brought home a hold full of fish in the last few years.

6.4 Fishers' Awareness of the Regulations

Based on the interviews, it would appear that the local fishers' collective awareness concerning the regulation of the fisheries in the three fishing communities is quite low. Most respondents are not fully aware of any regulations that apply to their fishing boats and to their fishing activities. Moreover, the fishers apparently feel burdened if given any responsibility over and above fishing, such as obtaining port clearance before leaving the port and in reporting total fish catches when they return to port.

In addition, and for mainly economic reasons, the respondents argued that a number of the regulations are quite difficult to fulfil, an example being the requirement to provide safety equipment on-board in order to obtain port clearance. Providing the life jackets, life buoys and additional safety equipment means further spending which is considered to be burdensome by the local fishers.

The enforcement of the port clearance regulation is one of the greatest challenges for the administrators at the local fishing ports and local fisheries departments. According to the national regulations regarding fishing activities, each fishing boat must obtain approval from the harbour master, in the form of port clearance, immediately prior to leaving the port. To gain the port clearance certificate, a fishing vessel should pass an inspection by the fisheries inspectors, related to the availability and the condition of the equipment on-board, as listed in Table 6.1. However, the local fisheries officer in

Table 6.1 Points of inspections on-board in order to obtain a port clearance

No	Point of Inspections
1	Boat certificates and fishing licences
2	Crew certificates
3	Number of crew in accordance with the fishing licences
4	Safety equipment complies with the requirements
5	Fishing gear in accordance with the fishing licences
6	Navigation equipment complies with the requirements
7	The engine and its equipment are in good condition and fulfil the requirements
8	All bilge pumps in good condition and work properly
9	Radio communication complies with the requirements
10	The devices used for pollution prevention work correctly
11	The draught of the boat does not surpass the maximum load line
12	The boat has good stability to sail
13	The tonnage measurement number is marked accurately
14	The freeboard mark is marked accurately
15	The fire extinguishers comply with the requirements.

Muncar reasoned that it is almost impossible to handle port clearances every single day for the hundreds of fishing vessels that may only go fishing on a daily trip basis.

Furthermore, the harbour master in Brondong acknowledged that if he was strict with enforcing all of the requirements, as listed in Table 6.1, and only issued port clearance when compliant with listed requirements, there would be no fishing boats going to sea. Therefore, the enforcement of this regulation has become applied in a more flexible way for local fishing boats.

Based on the aforementioned discussions, the lack of the fishers' awareness about the many regulations related to their fishing boats and fishing activities should be carefully considered during the design process of the new fishing vessels. The most appropriate solution to this problem should be a comprehensive solution that fully involves the fishers.

6.5 Fishers' Views on Preventing Marine Pollution

One section of the questions asked during the in-depth interviews was associated with fishers' awareness concerning the prevention of marine pollution by activities that take place on-board. The discussion in this context was in conjunction with how the respondents handled the waste from the galley, the engine room, and from any activities on deck that may cause any pollution. The replies from the respondents revealed that the potential for marine pollution from fishing activities in the three fishing communities is still one of the principal challenges that needs to be overcome.

(a) (b)

Figure 6.6 The sea water pollution in the Brondong fishing harbour
a) The notice board around the harbour: "My beautiful sea without waste" (In Indonesian) (Photo by the Author); b) A bucket filled with lubrication oil waste and plastic waste in Brondong fishing harbour (Photo by the Author).

None of the respondents claimed that they have the correct temporary facilities for waste storage on-board. Furthermore, almost all the respondents admitted that they always discharge all the waste from their activities on-board into the sea, even when the fishing vessels are moored at the harbour docks. Figure 6.6 demonstrates how the notice board in Brondong fishing harbour encourages local communities, the fishers in particular, to protect the ocean by not simply disposing their waste into the sea. However, the conditions of the sea water around the port show the opposite.

Given that the awareness of the local fishers is the main concern in terms of preventing marine pollution, therefore the development of a better fishing vessel with proper equipment to prevent marine pollution should be accompanied by programmes to educate the local fishers about the importance of avoiding marine pollution and its impact on the sustainability of fish resources.

6.6 Health and Safety Working Environment on Traditional Fishing Vessels

Working on fishing vessels is one of the most hazardous of jobs in the world, particularly in adverse weathers. The only way to reduce the level of danger is by reducing the risks associated with the operation of the vessels. In addition to the actual design of the vessels, potential risks on-board are evidently influenced by fishers' awareness of the importance of establishing and maintaining a safe working regime and environment during their fishing trips.

Based on the interviews, the local fishers in the three selected fishing communities are very conscious of the risks that they confront being fishers. It can be revealed from the anxiety they demonstrated in relation to their sons possibly following in their steps and themselves becoming fishers, as stated below:

> *"I don't want my son to be a fisher someday. It is very hard and even if it is heavy rain you still should keep working. The risk is very high, especially in the last few years when the weather has been very extreme"* (Respondent B.F.03).

> *"I don't want my son following in my steps because the risk is very high and it is even a risk to your live"* (Respondent B.F.07)

However, health and safety practices on the fishing vessels have not yet become routine or second nature for local fishers in the three selected fishing communities.

Lack of awareness to the standards or regulations in associated with health and safety working environment on the fishing vessels is the one of the most challenge to

Figure 6.7 Inadequate crew protections on fishing boat in Latuhalat
(Photo by the Author).

implement responsible fishing practices in three selected communities. As illustrated in Figure 6.7, local fishers prefer to have lower bulwarks given that the standard bulwark, which has a minimum height of 1 meter (FAO/ILO/IMO, 2012), can disturb the flow of fishing activities on deck and therefore considered to be inefficient according to local fishers.

Furthermore, according to respondents, almost none of the fishing vessels in Muncar and Latuhalat have standard life jackets and lifebuoys on-board. Although a few respondents in Brondong did say that they do have those two types of safety equipment, however the quantity of their life jackets is considerably less than the number of crew on-board.

Figure 6.8 The bucket as substitution for life-saving appliances in Muncar
(Photo by the Author).

Based on the interviews, the fishers are reluctant to purchase safety equipment, seeing that it is not considered to be important enough for them and they argue that the conventional safety equipment could be substituted for by other objects available on their fishing vessels. For example, fishers in Muncar argued that they can use the plastic buckets that are normally used for meal and cloths storage as a substitute for life-saving appliances, as illustrated in Figure 6.8.

However, not all of the respondents agreed with this common argument, as one of respondents in Brondong opined:

> "It *(safety equipment) is very rare around here. We never wear life jackets on-board, so if the boat sinks, it is most likely we will not be saved, as there is a lot of heavy equipment on-board so the boat will sink very fast. Even if there is something on-board that we can possibly use to float, it will scatter everywhere and be very difficult to reach"* (Respondent B.F.16).

An additional weakness in the health and safety environment on traditional fishing vessels is in the condition of accommodation that is provided for the crew. The respondents in Muncar, Brondong and Latuhalat all argue that most of their time will be spent actually catching fish; therefore, they believe that they do not need proper permanent accommodation on-board. In many traditional fishing boats, the 'cabin' used by the crew is a simple shelter with a tarpaulin as the roof. The similar conditions can also be found for the cooking and sanitary facilities in the vessels operating in the three selected fishing communities.

Figure 6.9 The open space galley on fishing boats in Brondong
(Photo by the Author)

In Brondong, for example, the cooking facilities for fishing boats that go to sea for more than two weeks at a time is only a simple stove that is placed inside a wooden box to avoid the wind and positioned in an open space on deck without any shelter, as illustrated in Figure 6.9.

With regard to sanitary facilities, none of the fishing vessels in the three selected fishing communities have sanitary facilities on-board, even for vessels that go fishing for more than two weeks. One respondent said:

> *"There is no toilet on-board. However, if we need to do so, there is a space at the stern just beside the stern post next to the skipper's position. Of course it is an open space and we just hold on to the bulwarks or other structures at the stern"* (Respondent B.F.06).

However, measures to promote better sanitary facilities in Indonesian fishing vessels have been carried out by the government. Figure 6.10 is a grant aid vessel provided by the government for a group of fishers in Latuhalat, and which is equipped with a simple closed space at the stern to be used as a toilet.

An additional significant issue is local fishers' willingness to provide fire extinguishers on-board. There is a relatively high risk of fire on-board, particularly when considering the fishers' habit of smoking during their fishing activities and how the local fishers frequently treat their engine's fuel system, as illustrated in Figure 6.11. Respondents argue that they do not need to worry if a fire occurs on-board, as there is a significant amount of water surrounding the boat.

Concerning the navigational devices on-board, many fishing vessels in Brondong have been equipped with Global Positioning System (GPS) equipment in order to help fishers to navigate their vessels. Respondents stated that they had gained a considerable

Figure 6.10 A grant aid vessel for fishers in Latuhalat with a toilet situated at the stern (Photo by the Author).

Figure 6.11 Daily fuel tank on-board a traditional fishing vessel in Brondong
(Photo by the Author)

advantage by using GPS on-board; not only as it can guide them home more easily, but also as it assists them to locate their FADs and to record the coordinates of possible fishing grounds for future fishing trips. It was interesting to ascertain from one of the respondents in Brondong, a 35 year old skipper, who confessed that he really depends on the GPS to guide him home, as he does not have the skill to navigate in a traditional manner using astronomy and other natural signs, like his ancestors had done.

In contrast with the fishers in Brondong, fishers in the other two fishing communities have never operated any navigation devices on-board. Fishers in Muncar and Latuhalat argue that their fishing ground is quite close to land and that they can still use any known site on land in order to locate their position and to navigate back to port.

In term of communication devices on-board, most fishing vessels in the three fishing communities prefer to use mobile phones to communicate with their home port, although the use of mobile phones for communication on-board local fishing vessels does not always work properly especially when well out at sea. According to respondents, their mobile phones only work properly if the vessel is reasonably close to the islands that support the network coverages.

A further aspect is that of on-board navigation lights which are not common in all three fishing communities. According to respondents in Brondong, accidents frequently happened at sea, in which local traditional fishing boats were accidentally struck by large ships during the night, predominantly coal bulk carriers, because most of the boats are not equipped with the navigational lights.

By considering the potential risks that the local fishers could be confronted with, especially those who go fishing over further distances and for longer durations, the design of the new fishing vessels should fulfil the regulations and recommendations that are related to health and safety on-board. Concerning the fishers' common practices that may contradict with the regulations, in terms of health and safety, the boat designer should endeavour to locate any alternatives that fulfils the requirement of the regulations, whilst simultaneously covering the main reasons that bring the fishers' into conflict with, or inconvenienced by, the regulations.

6.7 Existing Technology in Traditional Fishing Vessel and Its Problem

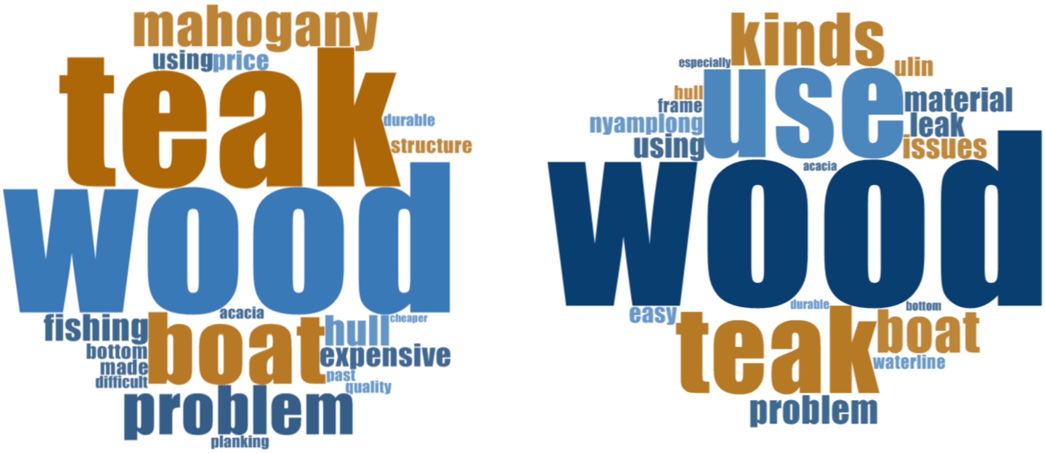
Major improvements in many aspects of the fishing vessels in the three selected fishing communities have occurred over the last three decades and have significantly altered the fishing practices of local fishers. However, current circumstances and the future demands of the fisheries demonstrate that there are still many challenges to be meet and resolved with regards to the existing technology used in traditional fishing vessels.

In the following sub-section, the technologies that are currently applied in traditional fishing boats are presented and discussed, together with any actual and potential problems related to each technology that the local fishers have had to confront. The existing technologies that are discussed in the following sub-sections include the construction materials, the main engines, the fish preservation system, the electrical power sources, and fishing aids.

6.7.1 Construction material

Based on the field observations, as shown in Figure 6.13, wood is still the most common constructional material for fishing vessels in the three selected fishing communities. It was confirmed by the respondents' statement as shown in a "word-cloud" of interview results, concerning construction material that is used in existing traditional fishing boats.

The word-cloud, as seen in Figure 6.12, produced using Nvivo software, is in the form of simple graphical interpretations of the respondents' responses. The size of each individual word in the word-cloud identifies the relative frequency of the occurrence of each word that is used in the respondent's responses, in connection with the specific issues.



(a) (b)

Figure 6.12 Word-clouds illustrating respondents' responses regarding construction materials used
a) Brondong; b) Muncar

As evidenced in Figure 6.12, teak (*tectonagrandis*) is the material most commonly associated with the construction of wooden fishing boats in Brondong and Muncar. The durability and strength of this type of wood is the main reason that local fishers and boatyards employ teak as their main construction material. However, as the price of teak has become progressively more unaffordable and relatively difficult to be obtained, most fishing boat owners and boatyards have thus substituted teak with other types of wood for several structures on their boat, particularly the structures situated above the water line. These different types of wood, which are less durable and less strong, include mahogany (*swieteniamahagoni*), acacia (*acacia mangium*), and nyamplong (*calophyllum*).

(a) (b)

Figure 6.13 Wood used as construction material for fishing boats
a) Brondong (Photo by the Author); b) Muncar (Photo by the Author)

On the one hand, the problem pertaining to the availability of wood has been partially overcome by using a few alternative types of wood. However, conversely, a new problem has emerged. This is revealed by the opinion of one of the respondents, as follows:

> *"The boat's structure has become less strong in the long term, particularly for the above structure (which is mostly made of lower quality wood). In the past, a wooden boat could last for more than 30 years; nowadays it is no more than 10 years"* (Respondent B.F.15).

This condition has been exacerbated by the increase in engine power, which means that there is a commensurate increase in the dimension and weight of the main engine mounted on-board. For instance, the traditional fishing boats in Muncar have 1–3 diesel outboard engines on both sides of the weather deck with a long shaft propeller, as shown in Figure 6.19. Thus, due to any improper setting up of the engine, the lifespan of fishing vessels in Indonesia can decrease from more than 30 years to less than 15 years (Rosyid and Johnson, 2005).

As noted in Figure 6.14, wood is also the principal material for fishing vessels in Latuhalat, Ambon. And different from the two communities in Java, Gofasa wood (*vitexcofassus*) is the common type of wood for fishing boats in Latuhalat.

In contrast to the fishing vessels in the two other fishing communities in East Java, fishers in Latuhalat are reasonably familiar with the use of Fibreglass Reinforced Plastic (FRP) as a material for their fishing vessels. A significant number of FRP fishing vessels and also wooden hulls that are covered by a layer of FRP, have been operated by local fishers and built by local boatyards, particularly the small long boats that are employed for hand line fishing, as illustrated in Figure 6.15.

Figure 6.14 Word-cloud of respondents' responses regarding hull construction materials in Latuhalat

(a) (b)

Figure 6.15 The FRP as construction material for fishing boats in Latuhalat
a) FRP long boat for hand line fishing (Photo by the Author); (b) The construction process of a FRP long boat in Latuhalat (Photo by the Author).

Despite wood being the most common material of choice for fishing vessels in the three selected fishing communities, according to the respondents the use of wood for fishing vessels has several limitations. As noticed in the word-clouds shown earlier, leakage is the most commonly mentioned in-service problem for wooden hulls, therefore, more routine inspections and maintenance actions are required.

According to respondents in Brondong, at every 1–3 months or so, depending on the age of the vessel, the wooden vessels should be docked or grounded for re-caulking and others repairs, as observed in Figure 6.16. Poor construction, which is frequently found in most traditional wooden boats in Indonesia (Dijkstra and Schutter, 1995; Rosyid and Johnson, 2005; Gudmundsson and Davy, 2006), particularly in the joints between the

(a) (b)

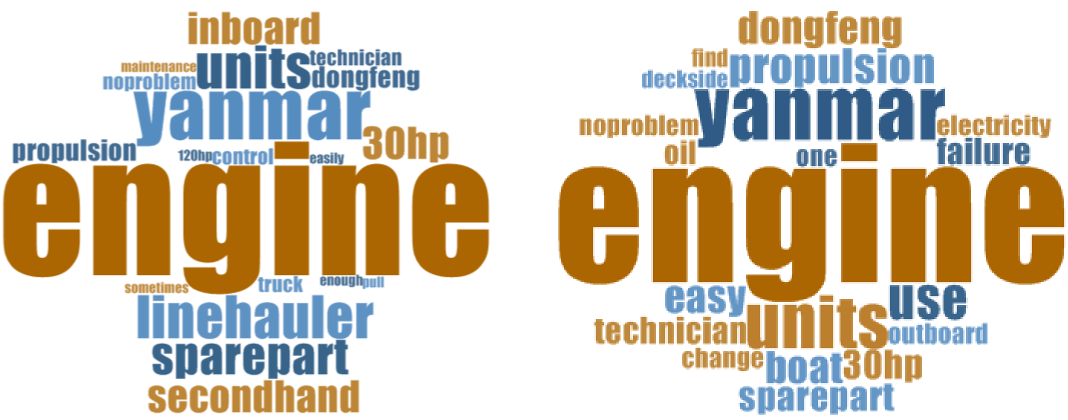
Figure 6.16 Repairing and maintenance activities being undertaken on traditional wooden boats
a) Re-planking of hull bottom in Brondong (Photo by the Author); b) In Muncar, fire is used to dry the planks and to eradicate fouling below the waterline (Photo by the Author).

planking, is the main reason that hulls are not sufficiently water-tight. Also shipworms and fouling that attack the planking below the waterline also increases the risk of leakage and weakens the hull structures. Moreover, given that the more superior modern putty or silicon rubber is relatively expensive and frequently unaffordable for local fishers, traditional putty, which is inexpensive and formulated on traditional experience, is routinely used for sealing the planking seams. Fishers in Muncar and Brondong use a mixture of white cement and white glue (polyvinyl acetate) for the putty, while for the anti-fouling requirement, a number of respondents said that they use only oil based wood paint mixed with pesticides or even mosquito repellent.

6.7.2 Main engines

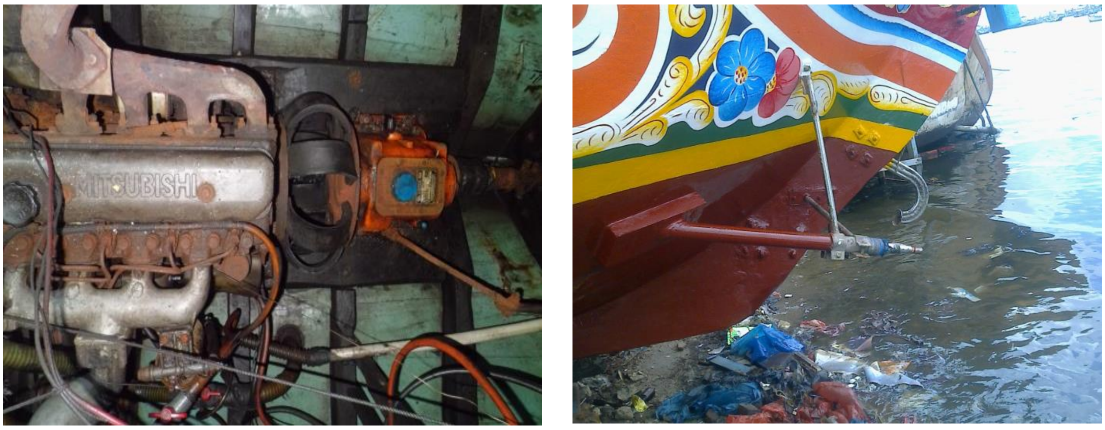
According to the respondents' answers, the diesel engine was introduced in both Brondong and Muncar in the earlier 1980s for vessel propulsion. In Latuhalat, the petrol engine with long-shaft had been in operation since the early 1970s, and afterward was replaced by the marine-use outboard engine in the 1980s. Subsequently, the choice of engine employed for propulsion in the three selected fishing communities has further developed over the past few decades, based on local fishing practices and other practical considerations, including economic reason.

As illustrated in the word-cloud in Figure 6.17, the local fishers' preferences regarding the main engine in both Brondong and Muncar are relatively similar. The entire motorised fleet of traditional fishing boats in these communities employ non-marine type diesel engines or second-hand truck diesel engines suitably modified to propel their boats. The different applications regarding the various engines in both areas are related



(a) (b)

Figure 6.17 Word-cloud concerning the propulsion of traditional fishing boats a) Brondong; b) Muncar.



(a) (b)

Figure 6.18 Inboard diesel engine installed in a traditional fishing boat in Brondong
a) Second-hand truck engine inside the engine room (Photo by the Author);
b) Propeller shaft cut through the hull planking (Photo by the Author).

to how the local fishers physically install the engines on their boats. Fishing boats in Brondong commonly install 2–3 inboard diesel engines, each with individual shafts and propeller, and engines size that vary in power from 30hp to 120hp based on their fishing gears. While the fishing vessels in Muncar generally have installed 2–6 diesel engines, which are predominantly 30hp, each comprised of a long shaft propeller and installed on deck, arranged on both the starboard and port sides of the boats. Figure 6.18 and Figure 6.19 show how diesel engines are typically installed on traditional fishing vessels in Brondong and Muncar.

In contrast with the two fishing communities in East Java, and as illustrated by the word-cloud in Figure 6.20, the respondents in Latuhalat stated that all fishers use outboard marine engines run on kerosene for their fishing vessels. Typically, 2–3 of

(a) (b)

Figure 6.19 Diesel engines with a long shaft propeller on fishing boats in Muncar
a) An old used diesel engines are still extensively employed (Photo by the Author); b) Fishing boat with three diesel engines mounted on each side of the deck (Photo by the Author).

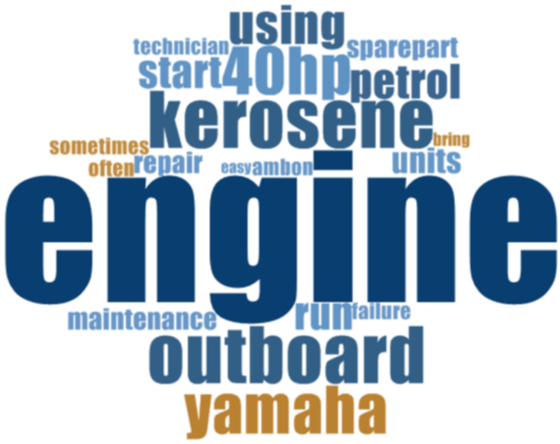


Figure 6.20 Word-cloud in relation to the main engines for fishing boats in Latuhalat

40hp outboard marine engines are installed on fishing vessels that operate a purse seine, while fishers employing hand lines primarily attach 15hp outboard marine engines on their small FRP long boats, as can be seen in Figure 6.21

A potential problem associated with the main engine for the fishers in the three fishing communities is the increasing round trip fuel consumption due to the increase in the duration of fishing trips, as well as the high fuel consumption of some of the selected main engines. Given that the cost of the fuel is a significant proportion of the total operational cost, the high volume of fuel consumed, in addition to the high price of the fuel will significantly reduce the fishers' profits.

Furthermore, based on the results of the interviews, local fishers are concerned about the actual price of the fuel. Although the price of fuel for fishing boats up to 30GT is still subsidised by the government, problems in connection with the supply logistics, especially in relatively remote areas, affects the delivered local price of the fuel. For

(a) (b)

Figure 6.21 Outboard marine engines on fishing boats in Latuhalat
a) On larger boats that operate a purse seine (Photo by the Author); b) On small long boats that operate hand lines (Photo by the Author).

instance, during the Author's field study in 2013, the price of subsidised kerosene in most coastal areas in Java Island was Rp. 2,500/litres (approx. £00.13/litres); however, in the more remote Latuhalat, the price paid by the local fishers was 60% higher than the official price.

Similar challenges occur in the supply chain regarding the engine and its spare parts. The remote geographical positions of some of the fishing communities that cause the distribution problems tend to be one of the challenges regarding the potential implementation of alternative technology for the newly designed fishing vessels. Respondents in Latuhalat, for example, stated that they quite often prefer to purchase outboard engines or other spare parts from Surabaya City, East Java rather than from the nearest supplier who is in Ambon City due to the lower prices and greater availability in Surabaya city.

6.7.3 Electricity power sources

The type and capacity of electricity power sources that needs to be installed in fishing vessels will depend on the selected fishing method and the fish species that they are targeting. Fishers that need to attract certain fish species with lights over the water clearly need more electrical power on-board compared to those that only use lights to illuminate the working deck and the accommodation at night.

Fishers in Brondong who operate seine nets, hand lines or long lines mostly catch fish in the daytime, which are not attracted by light; therefore, their boats require

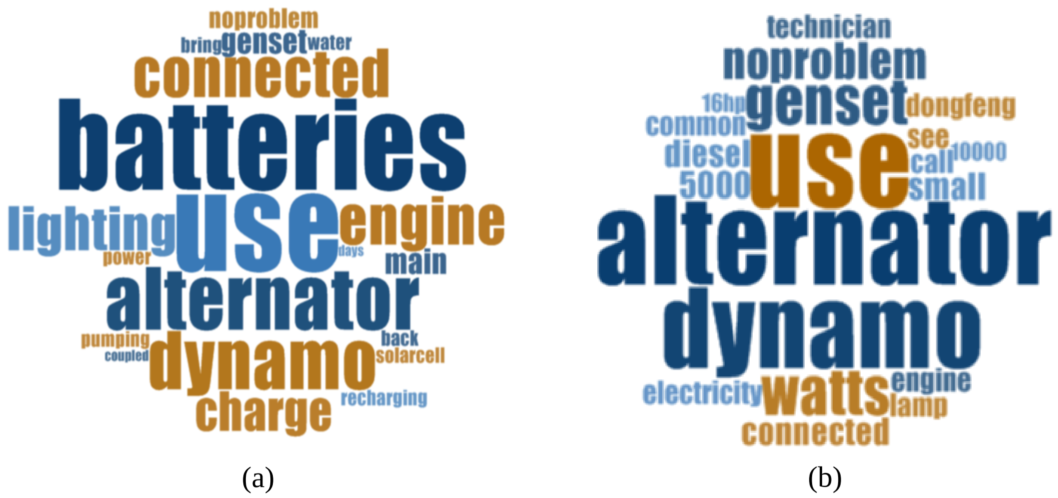


Figure 6.22 Word-cloud for the electricity power sources employed on fishing boats a) Brondong; (b) Muncar.

Figure 6.23 Solar panel on traditional fishing boats in Brondong
(Photo by the Author)

correspondingly less electricity for general lighting at night. For that reason, local fishers principally carry batteries as the electricity sources for lighting, as depicted in the word-cloud in Figure 6.22(a). In order to recharge the batteries, fishers that go fishing for a longer time will take an alternator that is mechanically coupled to their main engine. For the smaller fishing boats that go fishing for only a few days, the fishers will charge their batteries at home or by using solar cells continuously during daytime on-board, as seen in Figure 6.23. According to the respondents, the solar panels that are installed on local fishing boats are part of the group of solar panels that were originally granted by the local government to more than one hundred traditional fishing boats in Brondong, a number of years ago. However, at present only a few of the local fishers that operate long lines and hand lines still use them.

In contrast, the fishers who operate purse seine in Brondong, usually employ strong lamps in their fishing boats in order to attract the fish to the surface at night time. In order to supply enough electricity for numerous high powered lights, for large vessels, minimum 10kWh alternator coupled to the main engine or with a separate diesel engine. Moreover, a small motorised up to 2 kWh electricity generator, which operates on petrol, is fitted on a simple raft that is equipped with 1–2 lamps and that is launched from the boat in order to aggregate the fish into the water surface.

Based on the respondents' responses revealed in the word-cloud in Figure 6.22(b), the alternator is the main electricity source that is employed by local fishers in Muncar. From the larger fishing boats that operate a purse seine down to the small boats that use gillnets and hand lines, most have an alternator on-board coupled with a separate diesel

Figure 6.24 A simple polyurethane raft equipped with a genset for FAD in Muncar (Photo by the Author)

engine. Moreover, just like the fishers in Brondong, a small genset run on petrol is only used on a simple raft as a FAD for fishing boats that operate a purse seine, as illustrated in Figure 6.24.

It is worth noting that in Latuhalat, slightly different electrical sources can be found on fishing boats, as observed in the word-cloud in Figure 6.25. The local fishing boats measuring roughly 18 metres in length and that operate a purse seine employ small 1kW – 3kW electrical gensets run on petrol in order to supply sufficient electricity on-board. While for lighting on the FADs, the local fishers prefer to use the “Petromax” lantern, which is a pressurised kerosene lantern, since it is inexpensive to buy and to use compared to a genset.

The same as the problem in employing main engines, local fishers in the three fishing communities are also concerned about the operational cost of the electricity source. Their

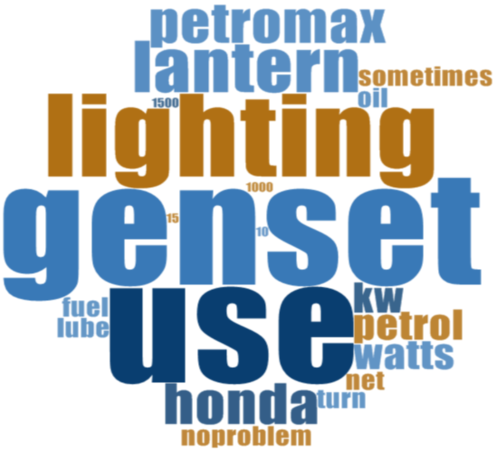


Figure 6.25 Word-cloud for electricity power sources employed on fishing boats in Latuhalat

choice of power sources on-board is related to their attempt to minimise the operational cost. Fishers in Latuhalat prefer to use kerosene pressure lantern for their FAD, seeing as it is cheaper than a genset operating on petrol, while fishers in Muncar select alternator that is coupled with diesel engine for the high power sources on-board, for the reason that it runs on diesel that is less expensive than petrol.

6.7.4 Fish preservation

Fishers in Brondong tend to fish on voyages of longer duration than the other two fishing communities. According to the local respondents, it can take 1-3 days to reach the targeted fishing ground. Therefore, most fishers in Brondong stay at sea for normally 7 to 14 days. In order to keep their fish catches in a good condition during the fishing trip, the fishers in Brondong have been relying on ice in order to preserve their fish, as revealed in the word-cloud in Figure 6.26(a) and as shown in fishing preparation in Figure 6.27

The amount of ice blocks that each vessel takes to sea depends on the size of the vessel and on how long they plan to go fishing for. Thus, a typical local fishing boat in Brondong that is 15 metres in length with seine net fishing gear on-board, and which intends to go fishing for 14 days, could take prior to departure 400–600 blocks of ice of 25kg each with a combined weight of 10 tonnes–15 tonnes. Later, as the fish are being caught, these blocks of ice will be crushed manually into flakes of ice prior to being used to cover successive layers of fish in the fish hold.

(a) (b)

Figure 6.26 Word-cloud concerning fish preservation systems on fishing vessels a) Brondong; b) Muncar.

Figure 6.27 Fishers in Brondong stocking block ice in the fish hold before going fishing (Photo by the Author).

Similar to the fishers in Brondong, the local fishers in Muncar also use the same method for fish preservation, as observed in the word-cloud in Figure 6.26(b). The difference in approach between the two groups of fishers is only with regards to the amount of block ice that they carry on-board. Fishers in Muncar predominantly go fishing for less than 18 hours on each fishing trip; therefore, the amount of ice that they take to sea is much less than that take by the fishers in Brondong. Typically, the 10 meter fishing boats in Muncar, as shown in Figure 6.28, that operate hand lines or gillnets, will take only 2–3 blocks of ice in simple portable fish boxes for one single fishing trip.

Respondents from these two fishing communities, as presented in Figure 6.26, confirmed that they have no issues with utilising ice to preserve their fish. All the respondents claimed that on condition that fishers maintain the amount of ice in the fish hold and

Figure 6.28 Small fishing boat in Muncar usually carries 2–3 blocks for a single trip (Photo by the Author).

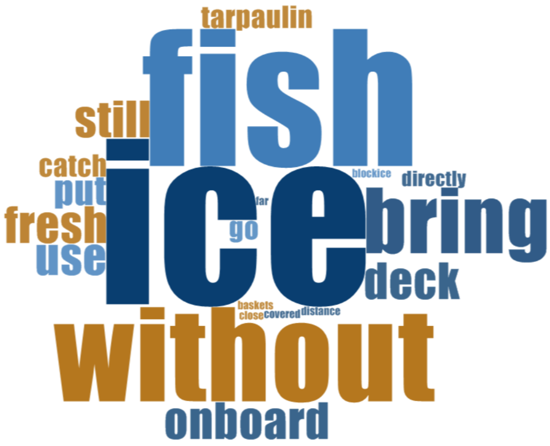


Figure 6.29 The word-cloud concerning the fish preservation system on fishing vessels in Latuhalat

regularly pump out the water inside, then the fish will remain fresh throughout the journey back to the home port, even for those who go fishing for up to two weeks.

However, according to the respondents in Brondong, the challenges that local fishers face in using block ice for the preservation of their fish is in the unpredictability of the volume of their catches. This eventually affects the numbers of the ice block that they carry on-board for every fishing trip. Quite often the amount of ice that the fishers load on-board is far too much when compared to the amount of fish that they ultimately catch. Conversely, if the fishers chose to take less ice on-board and then subsequently catch more fish, this reduces the quality and value of their landed catches.

As revealed in the word-cloud in Figure 6.29, in contrast to the other two fishing communities in East Java, the fishers in Latuhalat do not carry ice on-board in order to preserve their fish. They argue that they do not need any ice on-board for the length of their fishing trips, which only lasts for 5 hours on average, for fish to be kept fresh. Therefore, the 18 metre fishing boats with a purse seine, do not have either a fish hold or a fish box on-board to be used for storing fish. Their catches, which are mainly tuna fish, are placed on the weather deck and are covered with tarpaulin sheet. The respondents in Latuhalat claimed that the fish remains fresh when it arrives at the fishing port, on the condition that they keep the fish under the tarpaulin sheet always wet.

Based on observations of the fish holds in local fishing boats in Muncar and Brondong, there appears to be insufficient insulation on the fish hold partitions. The partitions between the separate fish holds only use timber that is 30mm–50mm thick without any additional insulating material being attached to it. This relatively thin insulation leads to an increase in the melting rate of the blocks of ice, and so requires fishers to carry more ice in their fish holds for each fishing trip. The addition of insulations therefore needs to be considered during the design of the proposed fishing vessel.

6.7.5 Fishing aids

The employment of fishing aids in order to increase the catching efficiency of the fishing gear in the three selected fishing communities varies, depending on the fishing gear and fishing methods employed by the local fishers. Based on the results of the interviews and on personal observations of actual local fishing vessels, the fishing aids used by local fishers in Brondong comprise Fish Aggregating Devices (FADs) and fish finders, while in Muncar and Latuhalat, the local fishers only employ FADs.

The electronic fish finder is a device that can frequently be found on small fishing vessels in most developed countries. However, based on respondents' responses, only a few fishing boats that operate either hand lines, long lines or a purse seine in Brondong use this device to assist in their fishing practices. The cost of the fish finder is the main reason that local fishers in Brondong have not equipped their boats with this valuable tool. Other respondents argued that they prefer to rely on their natural skill and experiences to predict the position of fish rather than to equip their boats with this expensive device that most local fishers simply cannot afford. The same reason was also expressed by fishers in Latuhalat. Many of the local skippers are actually very familiar with this device, as most of them have some experience gained by working as crew on foreign fishing vessels equipped with various modern devices, including fish finders. However, since the fishing boat owners in Latuhalat refuse to invest in this tool, the local skippers have no choice other than to use their natural skill to locate schools of fish.

In Muncar there is a different and complex reason for not using fish finder. The local fishers' objection to the use of the fish finder is in connection with the social problems associated with having fair and unbiased equal access to local fish resources. According to local respondents, given that the price of the device is not affordable for most of the fishers in Muncar, if it is allowed to be used on the local fishing grounds, this device will only be employed by the more wealthy fishers, which consequently will assist this relatively small group of fishers to gain easy and unfair access to limited fish resources. According to respondents from Muncar, there was an incident many years back, when a

Figure 6.30 A “fish finder seat” on fishing boat in Muncar
(Photo by the Author)

fishing boat from another region was attacked and burnt by local fishers as it used a fish finder in order to fish in the Muncar fishing grounds. The respondents therefore claim that the fish finder is prohibited in their fishing area. The interviews also revealed that a lack of knowledge and information associated with the device has also aggravated the circumstances. Local fishers assumed that the fish finder, which is actually sonar used to detect the presence of fish below the water surface, is a device to call or lure the fish.

For this reason, fishers in Muncar retain a simple structure in their fishing boats to help the skipper in visually looking for signs of fish schools. This structure, which is called “*Pantoan*” locally, is in the form of a chair that is positioned relatively high above the weather deck, just like the traditional crow’s nest platform in European wooden tall ships. An example of a typical “fish finder seat” can be seen in Figure 6.30.

The only fishing aid that can be observed in each of the three selected fishing communities is the Fish Aggregating Devices (FADs), which includes the anchored FAD and the moveable FAD devices. The first one is a simple raft or metal/plastic container that has coconut leaves tied to it below the water surface and is anchored to the seabed. This type of FAD acts as a floating artificial habitat for the fish that are being targeted in the potential fishing ground. The moveable FAD is a simple raft or boat typically measuring 1–2 metres in length with a few strong lamps fitted on it in as seen in Figure 6.32

(a) (b)

Figure 6.31 Powerful lights fitted on-board to attract fish in Muncar
a) On a small fishing boat that operates a hand line; b) On a larger fishing vessel that operates purse seine.

This moveable FAD fitted with lamps together with a large number of high-power lights on the main fishing boat that are used to illuminate a larger region of the water around the vessel, as seen in Figure 6.31, are used to attract fish during the night. The lamps on-board will be lit when the vessel is searching for schools of fish**.** When the skipper detects the fish school approaching the boat, the small craft with its lights on will be launched and rowed away from the main boat. As soon as the small boat or raft reaches a certain distance from the fishing boat, which is far enough away for the main boat to be able to encircle the raft with the net, the light level on the fishing boat will be reduced gradually and subsequently turned completely off; therefore only the light on the small boat or raft remains on. This condition will guide the school of fish towards the small raft, where the net can be moved to encircle the raft with the fish around it.

(a) (b)

Figure 6.32 FADs that are used to attract fish in Muncar
a) Simple lantern for attracting fish (Photo by the Author); b) A small FRP boat equipped with genset and lamps (Photo by the Author).

6.8 Concluding Remarks

The field study conducted in the three selected fishing communities in Indonesia revealed interesting and valuable information in relation to preparing the input for designing sustainable fishing vessel tailored for the targeted fishing community in Indonesia.

Based on the in-depth interviews, all three fishing communities have experienced a decline in fish stock in their traditional fishing grounds that have consequently forced local fishers to go fishing over further distances than in the past. Without any improvement in their current fishing vessels, the potential profit that the fishers could obtain cannot be maximised. The possible change to the mission profiles and furthermore the increased risk as a result of operating in fishing ground located further away need to be considered during the design of the new fishing vessels for the selected communities.

The result of the in-depth interviews revealed that local fishers' have relatively little or no awareness on the implementation of health and safety on-board, compliance with the regulations and moreover, concerning marine preservations. The lack of understanding of local fishers' regarding these three aspects have hampered the implementation of responsible fishing practices, and make it more challenging with respect to designing a sustainable fishing vessel for these particular communities. The potential conflict of interest therefore needs to be considered during the design process.

Concerning the potential improvement related to the technologies employed in current fishing vessels or regarding the selection of alternative technologies that could possibly be applied on new fishing vessels in these communities, based on this field study, many factors need to be considered. They include the relatively low of level of education of most local fishers and the inadequate financial support; the competencies of local fishers and local boatyards in employing and maintaining alternative technologies; the availability of suitable infrastructure, including the continuity of the supply chain to support the operation of the technologies, principally for more remote areas; and any potential conflict with the local social cultures that potentially refuse to implement such technologies.

Chapter 7. Selection of technologies to be applied on Indonesian fishing vessels

7.1 Introduction

Many of the difficulties that fishing vessels in Indonesia are confronted with are due to the relatively low level of technology that is employed on-board. This condition clearly affects both productivity and the profit that the fishers can earn from fishing and, in many cases, it also inhibits the implementation of responsible fishing practices. In order to identify improvements that can be implemented for both current and future fishing vessels regarding their technologies, a number of alternative technologies that could possibly be employed on fishing vessels have been identified in Chapter 5. However, in order to ensure that the selected technologies can support sustainable fishing vessels and the sustainability of the fisheries, these alternative technologies need to be assessed regarding their social acceptability, economic viability and the potential impacts to the environment.

In order to answer the research questions concerning what are the appropriate technologies for fishing vessels in Indonesia that fulfil the requirements of the three pillars of sustainability, assessments of alternative technologies that could be employed were undertaken. Results from these assessments were subsequently used as input to decide which technologies could best be implemented on the proposed fishing vessel.

7.2 Methodology to Select the Appropriate Technologies

Landamore *et al*., (2007) identified sustainable technologies for the design of small craft by combining stakeholder requirements with expert opinion. Lists of the latest technologies were first developed by a group of experts, and subsequently evaluated by local stakeholders. In order to ensure minimum impact on the environment, each of the selected technologies were assessed by a Life Cycle Assessment (LCA). Finally, cost-benefit analysis was used to assess the economic aspects (Landamore *et al.*, 2007).

It should be noted that a relatively similar methodology was applied for this research project. In relation to fishing vessels, four groups of significant technologies were listed and each assessed concerning the three pillars of sustainability. These four groups of technologies are construction materials, main engines, electricity sources, and fish preservation systems

Table 7.1 Group of technologies for construction materials assessments

Group of Technology	Fishers' Preferences	Cost Analyses	LCA
Construction materials	• Wood (benchmark) • Wood laminate • FRP • Aluminium alloy • Steel	• Wood (benchmark) • Wood laminate • FRP • Aluminium alloy • Steel	• Wood (benchmark) • Wood laminate • FRP • Aluminium alloy • Steel

In terms of the social aspect, the technologies were each assessed regarding their level of acceptability to the local fishers. As a result, the order of technologies based on the fishers' preference in each community was identified. For the economic viability, a cost-analysis was applied to the each of alternative technologies. The initial investments and total operational costs for a target operational lifespan of 20 years for each technologies were compared. Furthermore, the impact of each of the alternative technologies on the environment was assessed over its life cycle by means of a Life Cycle Assessment (LCA). As a result of the LCA, the technology with the minimum negative impact on the environment during a life cycle of 20 years was identified.

Each group to be assessed, as seen in Table 7.1 to Table 7.4, consists of the existing technologies as the benchmark and a few alternative technologies. Seeing as the current technologies for main engines and electricity sources are different for Latuhalat and the other two communities in East Java, the alternative technologies for these two groups of technologies were divided into two sets, one set for Latuhalat and other set for Muncar and Brondong, as illustrated in Table 7.2 and Table 7.3

Table 7.2 Group of technologies for main engines assessments

Group of Technology	Fishers' Preferences	Cost Analyses	LCA
Main engines	*Muncar & Brondong*: - Non-marine diesel (benchmark) - Marine diesel - Electric hybrid engine - Engine run on bi-fuel (diesel + LPG) - Engine + sail *Latuhalat*: - Outboard engine run on kerosene (benchmark) - Marine diesel - Electric hybrid engine - Outboard engine run on LPG - Engine + sail	*Muncar & Brondong*: - Non-marine diesel (benchmark) - Marine diesel - Electric hybrid engine - Engine run on bi-fuel (diesel + LPG) *Latuhalat*: - Outboard engine run on kerosene (benchmark) - Marine diesel - Electric hybrid engine - Outboard engine run on LPG	*Muncar & Brondong*: - Non-marine diesel (benchmark) - Marine diesel - Electric hybrid engine - Engine run on bi-fuel (diesel + LPG) *Latuhalat*: - Outboard engine run on kerosene (benchmark) - Marine diesel - Electric hybrid engine - Outboard engine run on LPG

Table 7.3 Group of technologies for electricity sources

Group of Technology	Fishers' Preferences	Cost Analyses	LCA
a) AC power sources	*Muncar & Brondong*: - Alternator + diesel engine (benchmark) - Genset run on LPG *Latuhalat*: - Genset run on petrol (benchmark) - Genset run on LPG	- Alternator + diesel engine - Genset run on LPG - Genset run on petrol	- Alternator + diesel engine - Genset run on LPG - Genset run on petrol
b) DC power sources	- Battery with land grid charging (benchmark) - Solar cell - Wind turbine	- Battery with land grid charging (benchmark) - Solar cell - Wind turbine	- Battery with land grid charging (benchmark) - Solar cell - Wind turbine

All the benchmarks and alternative technologies were accessed in three aspects of sustainability, excluding an engine assisted by sail, which was only assessed regarding its social acceptability. Given that a sail can assist all types of engines and offer a similar percentage pertaining to a reduction in fuel consumption, as a result of the reduction in the engines operational time, then the percentage of reduction in terms of cost and environmental impact for each engines that is assisted by a sail are similar and did not affect the comparison of the main engines. Therefore the cost analysis and LCA for an engine assisted by sail was not considered further in this study.

The results from each type of the previously mentioned assessments vary in terms of the ranking of the alternative technologies. In order to compose a final overall ranking that considers the three aspects of sustainability, the results from the three assessments were used as an input for a Multi-Criteria Decision Making (MCDM) procedure. This was in order to create a final ranking regarding the alternative technologies and to determine the most appropriate technology to be employed in fishing vessels for each fishing community.

Table 7.4 Group of technologies for fish preservations

Group of Technology	Fishers' Preferences	Cost Analyses	LCA
Fish preservation systems	- Block ice from home port (benchmark) - On-board ice machine - On-board freezer	- Block ice from home port (benchmark) - On-board ice machine - On-board freezer	- Block ice from home port (benchmark) - On-board ice machine - On-board freezer

7.3 Fishers' Preferences on Alternatives Technology for Fishing Vessels

In this section, the local fishers' preferences in the three selected fishing communities concerning the aforementioned groups of alternative technologies are identified. The following subsections present the method that was employed in order to elicit the fishers' preferences on alternative technologies. Subsequently, the results for each group of technologies are presented in conjunction with the discussions on the reason and rationale for their preferences.

7.3.1 Methodology for identifying fishers' preferences

Fishers' preferences on the alternative technologies were identified by asking local fishers how they rate their level of interest in each alternative technology. In order to approximately quantify the fishers' level of interest, the attitude measuring method known as the Likert scale was employed. The Likert scale is a graded response scale that is used to measure people's attitudes in association with their opinions, preferences, or perceptions concerning the issues being asked (Moser and Kalton, 1971; Göb *et al.*, 2007; Trochim and Donnelly, 2008).

The 1-5 point response scale was used to identify the fishers' preferences to each alternative technology with the level of interest being: (1) very low, (2) low, (3) moderate, (4) high, and (5) very high. The results of the response scale for each group of alternative technologies are presented in the form of bar charts in the following sub-sections.

7.3.2 Result of fishers' preferences with regards to technology

Based on the results of the in-depth interviews, local fishers' levels of interest regarding the alternative technologies are influenced by many factors including their general knowledge concerning the technologies, the level of user difficulty in operating alternative technologies, and the cost for procuring and operating and maintaining the technologies. More detailed results of fishers' interest in each of the four groups of alternative technologies are presented in the following descriptions.

A. Construction material

The results of the in-depth interviews in the three selected fishing communities regarding local fishers' preferences on construction materials can be seen in the bar charts as illustrated in Figure 7.1. Based on this figure, wood clearly remains as being the main preference used for construction material in the three fishing communities.

Fishers' level of interest related to materials other than wood is relatively low, in the three communities, except in relation to FRP. According to the respondents, the laminated wooden boat is too complicated in terms of its structure, and therefore, is somewhat difficult to repair if there is any damage to the hull. Moreover, several respondents believed that solid wood in a conventional wooden boat is stronger than glued wood planks on a laminated wooden boat. While for metal boats, the cost of constructing in steel or aluminium alloy, which is higher when compared to a traditional wooden boat, has reduced the local fishers' interest in metal materials. Moreover, relatively small metal fishing boats are types of vessels that local fisher are not familiar with, and respondents' argued during the interviews that steel is more suitable for large merchant ships rather than in a fishing boat.

A mix of responses was ascertained however in the three communities regarding the potential employment of FRP. The primary concern of the local fishers in Brondong and Muncar that have little or no interest in FRP is in the strength of the FRP material itself. Local fishers, principally those that operate heavy fishing gear, such as purse seine and

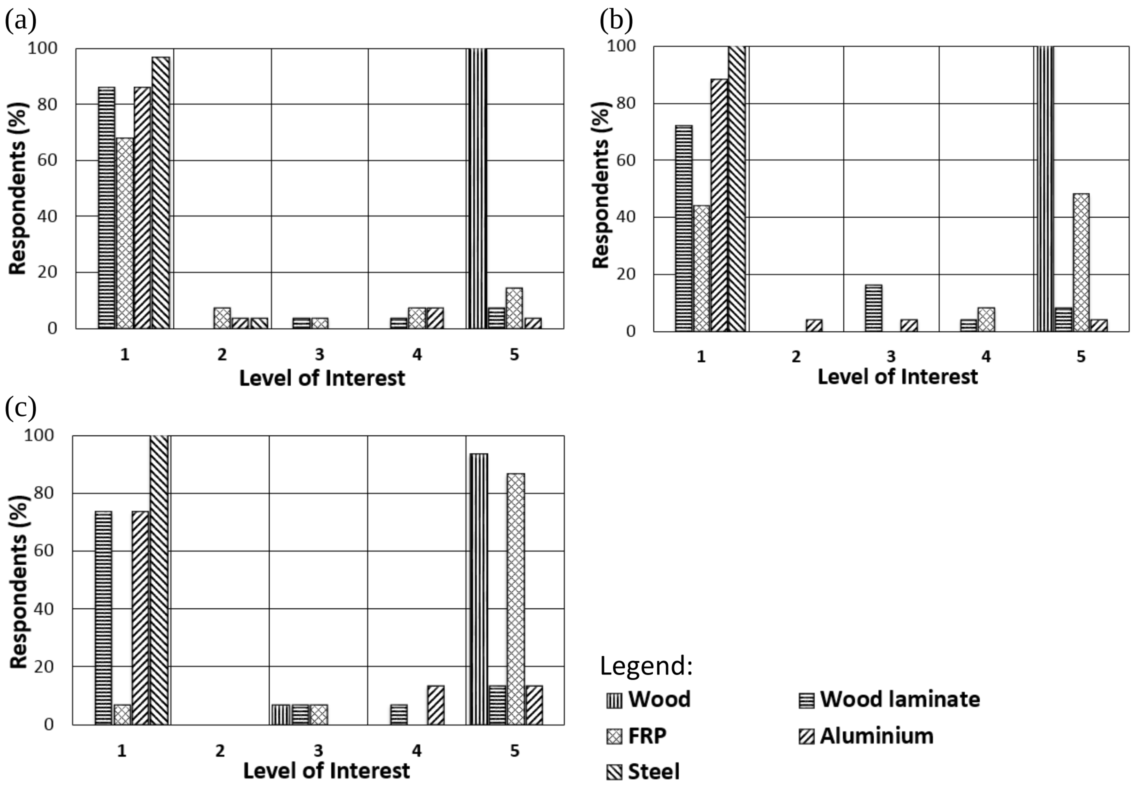


Figure 7.1 Respondents' preferences regarding the construction materials
(a) Brondong; (b) Muncar; (c) Latuhalat

seine nets, question the strength of FRP to deal with any large and repetitive impacts that the structure may possibly receive, particularly during fishing activities and moreover, when undertaking a beach landing in order to carry out repairs. In Brondong this situation has been exacerbated by the experiences of local fishers who have witnessed the poor quality of a number of the current FRP fishing boats, which were built rather inappropriately.

In contrast, fishers who operate smaller boats in Muncar, of up to 10 metres in length and that employed handlines or gillnets, showed an interest in FRP. The relatively light weight of the FRP boat has particularly attracted this group of fishers given that it will be physically easier for a crew of 2-3 to operate. Moreover, the presence of the FRP long boats with outriggers in Muncar has recently encouraged this group of fishers to change their wooden boats to FRP boats.

The highest level of interest regarding FRP was found to be in Latuhalat, as seen in Figure 7.1(c). Fishers in Latuhalat have been familiar with FRP since the introduction of small FRP long boats for artisanal fishing, more than one decade ago. Subsequently, local fishers who operate larger vessels, approximately 18 metres in length, also expressed their interest in FRP, since the local fishers found that the FRP boat was more water-tight and required less maintenance when compared to the traditionally constructed wooden boat. However, according to the local respondents, the cost of constructing a FRP boat is 70% higher compared to that of building a similar sized wooden boat in Ambon. As a result, there are only a few large fishing boats made of FRP in Latuhalat.

B. Main Engine

Respondents' responses in Brondong and Muncar related to the main engines were relatively similar. The non-marine diesel engines that are found on local fishing boats, which are the second-hand truck engines or multi-purpose diesel engines, remained the principal choice for local fishers in these two communities, as can be observed in Figure 7.2.

Based on the interviews, many aspects influence local fishers' interest pertaining to the alternative main engines. In terms of affordability, respondents have concerns regarding the costs of procuring the alternative engines. According to respondents in these two communities, local fishers prefer to use non-marine diesel engines, seeing as it is

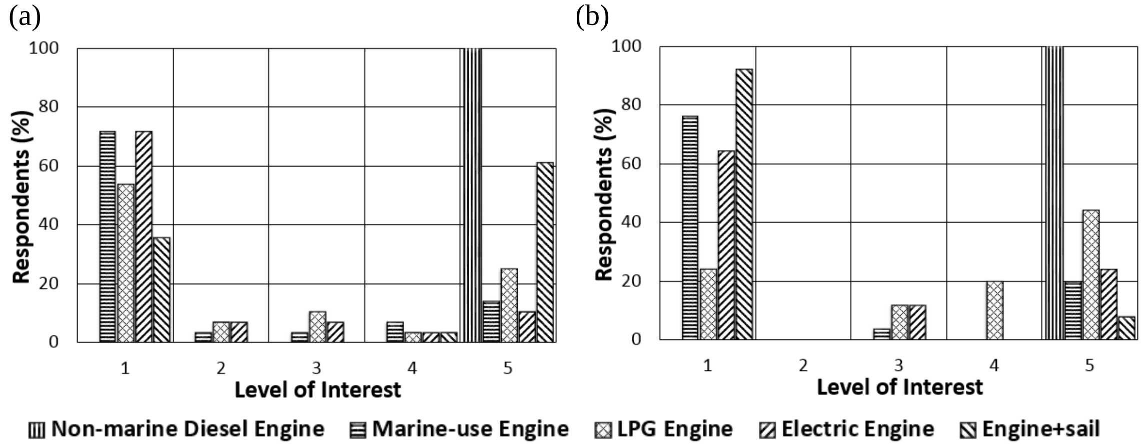


Figure 7.2 Respondents' preferences in Brondong (a) and Muncar (b) regarding the main engines

approximately 75% cheaper in contrast to marine-diesel engines. The maintainability of the engines is another concern. According to respondents, the fishers' are reluctant to install marine diesel engines because they are relatively more complicated to be maintained when compared to their current engines.

Regarding the engine that is run on LPG or the electric hybrid engine, respondents in Brondong have little interest in these engines since they questioned the reliability of these two types of engines to be able to propel boats that drag heavy nets with full catches inside.

In contrast to the respondents in Brondong, the respondents in Muncar demonstrated their interest in the engine run on LPG. However, there are still concerns among the respondents in Muncar related to the possible risk of the LPG exploding when it is exposed to tough conditions at sea. Moreover, the general availability of this type of fuel locally is an additional concern. There is currently a problem with the continuity of the supply chain in connection with LPG in Muncar. As an example, respondents remarked that there was often a shortage of LPG for use in households in their community.

Based on Figure 7.3, the outboard marine engine that runs on kerosene remains the principal choice of the fishers in Latuhalat. Respondents argued that the length of their fishing trips, which are typically less than 5 hours, is the primary reason why they prefer to employ the outboard type marine engine, while kerosene is preferred due to its low price as a result of government subsidies with respect to this type of fuel. However, as discussed in Chapter 6, the Indonesian government's current policy to convert usage

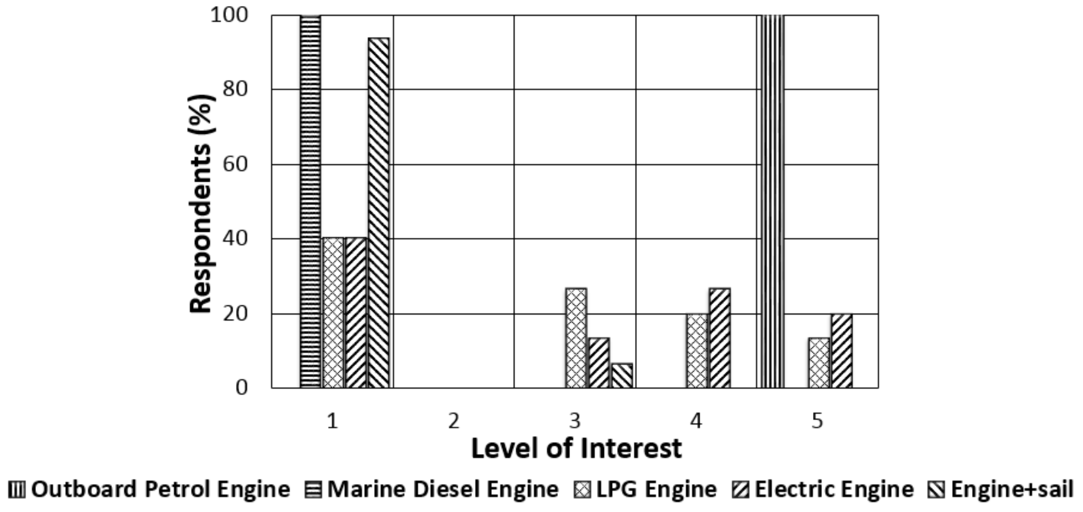


Figure 7.3 Respondents' preferences in Latuhalat regarding the main engines

from kerosene to LPG could end up with the removal of subsidies for kerosene hence increasing its cost. Therefore, it is important for local fishers in Latuhalat to consider alternative types of engines for the future. According to Figure 7.3, respondents in Latuhalat are moderately interested in the engine that runs on LPG and also in the electric drive propulsion.

Furthermore, according to the respondents, the main reason for the rejection of the inboard marine diesel engine in Latuhalat, as seen in Figure 7.3, is because it is easier to operate and to conduct maintenance on the outboard engine compared to the inboard marine diesel engine.

In term of the employment of a sail to assist the main engines as propulsion, according to Figure 7.2 and Figure 7.3, only respondents in Brondong that still have some interest in this particular method of propulsion. In fact, local fishers in Brondong still bring sail in their boats, however, according to the respondent, it is mostly as a backup for the possibility of failure engines and to keep the boat more stable in rough condition.

C. Electricity Sources

The respondents in Brondong have relatively less interest in alternative electricity sources apart from their current technologies, as seen in Figure 7.4(a). The alternator coupled with a diesel engine is still the foremost choice for the Alternating Current (AC) power sources. The principal reason that respondents’ are less interested in the generator run on LPG is due to their scepticism that it can provide the same power when compared to the alternator coupled with a diesel engine. Moreover, fishers are still worried about operating LPG on-board their boats.

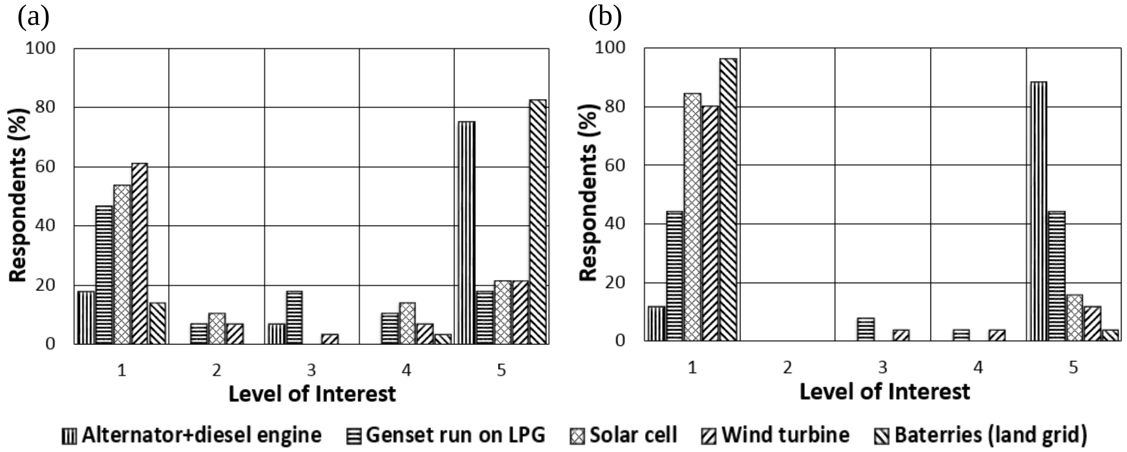


Figure 7.4 Respondents' preferences in Brondong (a) and Muncar (b) regarding the electricity sources

Regarding the DC power sources, respondents argued that to recharge their batteries by an alternator coupled to their main diesel engine or just recharge it using the land grid at home is more straightforward compared to solar panels, particularly during the cloudy rainy season. Moreover, they considered that solar panels are relatively expensive to invest in.

Based on Figure 7.4(b), an alternator coupled with a diesel engine remains the favourite choice for electricity source in Muncar for all type of boats. Furthermore, just as their stated interest in a propulsion engine that runs on LPG, the respondents in Muncar also demonstrated a reasonable level of interest in an electricity generator set running on LPG. However, similar to the case of the alternative engine running on LPG, the same risk of using LPG as fuel for the generator and of the local problem in terms of the availability of LPG were still the primary concerns of the respondents.

The results of the in-depth interview in Muncar also showed that the fishers' had little interest in DC power sources. According to the local respondents, in addition to employing an alternator on-board, it is still common for the smaller fishing boats, up to 10 meters length that operate handlines and gillnet, to only equipped their boats with simple kerosene lanterns for lighting on-board, and also for attracting fish.

The fear of an exploding LPG was also the foremost reasons that the local fishers in Latuhalat to have little interest in this type of electricity sources, as seen in Figure 7.5. For a strong light in order to attract fish, the respondents prefer to employ a generator that is run on petrol to supply the electricity. However, in contrast to the other two fishing communities, the respondents in Latuhalat showed a relatively high interest in

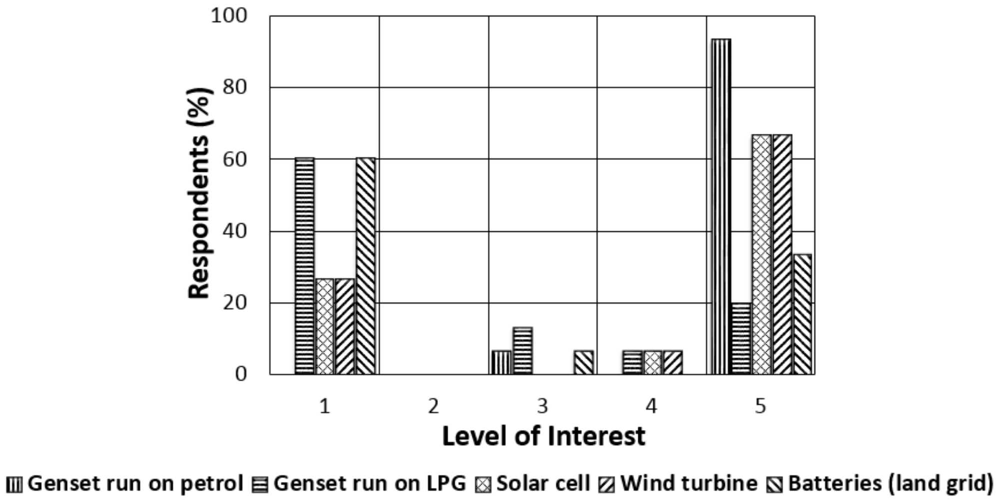


Figure 7.5 Respondents' preferences in Latuhalat regarding the electricity sources

employing solar cells and wind turbines on-board. The potential to reduce operational costs in relation to the lighting their boats and, moreover, as a backup for the generator were among the reasons given according to the respondents.

D. Fish Preservations

The results of the in-depth interviews revealed that taking block ice from the home port is still the main preference in the three selected fishing communities for fish preservations. However, the respondents' responses with regards to the two other alternative methods varied. Figure 7.6 illustrates that the respondents in Brondong have little interest in both the on-board ice machine and the freezer.

The respondents argued that investment in both alternative systems is unaffordable for local fishers. Moreover, according to the respondents, applying a freezer on-board will require higher operational costs in comparison to using block ice. Respondents in Brondong also argued that their boats do not have enough space in which to install either an ice machine or a freezer on-board.

Identical to the respondents' responses in Brondong, the respondents in Muncar and Latuhalat also have little interest in using an on-board freezer for fish preservation, as seen in Figure 7.6(b) and Figure 7.6(c), and which was caused by similar reasons. Conversely, the respondents in Muncar demonstrated a moderate interest in having an

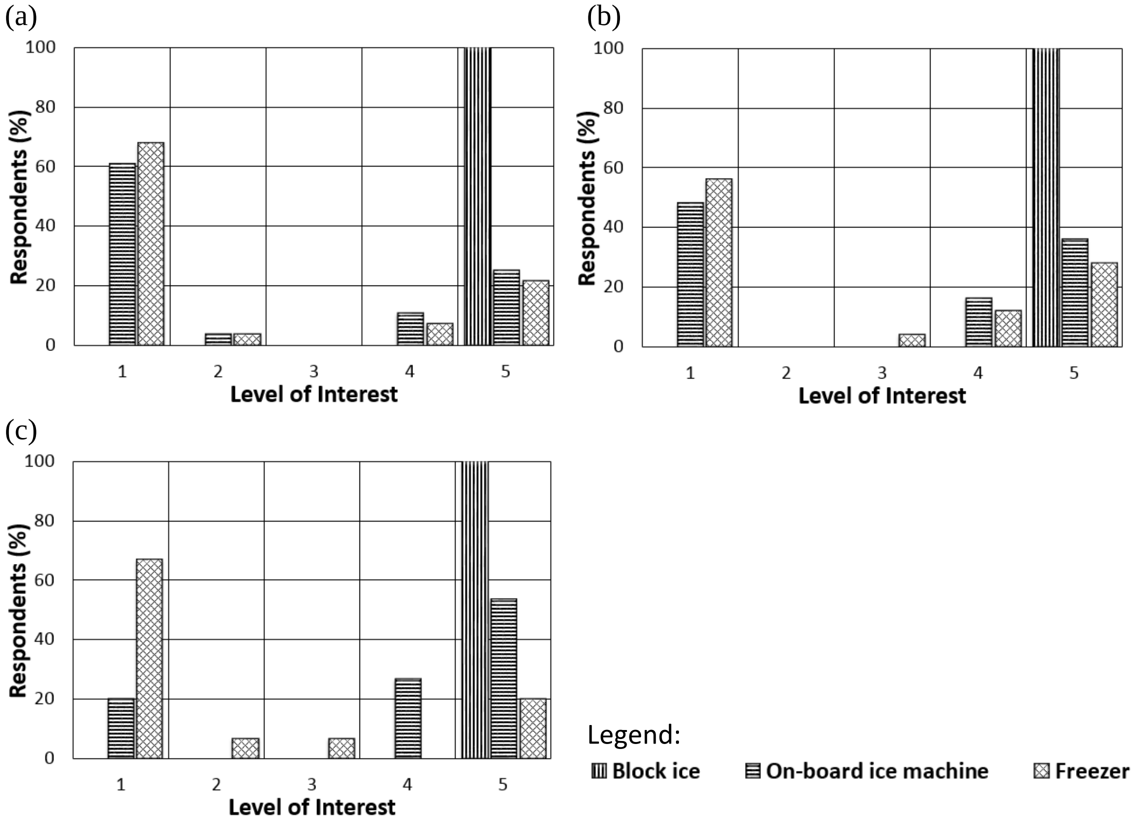


Figure 7.6 Respondents' preferences regarding the fish preservation methods Brondong; (b) Muncar; (c) Latuhalat

ice machine on-board. Even the respondents in Latuhalat showed a relatively high interest in having an ice machine on-board, particularly because it can essentially provide the amount of ice that is required at any given time. However, some respondents that have little interest with respect to an on-board ice machine asserted that the equipment is too complicated and too expensive to be employed on small boats.

7.4 Cost Analysis of Alternative Technologies on Fishing Vessels

Based on the respondents’ responses, one of the principal factors which affects local fishers’ lack of interest in employing alternative technologies is the price of procuring such technologies. The lack of financial support has limited local fishers’ preferences pertaining to the technologies to be employed on their fishing boats. According to one of the local fisheries officers in Muncar, the lack of local fishers understanding as regards the potential long-term benefits of each technology, in terms of operational cost, has also affected local fishers’ considerations regarding the choice of appropriate technologies.

The potential profit that can be gained by employing a fishing vessel is obviously affected by the operational cost of the vessel itself, which includes the cost of procuring, operating and maintaining the entire technologies on-board. In order to assess the alternative technologies regarding their economic viability, a cost analysis was conducted for each alternative technology along the anticipated service life of the proposed vessel, which was assumed to be 20 years. The four groups of technologies, as discussed with local fishers in the previous section, as listed in Table 7.1 through to Table 7.4 were separately assessed for the cost analysis.

The following sub-section describes the methodology of identifying the through-life cost of each alternative technology and provides a discussion related to the result of the analysis of each group of technologies.

7.4.1 Methodology for the cost analysis

A cost analysis of a product is conducted in order to identify the entire expense of the product during its service life. The first cost to be considered was the investment cost of procuring and preparing the product for service, so that the product is ready to function. While the other cost is associated with the periodic costs of operating and maintaining the product during its service life (Park and Jackson, 1984; White *et al.*, 1998).

Considering the alternative technologies in this project, the cost analysis process was started by identifying the cost components for procuring, through-life operating and maintaining each particular technology. The cost of each component in operating and maintaining the technologies was identified for every successive year throughout the notional 20 years of service life. However, seeing as the value of the cash flow in 20 years of time will be very different to the current value as a result of the escalation rate or inflation rate, it is highly recommended to consider the inflation rate during the lifetime as well when determining the future value of the cash flow (Buxton, 1987; Zimmerman, 2014). The future value (FV) of the cash flow at any given year can be determined by considering the inflation rate using the following equation:

$$FV = PV\,(1 + f)^{t} \qquad (7.1)$$

Where, PV, is the present value and, f, is the average inflation rate at the year t.

Before comparing the cost of each technology in any one group of technologies, the present value of the cost of each individual year of operational time, during 20 years of service life, was identified and finally, was accumulated to obtain the Net Present Value for each technology in terms of their cost.

A Net Present Value (NPV) analysis is one method that can be applied to compare several alternative choices based on their cash flow at a certain time. NPV can be determined by comparing the difference between the present value of the benefit, PV (B), and present value of the cost, PV(C), as seen in Equation 7.2 for each of the alternatives. The most appropriate choice among the alternatives is the alternative that has the highest value in relation to NPV (Boardman *et al.*, 2006; Zimmerman, 2014).

$$NPV = PV\,(B) - PV\,(C) \tag{7.2}$$

The present value, PV, of the benefit (B_t) and cost (C_t) of an alternative obtained in any given year, t, can be determined by dividing it with the value of $(1+ i)^t$, where, i is the interest rate in that year, as follows:

$$PV\,(B) = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} \tag{7.3}$$

$$PV\,(C) = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \tag{7.4}$$

However, seeing as the objective of this assessment was to identify the through-life cost of the implementation of each alternative technology, therefore the present value of benefit or profit from the operation of the vessels and the effect of each technology on such was not included in this assessment. As the result, the alternatives will have a negative NPV in this cost analysis, whereas the best alternative is still the highest value of the NPV.

Regarding the interest and inflation rates for the cost analysis in this project, data was obtained from the Central Bank of the Republic of Indonesia. According to the Central Bank, the level of inflation in Indonesia in the last 5 years has averaged 5.8%, while at the same time, the interest rate has averaged 6.8%. Based on these data, the inflation rate assumed for this assessment was 6% and the interest rate was assumed to be 7%, and it was assumed to be constant over the 20 years of the assumed service life. However, in order to ensure the validity of the results, a sensitivity test was conducted on each cost analysis result by considering the results of the NPV(C) at different interest rate and inflation values, which were in the range of ±1% of the aforementioned selected values. In order to have an overview of this cost analysis process, the example of cost analysis for one alternative technologies is presented in *Appendix B-1*.

7.4.2 Results of cost analyses on alternative technologies

A. Construction Materials

In order to compare the costs of alternative construction materials, the expenses required for manufacturing and maintaining the vessel throughout its service life were identified. The reference for the comparison was a fishing vessel with the main dimensions of 18.5 metres in length, 4.2 metres in breadth and 2 metres in depth. These representative dimensions were obtained from the main dimensions of the 30GT FRP fishing vessel that was granted earlier by the Indonesian government.

Table 7.5 following shows the selected cost components for the cost analysis of the different construction materials. The initial investment for each technology considered the production cost of the boat, which only measured the cost for manufacturing the hull and deck structures of the vessels.

The data of costs for manufacturing the vessels' structure with different construction materials were obtained from a few shipyards in East Java. Based on this information the cost/CUNO of each construction type of vessel was identified. The value of CUNO (the cubic number) represents the volume of a simple rectangular cuboid with its dimensions being the length, breadth and depth of the vessel.

The production cost of the vessels in this cost analysis were obtained by multiplying the CUNO of the benchmark dimensions, which is 155.4, with the value of the production cost/CUNO for the 5 different construction materials, as can be seen in Table 7.6.

Table 7.5 Cost components for the alternative construction materials

No	Construction Material	Cost Components	
		Initial Investment	Operating and Maintenance
1	Wood	Wooden boat manufacturing	- Fouling removing - Re-caulking - Re-painting - Antifouling coating - Re-planking
2	Wood laminate	Wood laminate boat manufacturing	- Fouling removing - Re-painting - Antifouling coating
3	FRP	FRP boat manufacturing	- Fouling removing - Antifouling coating
4	Aluminium alloy	Aluminium boat manufacturing	- Fouling removing - Antifouling coating - Zinc anode replacing
5	Steel	Steel boat manufacturing	- Fouling removing - Re-painting - Antifouling coating - Zinc anode replacing

Table 7.6 The estimated Cost/CUNO for each type of boat
(Compiled from boatyards in East Java)

No	Type of vessels	Cost/CUNO
1	Wooden boat	£ 147
2	Wood laminate boat	£ 169
3	FRP boat	£ 222
4	Aluminium boat	£ 449
5	Steel boat	£ 293

The component of the maintenance costs that were considered during this assessment were different according to the construction materials, as seen in Table 7.5. Most of the maintenance was conducted annually, except for the re-planking wooden boats which were assumed to be undertaken after 10 years of operation and where was assumed about 40% of the planking was replaced. Furthermore, based on the typical service life of a zinc anode, a new zinc anode for the steel and aluminium vessels was assumed to be fitted after the vessels had been in operation for three years.

In addition to the cost of materials in each maintenance component, the cost of labour was also included in this assessment. However the cost of the docking process was not considered, given that it was assumed that all the vessels used a similar method, which is to ground on to the beach; hence, the cost of the docking process was similar for all types of vessels.

The results of the cost analyses, including initial and operational costs, of construction materials for an assumed 20 years of service life regarding the vessels can be seen in Figure 7.7. The results illustrate that the FRP boat has the lowest cost for its 20 years of

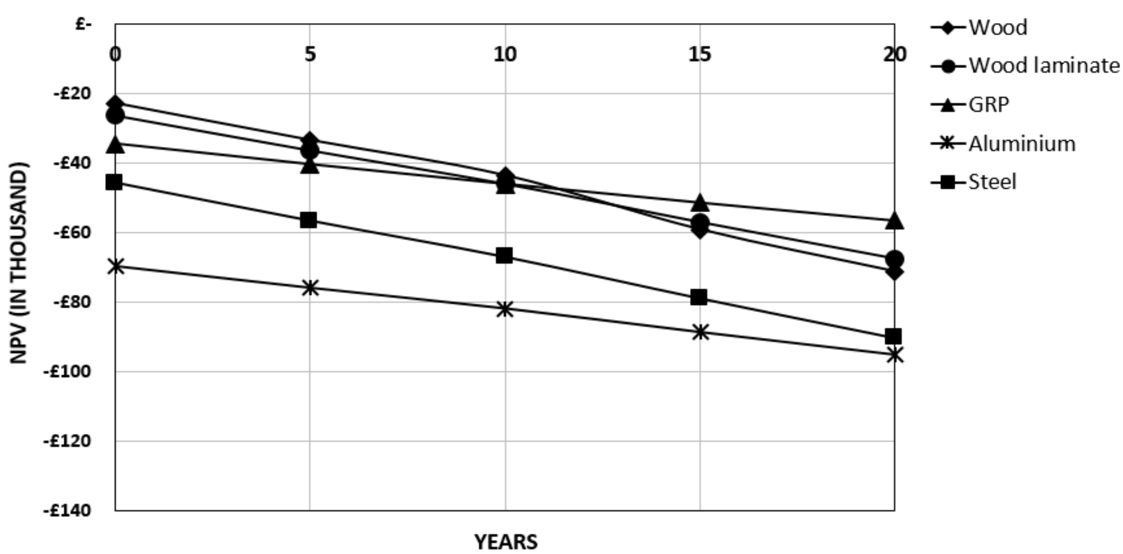


Figure 7.7 NPV of the cost for the construction material

service life, followed by the wood laminate boat, then the wooden, steel and aluminium boats respectively. Although the FRP boat is more expensive in terms of the production cost when in comparison to the wooden and wood laminate boats, the low maintenance cost resulted in less overall cost in relation to the NPV in 20 years of operation.

In term of wooden boat, the change of the trend of chart line, as seen in Figure 7.7, after 10 years operation is due to the significant increase in the total cost as the result of hull re-planking in the 10^{th} year of operation.

B. Main Engine

Table 7.7 show the cost components for the group of the main engines for Muncar and Brondong. The reference for comparison was a 30hp power engine that is operated for 15 hours per day and 21 days per month, and for 10 months of operation per year. For the engine that runs on bi-fuel, the combination of 60% diesel fuel and 40% LPG was considered for this assessment (Saleh, 2008; Poonia *et al.*, 2011). Additionally, for the electric hybrid engine, it was considered that the electric drive motor is combined with electricity generator that runs on diesel fuel to recharge the batteries continuously on-board for longer duration of fishing trip.

The specifications as reference for the assessment of main engines for Latuhalat were a 40hp power engine that was operated for 6 hours per day in 21 days of fishing trips per month, for duration of 10 months a year. The cost components for this group of main engines can be seen in Table 7.8. The engine run on petrol is totally convertible into an engine run on LPG, therefore the outboard petrol marine engine that has been converted to LPG is considered for the cost analysis in this second group. While for the employment of electric propulsion, by considering the length of a fishing trip in

Table 7.7 Cost component for main engines in Muncar and Brondong

No	Main Engines	Cost Components	
		Initial Investment	Operating and Maintenance
1	Non-marine diesel engine	Non-marine diesel engine 30hp	- Fuel consumption - Lube oil consumption - Engine replacement
2	Marine diesel engine	Marine diesel engine 30hp	- Fuel consumption - Lube oil consumption
3	Marine diesel engine run on bi-fuel (60% diesel fuel + 40% LPG)	- Marine diesel engine 30hp - Converter	- Fuel consumption - Lube oil consumption
4	Electric hybrid engine	- Electric motor - 9 units battery 12v 245Ah - Battery charger - Electricity generator 6.8 kW	- Fuel consumption - Lube oil consumption - Batteries replacement - Genset replacement

Table 7.8 Cost components for main engine in Latuhalat

No	Main Engines	Cost Components	
		Initial Investment	Operating and Maintenance
1	Outboard engine run on kerosene (subsidised and non-subsidised)	Outboard engine kerosene 40hp 2 stroke	- Fuel consumption - Lube oil consumption
2	Marine diesel engine (inboard)	Marine diesel engine 40hp	- Fuel consumption - Lube oil consumption
3	Outboard engine run on LPG	- Outboard engine petrol 40hp 4 stroke - Converter	- Fuel consumption - Lube oil consumption
4	Electric engine	- Electric motor - 9 units battery 12v 245Ah	- Batteries replacement

Latuhalat that is typically less than 5 hours, hence the electricity for the electric drive motor in this cost analysis was only supplied by few units of batteries that were charged when in harbour by the shore grid power.

The results of the cost analyses for the first group of main engines showed that the diesel engine that runs on a mixture of diesel fuel and LPG has the lowest NPV cost over 20 years of service life of the engine compare to the other alternative engines in this group, as seen in Figure 7.8. It cost 54% lower when compared to the benchmark of the non-marine diesel engine. The marine diesel engine that runs on normal diesel fuel also has a relatively low cost, and is 51% less expensive in contrast to the benchmark engine. With respect to the electric hybrid engine, although the initial investment is over ten times higher than for the non-marine diesel engine, its cost for 20 years of operation is 27% lower than for the benchmark. The steep slope of the graph related to the non-marine diesel engine is because the significant higher fuel consumption of this type of engine compared to alternative engines. Moreover, the life span for this engine, which

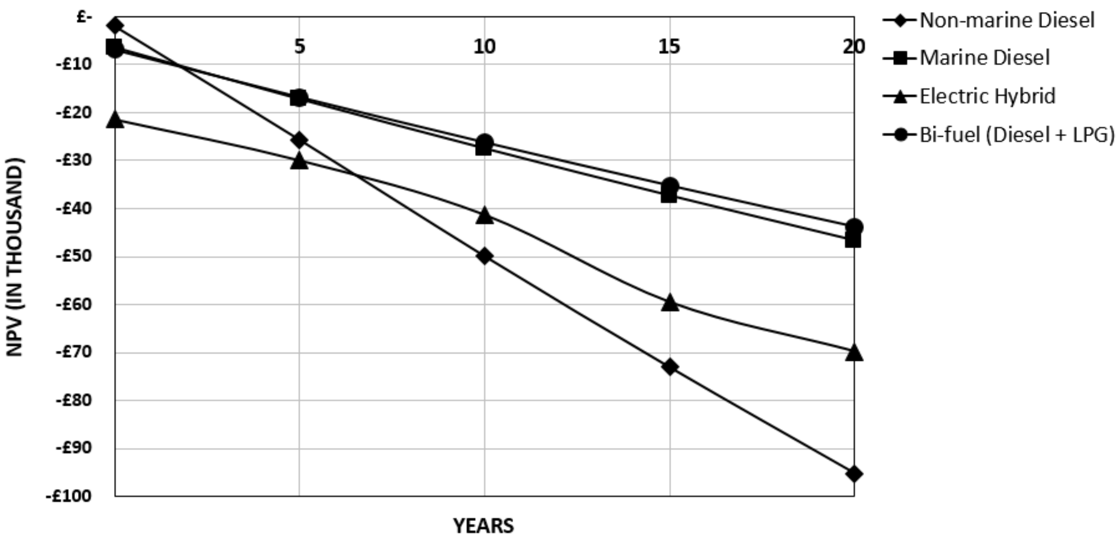


Figure 7.8 NPV of the cost for main engines in Muncar and Brondong

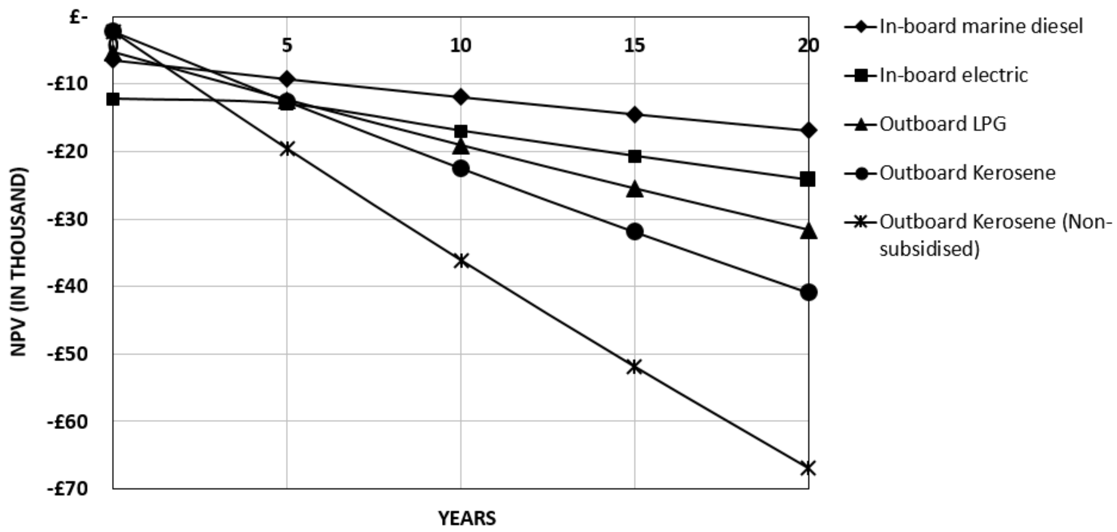


Figure 7.9 NPV of the cost for main engines in Latuhalat

according to local respondent is a maximum 5 years, therefore, a replacement is required every 5 years of operation. While different trend for electric hybrid in Figure 7.8 is because the replacement of the electricity generator after 10 years operation.

In the group of engines for Latuhalat, the Figure 7.9 shows that the benchmark outboard engine that runs on kerosene has the highest cost compare to the other alternative engines, even more so if the unsubsidised fuel price is considered. The lowest cost for 20 years of service life in this group of engines is the marine diesel engine, followed by the electric engine, then the outboard engine runs on LPG and finally, as noted above, the outboard engine run on kerosene respectively. The high fuel consumption of the outboard marine engine if compared to the inboard marine engine of similar power is the reason for the higher NPV cost at the end of 20 years operations of the engine, although its initial investment cost is lower than that for the inboard marine engine. However, specifically for the outboard marine engine, the conversion of the petrol outboard engine to an LPG fuel outboard engine resulted in the lowest operational cost when compared to outboard engine run on petrol or kerosene.

C. Electricity Sources

The cost analyses pertaining to the electricity sources was divided into two groups: the AC generators and the DC power sources. The associated cost components for both groups can be seen in Table 7.9. The reference for the power of the AC generators is a 2kW power generator that is operated for 10 hours per day and for 21 days per month. For the DC power sources, it was assumed that the total electricity required for lighting

Table 7.9 Cost components for the alternative sources of electricity

No	Alternative technology	Cost Components	
		Initial Investment	Operating and Maintenance
1	Alternator + diesel engine	- Alternator 12v 200A - Diesel engine YANMAR TF70 H-di 7.5hp	- Fuel consumption - Lube oil consumption - Alternator and diesel engine replacement
2	Genset run on petrol	Genset petrol Honda EP2500CX 2500 watt	- Fuel consumption - Lube oil consumption - Genset replacement
3	Genset run on LPG	Genset LPG GREENPOWER 2500 watt	- Fuel consumption - Lube oil consumption - Genset replacement
4	Battery + land grid	- 6 units Battery 200Ah 12 Volt	- Replacement of batteries
5	Battery + solar cell	- 4 units Battery 200Ah 12 Volt - 3 units Solar panels 100WP	- Replacement of batteries
6	Battery + wind turbine	- 4 units Battery 200Ah 12 Volt - 1 unit Wind turbine 85 watts	- Replacement of batteries

and various electronic devices on-board was only 100 watts. The lighting was assumed to be operated for 10 hours per day and for 21 days per month for each year.

The results of the cost analysis for the AC power sources can be seen in Figure 7.10. It shows that, although its initial investment is the highest when compared to the other two alternatives, the electricity generator that runs on LPG has the smallest NPV in terms of cost for 20 years of operation, followed by the genset run on petrol and the alternator coupled with a diesel engine respectively. The result confirms that the cost of the genset run on LPG, when the subsidised price was considered, is 50% less when compared to cost of the genset run on petrol and 55% less when compared to the cost of the alternator coupled to a diesel engine after 20 years of service.

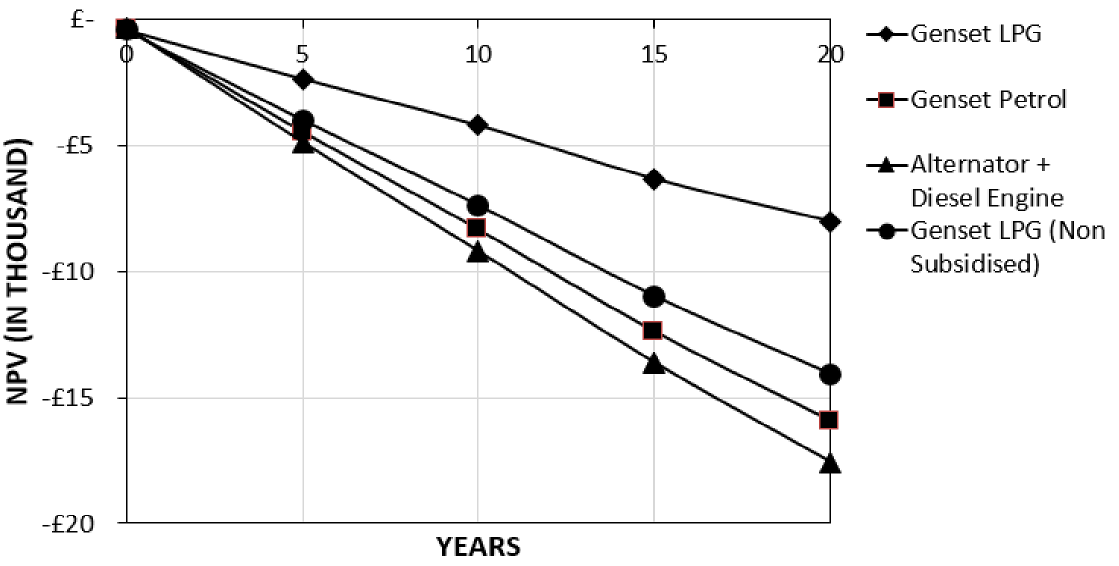


Figure 7.10 NPV of the cost for the AC electricity sources

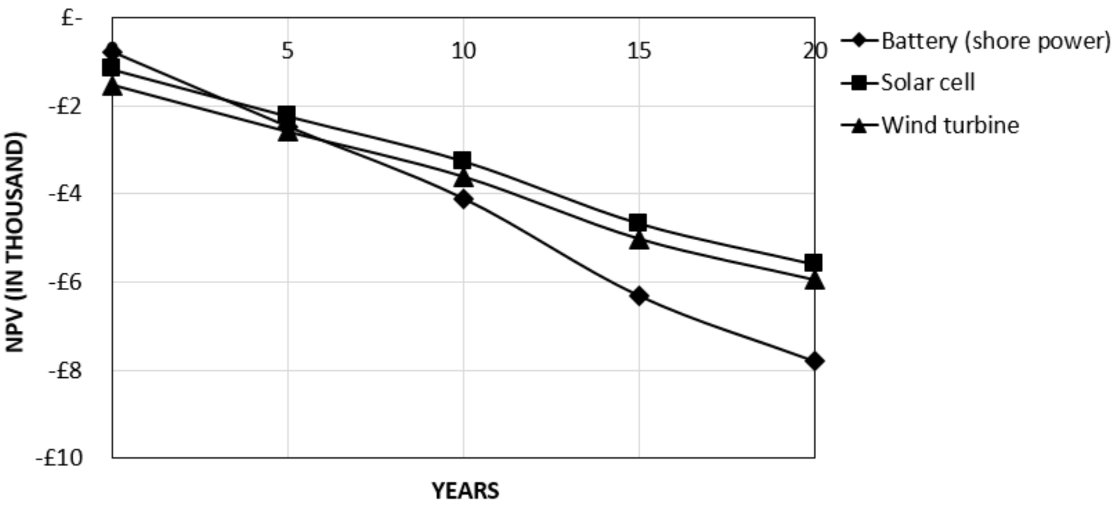


Figure 7.11 NPV of the cost for the DC electricity sources

The results of the cost analysis pertaining to DC power sources, as seen in Figure 7.11, demonstrate that the NPV of cost for 20 years of operation by means of batteries supplied by solar panels is 28% lower than the cost of the benchmark of batteries charged by the land grid, and approximately 6% lower than batteries charged by a wind turbine. The similar pattern related to the trend line of each DC power source in Figure 7.11, which are not straight lines, is the result of the batteries being replaced every 2 years. Moreover, as the numbers of batteries for the solar panel and wind turbine in this cost analysis were similar, the difference regarding NPV pertaining to the cost of both technologies was caused by the difference in initial investment.

D. Fish Preservation

Regarding the cost analysis for the fish preservation method for the three selected fishing communities, the reference for comparison was the fish preservation systems for 4 tonnes of fish during 7 days duration of fishing trip. The cost components for this group of technologies can be seen in Table 7.10.

Table 7.10 Cost components for fish preservation systems

No	Fish Preservation	Cost Components	
		Initial Investment	Operating and Maintenance
1	Block ice from home port	No initial investment	- Block ice consumption
2	Flake ice machine on-board	- Flake ice machine 1 tonne/day capacity - Genset Petrol 5.6kW	- Fuel consumption - Lube oil consumption - Refrigerant consumption
3	Freezer on-board	- Freezer system 4.5 tonnes capacity - Genset Diesel 7.6kW	- Fuel consumption - Lube oil consumption - Refrigerant consumption

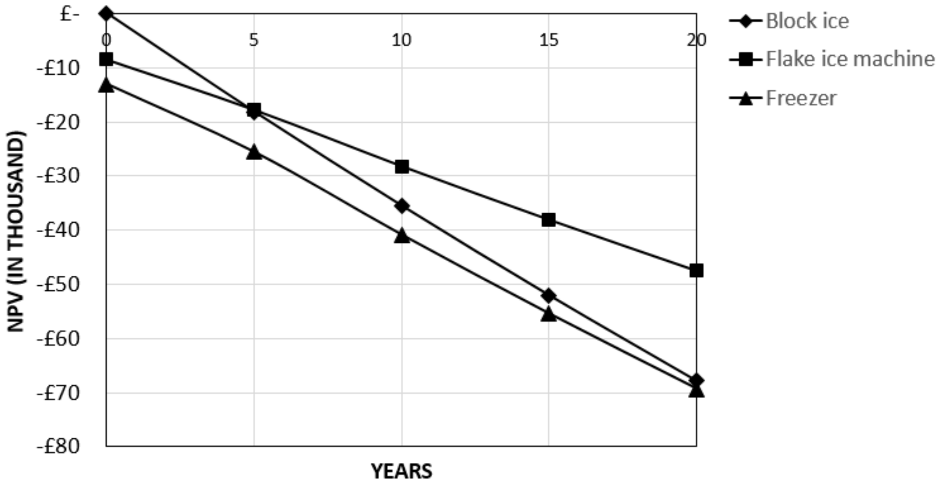


Figure 7.12 NPV of the cost for fish preservation systems

The results of the cost analyses for the fish preservation systems, as seen in Figure 7.12, show that to provide a flake ice making machine on-board can give the lowest NPV of cost for 20 years of service life of the fishing vessel. To take block ice from the home port, although it has no initial investment, however its cost for 20 years operational is 43% higher if compared to providing an ice machine on-board. The block ice preservation only slightly lower than the refrigerator system since the freezer is very expensive for its initial investment.

7.5 Environmental Impact of Alternative Technologies Employed on Fishing Vessels

As discussed in Chapter 2, one of the recommendations from the Code of Conduct for Responsible Fisheries, regarding the implementation of responsible fishing practices, is the employment of environmentally-friendly technologies in fishing vessels. This is in an attempt to minimise the potentially detrimental impact of fishing activities on the environment.

In order to obtain a comprehensive overview of the environmental impact of each of the alternative technologies, assessments were undertaken covering the entire service lifespan of the fishing vessel. Accordingly, the Life Cycle Assessment (LCA) method has been applied to assist in the assessment process.

7.5.1 Methodology for assessing environmental impact

The Life Cycle Assessment (LCA) is a process that is used to evaluate a product in association with its environmental aspects and any potential impact on the environment throughout the life cycle of the product. Since the increase in demand for

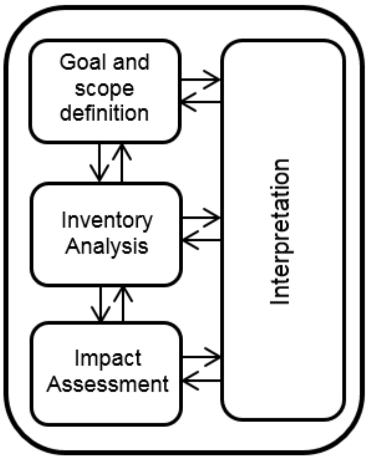


Figure 7.13 Life Cycle Assessment (LCA) framework
(Adapted from (ISO, 1997))

environmentally-friendly products, LCA is also frequently used to assist with selecting the most sustainable product from among several options, or to design and optimise a new product (Azapagic, 1999). Thus, the LCA was chosen for this study.

The LCA process is divided into four separate stages, as illustrated in Figure 7.13. The first stage of the LCA is outlining the Goal and Scope of the assessment. In this stage, the reason for conducting the assessment is identified. According to this goal, the system or product that is being analysed is described, in conjunction with the function and functional unit of the product, the boundaries and the various limitations of the assessment, including any assumptions considered in relation to the assessment (ISO, 1998).

The description of the function of the product in the initial stage is important in order to understand the input that is required during the life cycle of the product, for example any natural resources or energy that is consumed by the product being assessed. It is also necessary in order to understand any output that is produced and released by the product or the system into the environment (ISO, 1998).

When using LCA to compare two or more products or systems, the functional unit is required, in order to have a reference against which to undertake the comparison. Subsequently, based on this functional unit the quantity of both the input of the products/systems and of its output into the environment can be identified (ISO, 1998; Goedkoop *et al.*, 2013). For instance, in terms of comparing a few alternative main engines for fishing vessels as in this study, the functional unit can be the output rated power of the engines employed to propel the vessel.

The boundaries, assumptions and limitations of the assessment need to be defined at the initial stage, which are based on the goal of assessment and the available data in order to support the assessment. The complete LCA starts from the manufacturing of the product, continues throughout its service life, and ends with the disposal of the product. This approach of assessment is also known as a “cradle-to-grave” assessment. Other approaches have shorter system boundaries based on the goal of the assessment. The “gate-to-grave” approach considers the assessment from the beginning of the service life of the product up to and including its disposal. Special boundary is applied for the LCA of vehicles fuel, which is called “well-to-wheels” assessment. It is start from the fuel production to its consumption during operational of the vehicles (Shen *et al.*, 2012).

The second stage of LCA, the Life Cycle Inventory (LCI), is conducted with the aim of identifying the relevant inputs for the product/system, for example, the energy and natural resources required during the life cycle of the product are listed during this stage. Moreover, the output from the product/system into the environment (e.g. into the air and water) is also identified (ISO, 1998).

The next stage of the LCA is the Life Cycle Impact Assessment (LCIA). The effect of a product on the environment as a result of exploiting natural resources and of consuming energy during its life cycle is assessed (ISO, 2000a). The types of impacts that are assessed during this stage are based on the goal and scope of the assessment, as defined in the initial stage. The impacts that are typically assessed include ozone layer depletion, global warming, eco-toxicity and direct impact on human health (Goedkoop *et al.*, 2013).

The final stage of the LCA is the interpretation of the results that are obtained from the LCI and the LCIA evaluations, and their relationship with the goal and scope, which were defined earlier (ISO, 2000b). For the comparison study, the LCIA of the products being assessed are compared and ordered in relative merit, so as to ascertain which product will have the least impact on the environment.

In this study, only the LCA analyses related to the construction materials applied the “cradle-to-grave” system boundaries, whereas the other three groups of alternative technologies implemented the “well-to-wheels” assessment. Difficulties in obtaining the data related to the manufacturing of these groups of technologies was the primary reason for the implementation of the ‘well-to-wheels’ boundaries system regarding the main engines, electricity sources and fish preservation. More details pertaining to these boundaries related to each group of technologies are described in the assessments in the following sub-section.

In order to assist in undertaking the assessments, LCA software known as SimaPro was employed in this research. Furthermore, the impact assessment method called IMPACT 2002+ that is available within the SimaPro software was also applied. This method provides 15 categories of midpoint impact including: human toxicity (carcinogens and non-carcinogens), respiratory inorganics, ionizing radiation, ozone layer depletion, respiratory organics, aquatic eco-toxicity, terrestrial eco-toxicity, terrestrial acidification, land occupation, aquatic acidification, aquatic eutrophication, global warming, non-renewable energy, and mineral extraction (Goedkoop *et al.*, 2013). Subsequently, these midpoint impacts are classified into 4 endpoint categories of impact, namely human health, ecosystem quality, climate change and resources (Goedkoop *et al.*, 2013).

The result of LCIA in SimaPro is presented in bar chart that illustrates the impact of a product to the environment. The horizontal axis of the chart shows the type of endpoint impact or products to be compared, and the vertical axis represents the level score of impact. Each midpoint impact has their own unit of value, for example, kg CO_2eq (equivalent) for unit impact score of global warming, or kg CFC-11eq (equivalent) for unit impact score of ozone layer depletion. In order to be able to compare these midpoint impact and subsequently classify the midpoint impact into the endpoint impact, the normalisation of the impact value is required. The IMPACT2002+ method that was applied in this study uses the term of 'points' as the impact value unit. "Points" are equal to "person.year/$unit_{emission}$", which represents the average impact caused by a person in a specific category during one year in Europe (Jolliet *et al.*, 2003)

All data from the environmental impact in this study are based on the dataset that is made available in the SimaPro software. However, given that the database is very limited in connection with the Indonesian situation, all data, except for data regarding electricity, used the environmental impact data from Global (GLO) dataset. This is considered to be an average that is valid for all countries in the world, or alternatively there is also the Rest-of-the-World (RoW) dataset, which is valid for other countries that are outside of the countries whose dataset are available in this software. However, so as to determine the level of uncertainty of the results as a consequence of the availability of the data, hence a Monte Carlo analysis that is also available in the SimaPro software, was applied for this assessment. In the Monte Carlo analysis, it is assumed that the difference of two products to be compared is considered to be significant if 90% of the Monte Carlo runs are favourable for one product (Goedkoop *et al.*, 2013).

7.5.2 Result of LCA on the alternative technologies

This sub-section describes the results of the LCA in relation to each group of selected alternative technologies. The goal of the LCA for each group was to compare the impact of a few alternative technologies on the environment. The following descriptions consist of the system boundaries of LCA for each group, the associated functional units, a general description concerning the input for the inventory, and the results of the LCIA in conjunction with a discussion related to the goal for each group.

A. LCA result for the alternative construction materials

The system boundaries for the assessment of the hull materials started from and include the production of the fishing vessel, continued throughout the service life of the vessel (that was assumed to be 20 years), and end with the disposal of the construction materials.

In view of the fact that the carrying capacity measures of the vessel can be used in order to be able to compare vessels built from different primary materials, the Gross Tonnage (GT) of the fishing vessel was utilised as the functional unit. Thus for this study, the functional unit related to the assessment of the construction materials was a 30GT fishing vessel with the following dimensions: 18.5 metres length, 4.2 metres breadth and 2 metres depth. These dimensions were adapted from the dimensions of the granted fishing vessel provided by the Indonesian government to Muncar fishing community. Furthermore, seeing as a manufacturing location was required for the study, in order to obtain the input for transportation from sources of the raw materials, the boatyard for this study was assumed to be located in Muncar, where the proposed fishing vessel was targeted to be operated from throughout its life.

The input for production process of the fishing vessels considered the amount of construction material required, transportation to take the material from its sources and/or manufacturers to the boatyard, and total energy expended during the production stage, which in this case only considered the total electricity consumed for the various

Table 7.11 LCI input for the wooden vessel at the production stage

No	LCI Input	Amount	Remarks
Materials			
1	Hardwood	32 m^3	Kiln dried, planed
2	Steel	0.4 tonnes	For fastening
3	Alkyd based	45 kg	Main substance primer coat
4	Acrylic resin based	31.5 kg	Main substance top coat
5	Cooper oxide	27.5 kg	Main substance anti-fouling
6	Zinc oxide	13.75 kg	Main substance anti-fouling
Processes			
7	Electricity	1170 kWh	Powering electric tool
8	Transportation	5750 tonnes.km	Material transportation

activities during the production process. Throughout the service life of the vessels, input for the LCI was based on the activities of hull maintenance and repair. The maintenance and repair processes that were included in the LCA analysis were similar to the maintenance activities in Table 7.5 above. While the final decommissioning and scrapping of the vessels in this study only considered the disposal of the main construction materials in the LCI input. The disposal scenario will be different for each type of construction material: aluminium and steel will be re-cycled, while wood, wood laminate and FRP will be sent to landfill.

The example of the LCI input for construction materials can be seen in Table 7.11. Based on this table, the dominant input for the LCI of a wooden vessel is the timber that has been dried and planed, and brought to the boatyard from the sawmill assumed to be located approximately 250km from the boatyard. The electricity input was based on the electricity predominantly required for electric hand tools during the production process, such as for cutting and sanding the planks. Furthermore, an example of detailed inventory for each of the construction materials can be seen in *Appendix B-2*.

The results of the LCIA for the 5 alternative construction materials can be seen in Figure 7.14. It demonstrates that wood as construction material has the lowest total impact on the environment compared to other construction materials. A slight difference was determined in the laminated wood, although the amount of wood for this type of vessel was approximately 15% less than for the wooden boat; however, the application of a significant amount of epoxy resin for gluing the structure increased the impact on the environment. FRP is third best in terms of minimum total impact; nevertheless, it had less of an impact regarding ecosystem quality compared to the wood, especially because the impact of wood in land occupation is much higher than FRP. Moreover, in a number of midpoint impacts there was only a slight difference between the wood and

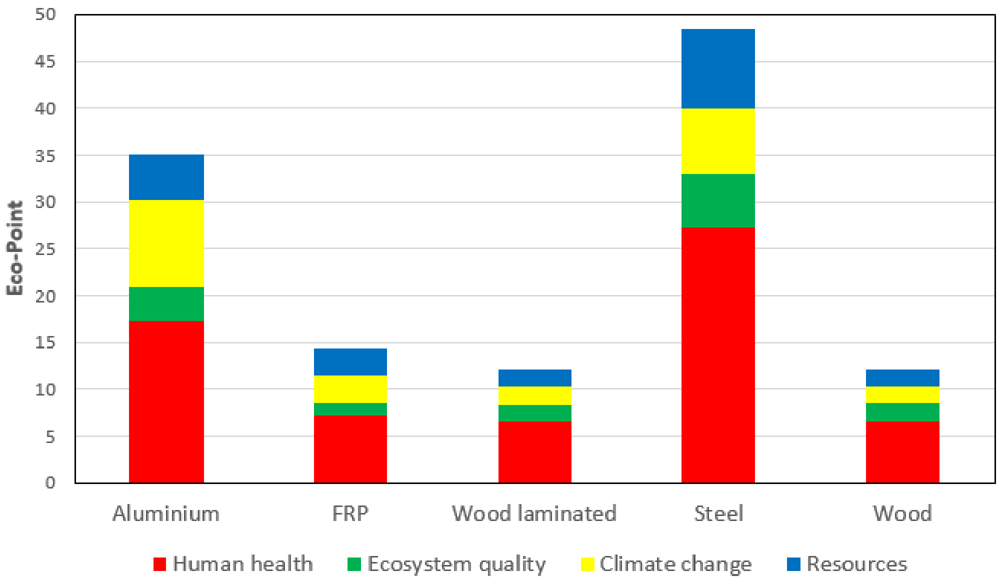


Figure 7.14 Result of the LCIA for the alternative construction materials

the FRP construction. Therefore, based on the Monte Carlo analysis, there is considered to be no significant difference between the total environmental impacts of wood and FRP construction, as seen in the Monte Carlo results given in *Appendix B-3*.

B. LCA for the alternative main engines

The assessments of the main engine was applied with reference to the "well-to-wheels" approach, which only considers the operation of the main engine in accordance with the service life of the vessel, which was assumed to be 20 years in this study. The upstream activities (e.g. the manufacturing of the engine) and the downstream activities (e.g. the disposal of the engine) were not considered in this study.

In order to compare the main engines in the first group, the functional unit was the power output of the engine, which was assumed to be 30hp. It is similar to the power of the Yanmar TF300 engine that is commonly employed on fishing boats in both Muncar and Brondong. While for the second group, the functional unit was a 40hp power engine, based on the power of the outboard marine engine run on kerosene typically used in Latuhalat. The example of the LCI for the main engines can be seen in Table 7.12.

The result of the LCIA for the first group of main engines can be observed in Figure 7.15. It reveals that the non-marine diesel engine has the greatest total impact on the environment compared to the other alternative engines. With regards to every single endpoint impact group, the non-marine engine also generated the highest impact in

Table 7.12 LCI input for marine diesel engine run on bi-fuel diesel and LPG

No	LCI Input	Amount	Remarks
Materials			
1	Liquefied petroleum gas	2,496 kg	Annual consumption
2	Diesel fuel	3,745 kg	Annual consumption
3	Lubricating oil	26.6 kg	Annual consumption

contrast to the other engines. Among the other alternative engines in this group, the electric hybrid engine had the lowest impact on the environment. Moreover, the replacement of 40% of diesel fuel with LPG for the bi-fuel marine engine caused a slight increase in almost all midpoint impacts that lead to a slightly higher total impact when compared to the pure marine diesel engine. Since basically all four engines in this group consume diesel fuel, the results were clearly affected by the specific fuel consumption of each type of engine. The results of the LCA assessment emphasised that the benchmark engine consumed more fuel compared to other types of engines in this group.

The results of the LCIA for the second group of main engines, in Figure 7.16, revealed that the benchmark for this group, the outboard engine run on kerosene, has the second highest total impact on the environment after the electric propulsion. The reason for the significant impact in connection with the electric propulsion in this study, particularly in terms of human health, is that the electricity was supplied by batteries that were charged

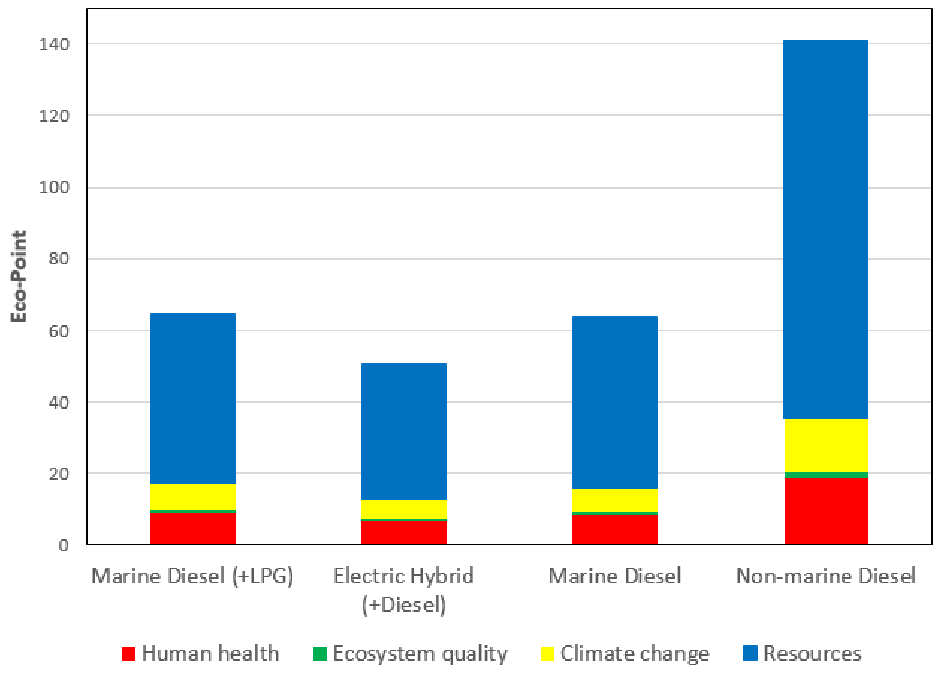


Figure 7.15 The results of the LCIA for alternative engines in Muncar and Brondong

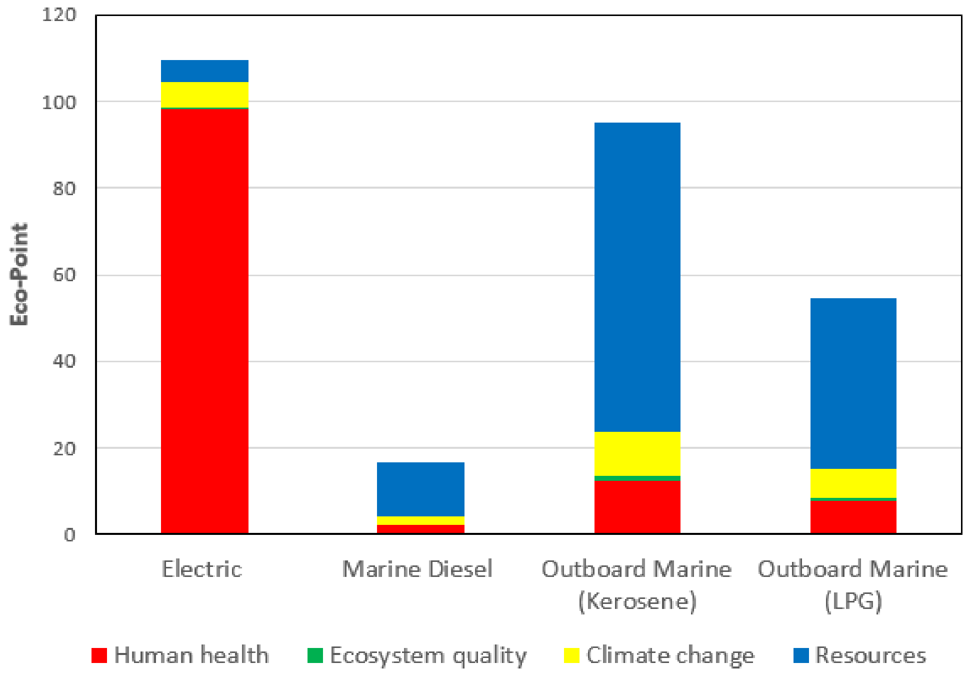


Figure 7.16 The results of the LCIA for alternative engines in Latuhalat

via the land grid. The dataset that was used for the land grid input was the Indonesian (ID) dataset that is available in the SimaPro software. As the power plants in Indonesia predominantly burn coal to produce electricity, thus the impact of this type of power plant on the environment is extremely high. Therefore the environment impact of electric propulsion that powered by electricity from the land grid in this study was very high.

The results in Figure 7.16 also reveal that the employment of an inboard marine diesel engine will offer a significant reduction regarding environmental impact when compared to the current outboard marine engine that is run on kerosene. The results of the Monte Carlo analysis justified the significantly lower impact of the inboard marine diesel engine compared to the outboard engine that is run on kerosene, as can be observed in *Appendix B-3.*

C. LCA for alternative sources of electricity

The LCA for the alternative electricity sources was conducted in two groups: DC power sources and AC power generators. The system boundary that was applied for this assessment was the "well to wheels" approach that is from the entry into service life of the vessel and over the course of the next 20 years of its continuous operations.

Table 7.13 LCI input for batteries with land grid charging

No	LCI Input	Amount	Remarks
Materials			
1	Lead (batteries)	236.4 kg	Replacement every two years
2	Sulphuric acid (batteries)	60 kg	Two years consumption
Processes			
3	Electricity (land grid)	288 kWh	Annual consumption

As the reference point for the comparison, the functional unit for the DC power sources was 100 watts of power, while for the AC power sources, the functional unit was 2000 watts of power. The input for the LCI of the AC sources was the fuel and lubrication oil consumption of the electricity generators. The input for the DC sources was the batteries used for storing the electricity, except for the land grid source that included the electricity from the land grid to charge the batteries while in the port. The example of the input for the electricity source can be seen in Table 7.13.

The LCIA results for the group of DC power sources illustrated that the electricity from the land grid that is stored in the on-board batteries had the highest total impact on the environment compared to other two alternatives in this group. Regarding each group of endpoint impacts, as seen in Figure 7.17, the land grid charging generated the highest impact in contrast to the other two DC power sources. The type of fuel that is used for the power plants in Indonesia, as described previously, was the main reason for the significant impact of this type of DC power source. Examining the two other alternative

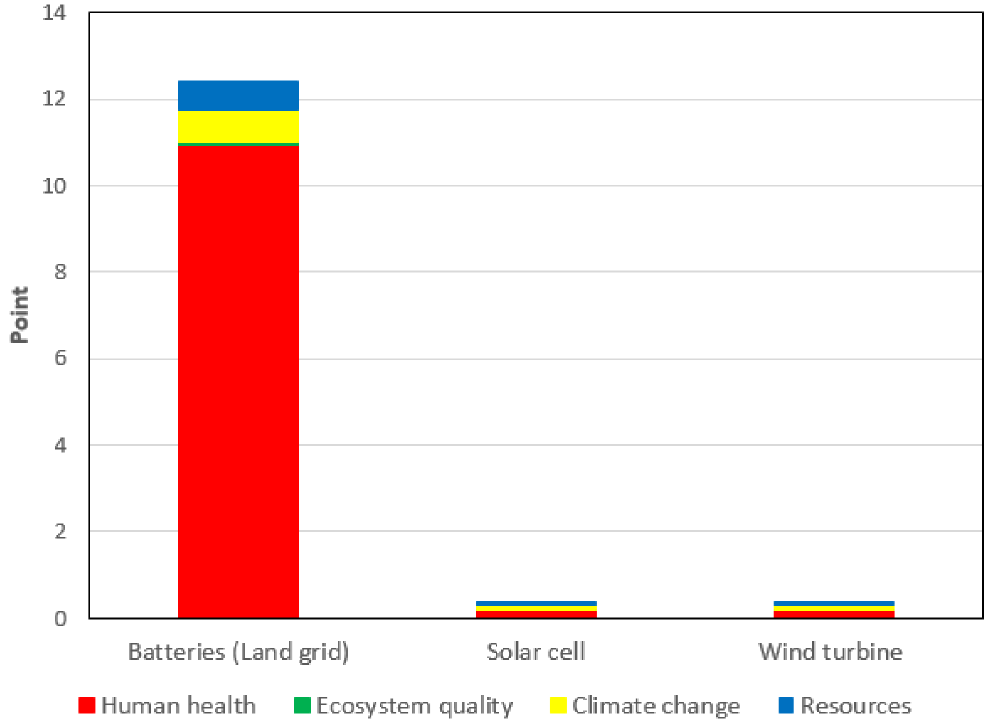


Figure 7.17 The results of the LCIA for the DC power sources

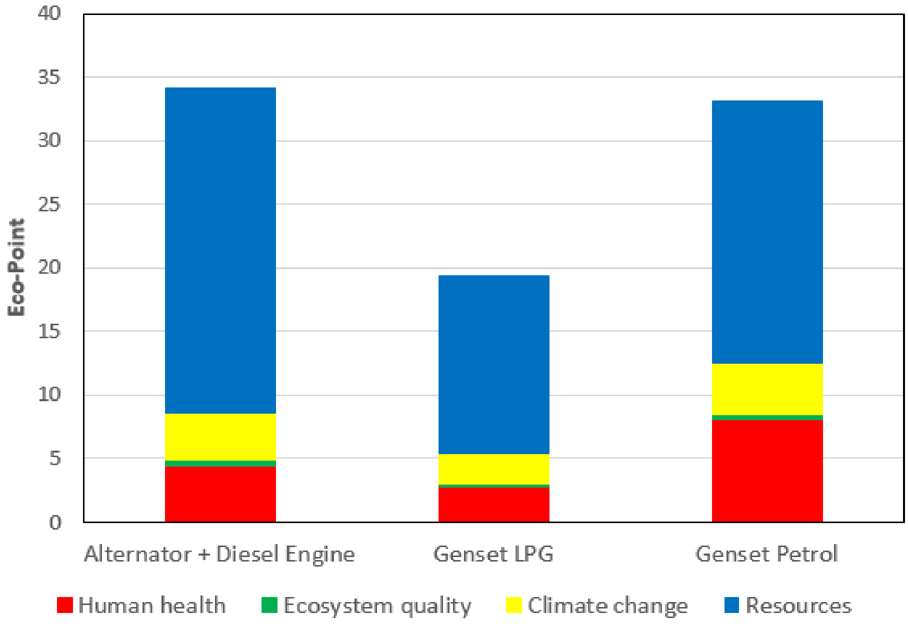


Figure 7.18 The results of the LCIA for the AC power sources

sources, since the assessment approach is the "well to wheels" and moreover the number of batteries employed for these two sources was similar, therefore the impact level of solar cell and wind turbine in this study is similar.

Among the AC power sources in this study, the alternator coupled with a diesel engine had the greatest impact on the environment, as seen in Figure 7.18. The electricity generator run on petrol had a slightly lower impact, whilst the lowest impact of the three possibilities was established by the generator run on LPG. The typical problem with the alternator coupled with a diesel engine in the fishing communities was in the inappropriate selection of a higher than necessary output power for the diesel engine, which thus resulted in inefficient fuel consumption.

D. LCA for alternative fish preservation methods

As with the previous two groups of technologies, the system boundary for the LCA pertaining to fish preservation also applied the "well to wheels" approach and covered the whole service life of the vessel for the full consecutive 20 years of operation. The functional unit for the assessment was a fish preservation of 4 tonnes during a 7 day fishing trip.

The input for the assessment was the materials and energy that are required to produce the amount of ice or to operate a refrigeration system for each year of the vessel's operation with total of 30 trips per year. For the fish preservation using ice blocks taken

Table 7.14 LCI input for the ice block fish preservation

No	LCI Input	Amount	Remarks
Materials			
1	The land grid electricity	1512 kWh	Annual consumption
2	Ammonia (NH_3)	15 kg	Annual consumption
3	Water (groundwater, well)	180 tonnes	Annual consumption
Processes			
4	Transportation	180 tonnes.km	Annual consumption

out from the home port, the input for one year of operation can be Table 7.14. The input concerned with the land transportation of the ice in this assessment is based on the assumption that the ice manufacturer was located only 1 km from the harbour.

The result of LCIA for fish preservation systems, as seen in Figure 7.19, show that the employment of a freezer on-board potentially generates a significant impact to the environment when compared to the benchmark, the ice blocks that taken out from the home port. The consumption of Hydrofluorocarbons R404A for refrigerant in both the freezer and the flake ice machine produced significant CO_2 emissions that have a high impact to the climate change. Conversely, the consumption of electricity from the land grid and ammonia for refrigerant in most ice block manufactures in Indonesia potentially generate a negative impact to human health especially related to the respiratory inorganics midpoint, as seen in Figure 7.19. However, if considering the total impact to the environment, the fish preservation with ice blocks that are taken out from home port has less potential impact compared to the other two alternatives in this study.

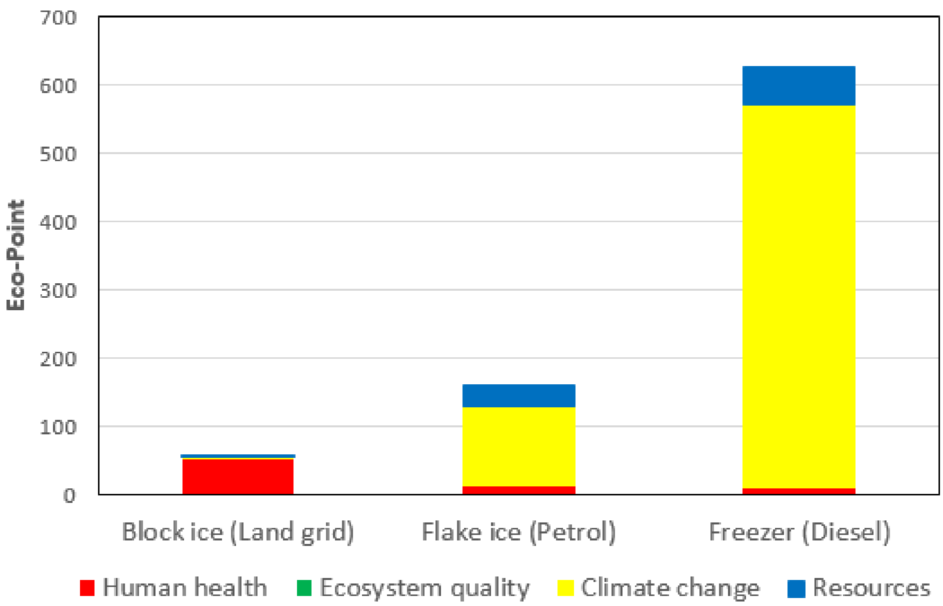


Figure 7.19 The results of the LCIA for the fish preservation systems

7.6 Decision Making for Selecting the Most Appropriate Technology

In order to identify the most appropriate technologies than can be employed in the fishing vessel in Indonesia, especially for the three selected fishing communities in this study, the assessments have been conducted in terms of the social aspects of the technologies, their economic viabilities and also the impact of the technologies to the environment, as described in the previous section. However in order to obtain the final results that at the same time considered all of the three pillars of sustainability, therefore a specific method of decision making was applied in this study.

In this section, the attempt to determine the most appropriate technology for each group of technologies based on the three pillars is discussed. One of the established decision making methods called the Analytical Hierarchy Process (AHP) is briefly described and followed by the results of an AHP analysis for each group of technologies that have been selected and examined previously.

7.6.1 Methodology for decision making

Throughout life, humans are confronted with a need to make decisions. It could be a simple decision that only considers a simple single criteria, or conversely it could be based on complex multi-criteria that influence decision making (Saaty, 2008). Multi-Criteria Decision Making (MCDM) is one of the techniques that is used to assist decision making involving several criteria that need to be considered during the decision process. The Analytical Hierarchy Process (AHP) is among several methods that apply the concept of MCDM (Pohekar and Ramachandran, 2004).

Decision making by the AHP method starts with the identification of the goal of the decision to be made (Saaty, 2008), which in this study was to identify the most appropriate technology from several alternative technologies, which could possibly be applied in Indonesia by considering the three pillars of sustainability.

Based on this goal, the structure of decision hierarchy is identified according to the level of decisions and the correlations between each level of decisions. The intermediate level of the decision hierarchy can be the criteria that need to be considered during the decision process. The lowest part of the hierarchy structure can be the alternatives or choices that need to be selected to support the goal of decision making (Saaty, 2008). Given that the three pillars of sustainability were the main criteria in relation to the

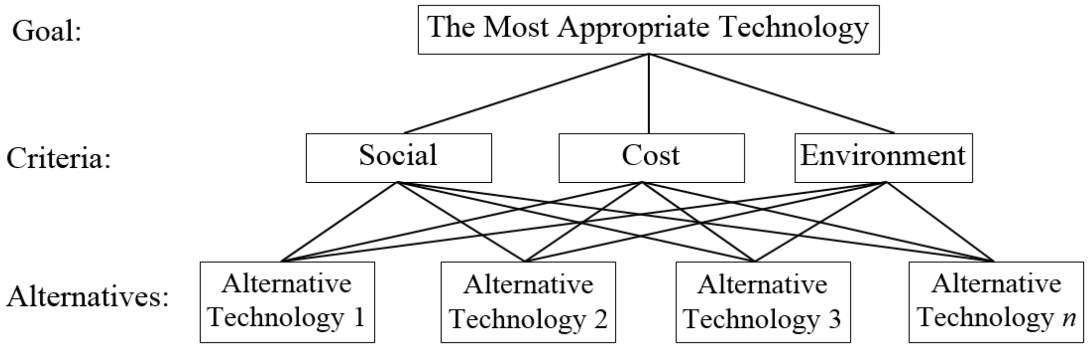


Figure 7.20 The decision hierarchy structure for alternative technologies

decision making to find the most appropriate technologies, therefore the intermediate level of the decision hierarchy structure in this study were the social aspect, the economic aspect and the environmental aspect. Subsequently, the group of alternatives technologies were placed in the lowest level of the decision structure. Accordingly, the hierarchy of decision making in this study can be structured as illustrated in Figure 7.20.

Based on to this structure, the next stage of the AHP method is creating a set of matrices that represent the pairwise comparison within the criteria and the alternatives. By considering each component in the hierarchy structure that is immediately above it, the components in the same level are compared based on the level of importance, as seen in Table 7.15 (Saaty, 2008). For this study, the results from the assessments of the technologies, in terms of the social, economic and environmental aspects, as discussed in previous sections, were used as the references for the pairwise comparison.

In terms of comparing the alternatives, the matrix in Equation 7.5 indicates the pairwise comparison for all the alternatives with respect to a certain criteria. In this matrix, the matrix component of a_{ij} shows the level of importance of the alternative a_i when compared to the alternative a_j with respect to a certain criteria (Shi *et al.*, 2014). In order

Table 7.15 Level of importance for pairwise comparison (Saaty, 2008)

Level of Importance	***Definition***
1	Equal importance
2	Weak / slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong
8	Very, very strong
9	Extreme importance

to ensure the consistency of the matrices of the pairwise comparison, the value of a_{ji} is the reciprocal value of a_{ij}. Moreover, the value of a_{nn} is always 1.

$$W = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (7.5)$$

Table 7.16 shows an example of the pairwise comparison in this study for the alternative construction materials, with respect to the social aspect criteria in Muncar fishing community. More detailed examples of the AHP result for the alternative construction materials in Muncar, can be seen in *Appendix B-4*.

Regarding the pairwise comparison for the main criteria, a similar step can be applied with respect to the goal of the decision making. In order to compare the three criteria in this study, two assumptions were applied. The first assumption was to consider the results from the in-depth interviews in the three selected fishing communities. The discussions during the interviews revealed that the social aspect was the most important feature for local fishers, followed to some extent by the economic aspect, while the environmental aspect was the least important. For this first assumption, by considering the level of importance in Table 7.15, the social criteria was strongly more important when compared to the environmental criteria, and slightly more important if compared to the economic criteria. The second assumption for the pairwise comparison of the main criteria was that all the criteria were equally important.

7.6.2 Result of AHP for choosing the appropriate technology

The results of AHP process for each of the four group of alternative technologies that were considered in this study are illustrated in Figure 7.21 through to Figure 7.26. The "A" character added after the name of each of the communities in these figures represents the results for the assessment when the social aspect was considered to be

Table 7.16 An example of the pairwise comparison for construction materials

Alternatives	Wood	Wood laminate	GRP	Aluminium	Steel
Wood	1	8	5	9	9
Wood Laminate	1/8	1	1/4	2	2
GRP	1/5	4	1	5	5
Aluminium	1/9	1/2	1/5	1	1
Steel	1/9	1/2	1/5	1	1

"strongly more important" than the environment aspect and "slightly more important" than the economic aspect (hence 5-4-1). While the "B" character represents the results for the assumption of the three pillars were considered to be equally important (hence 1-1-1).

A. AHP results for construction materials

According to the fishers' preferences, wood was the most preferred construction material in the three selected fishing communities, followed by FRP in second place. The results from the AHP analysis show that wood was still the top choice for construction materials in Brondong and Muncar. The significantly high level of fishers' preference, especially in Brondong, for wood as the construction material compared to other materials, has led to wood as being the best construction material for Brondong and Muncar, even when the three aspects of sustainability were considered to be equally important, as seen in Figure 7.21.

However, a difference result was found for Latuhalat. The outcomes from the AHP analysis show that the FRP is in the top rank as being the most appropriate construction material for Latuhalat for both assumptions , A or B, of levels of importance. Wood was slightly more preferred compared to FRP in Latuhalat, however, when the significantly lower cost of FRP was considered in the AHP analysis, FRP then moved to being the top rank of construction material for this community.

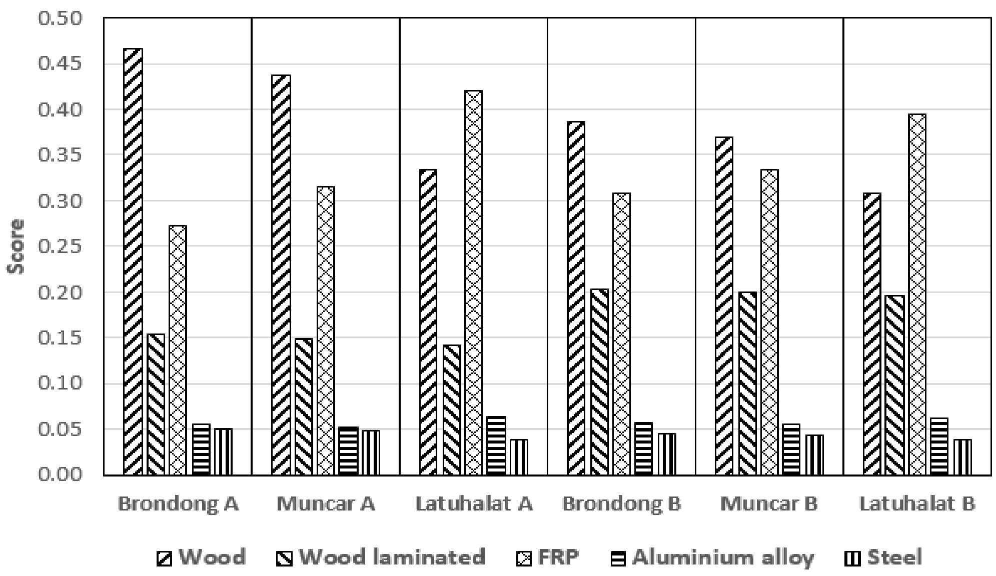


Figure 7.21 AHP results for construction materials in the three fishing communities

B. AHP results for main engines

The AHP results for the group of main engines for Muncar and Brondong can be seen in Figure 7.22, which shows that if the social aspect was considered to be the most important aspect, then the non-marine diesel engine was at the top rank for these communities. However, when the three aspects of sustainability were considered to be equally important, then the hybrid electric drive propulsion that was powered by electricity generator run on diesel fuel was the top rank. The lower cost and lesser environmental impact of electric hybrid engine compared to the current non-marine diesel engine have led this type of engine to be the top rank in alternative engines for Muncar and Brondong.

The results of AHP for group of engines for Latuhalat, as illustrated in Figure 7.23, show that the outboard engine run on kerosene is the top choice when the social aspect was considered as being the most important aspect, while if the three aspects are considered as being of equal importance, then the inboard marine diesel engine became the top rank. The lowest cost for 20 years operational, additionally with the lowest impact to the environment have led the inboard marine diesel engine as being the top rank when the three aspect were considered as being equal. In contrast to the previous group for Muncar and Brondong, electric propulsion was assessed to be the lowest rank in Latuhalat when the three aspects were defined to be equally important. The highest

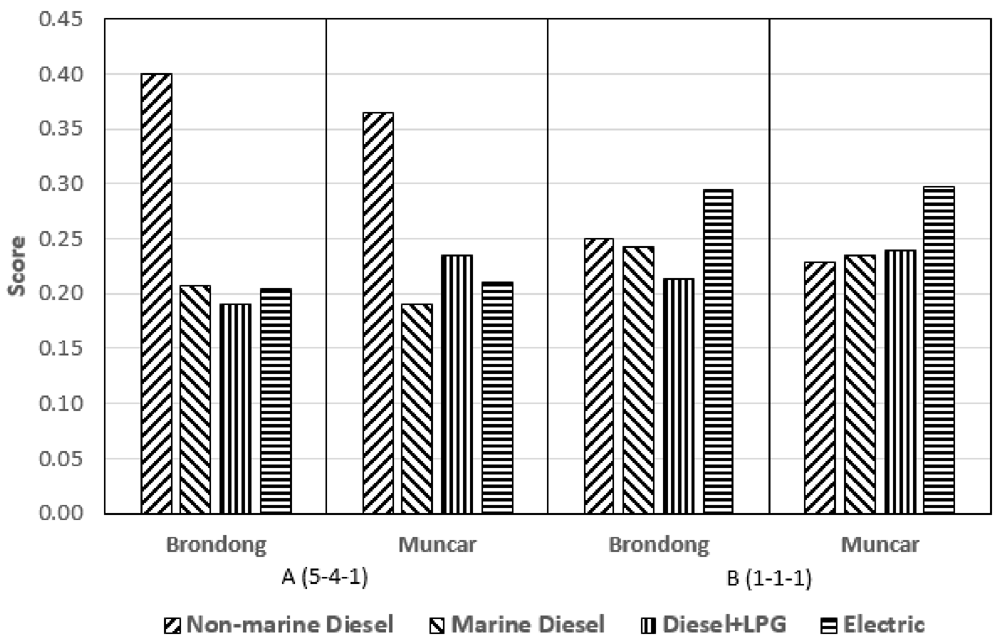


Figure 7.22 AHP results for main engine for Brondong and Muncar

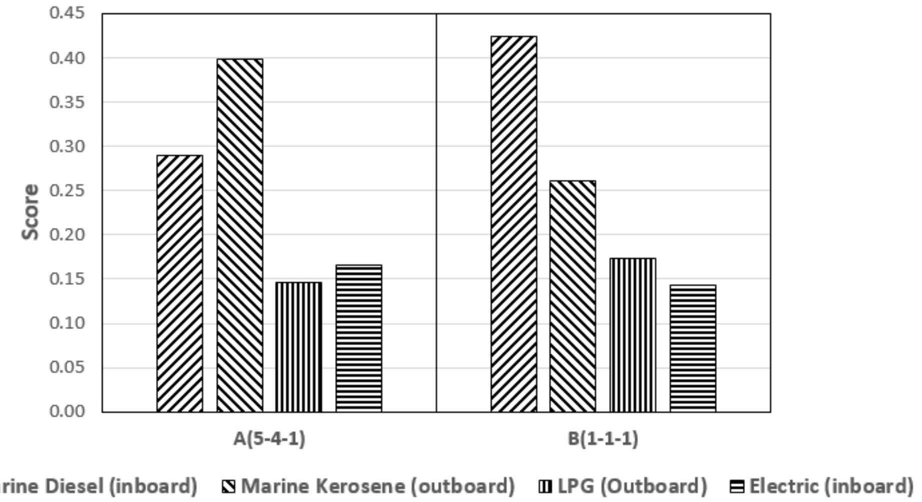


Figure 7.23 AHP results for main engines for Latuhalat

environmental impact of electric propulsion with a land grid supply to on-board batteries, which was significantly higher than for the inboard marine diesel engine, has caused the electric propulsion to be the lowest rank in this group.

C. AHP results for electricity sources

In Brondong and Muncar, the AHP results for AC power sources as presented in Figure 7.24 show that the electricity generator that runs on LPG was slightly higher in ranking compared to the alternator coupled with a diesel engine when the social aspect was considered to be the most important.

While for the same level of importance in Latuhalat, the genset run on LPG is slightly lower in ranking than the genset run on petrol that commonly employed in this

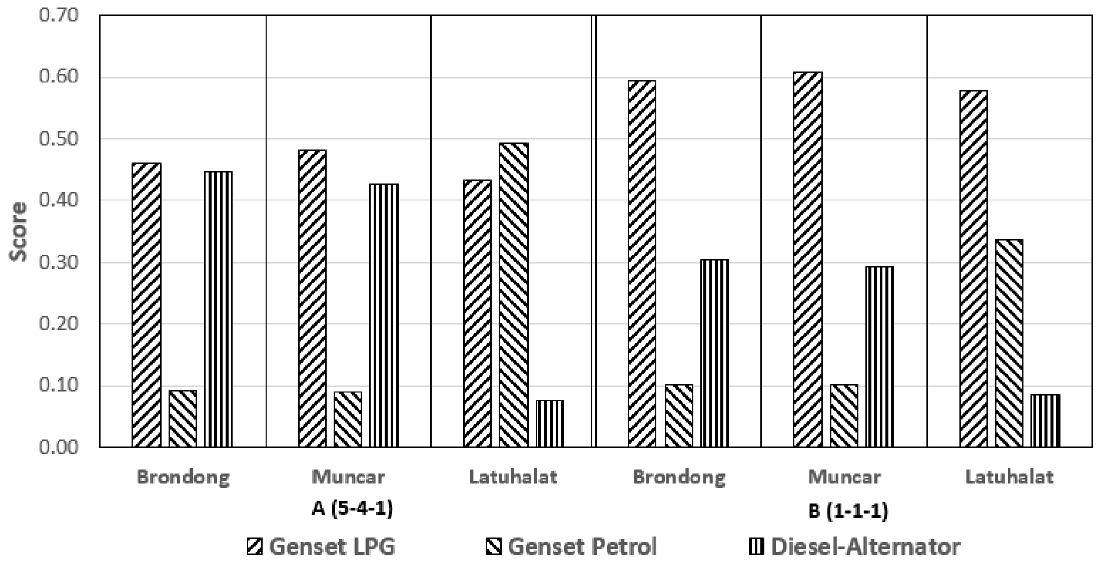


Figure 7.24 AHP result for AC power sources for the three selected communities

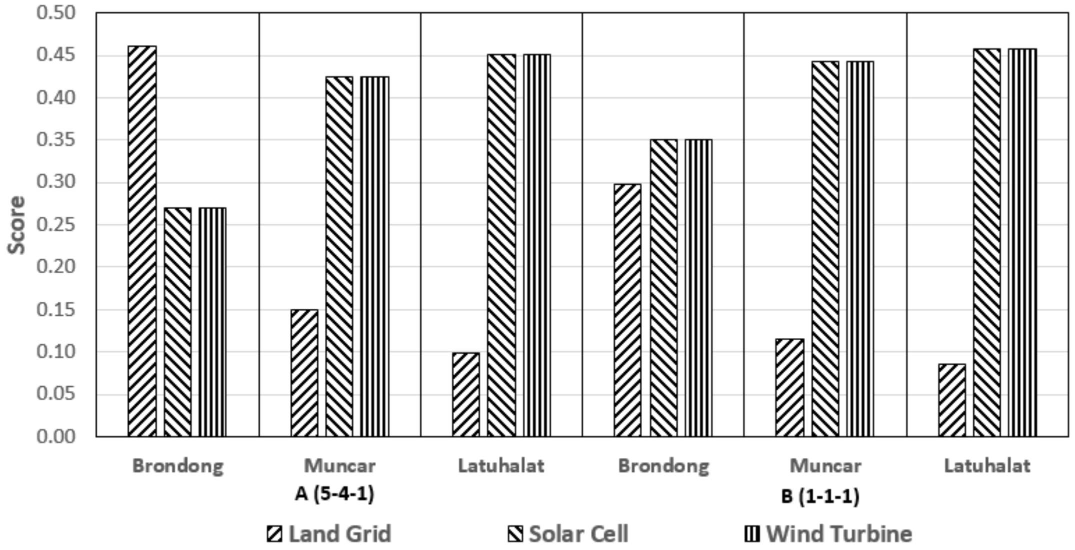


Figure 7.25 AHP results for DC power sources for the three selected communities

community. However, when the social, economic and environmental aspects are all considered to be equally important, then the electricity generator run on LPG was the top rank in all the three fishing communities.

In terms of the DC power sources, as seen in Figure 7.25, when considering that the social aspect was the more important in this AHP analysis, then the results show that both of the two alternative electricity sources were equally in the top rank for the Muncar and Latuhalat communities, while the land grid supply was still the top rank for Brondong in this social level of important. Similar results were obtained in Muncar and Latuhalat when the three aspects were considered to be equally important. However, a change in the outcome was found for Brondong, where both alternative DC power sources became rather higher in ranking compared with the land grid supply.

D. AHP results for fish preservations

Figure 7.26 shows that for the both assumptions of levels of important, A and B, the AHP results for fish preservations show a similar pattern in the results for the three fishing communities. According to this outcome, the fish preservation system using ice blocks was the top rank, followed by the flake ice machine and the freezer on-board respectively. Although, economically the ice blocks generated the highest cost in 20 years of its service life compared to the other alternative systems, however the relatively low level of the fishers' interest and combined with the high of environmental impact of each of the other two alternative systems caused the fish preservation method with ice

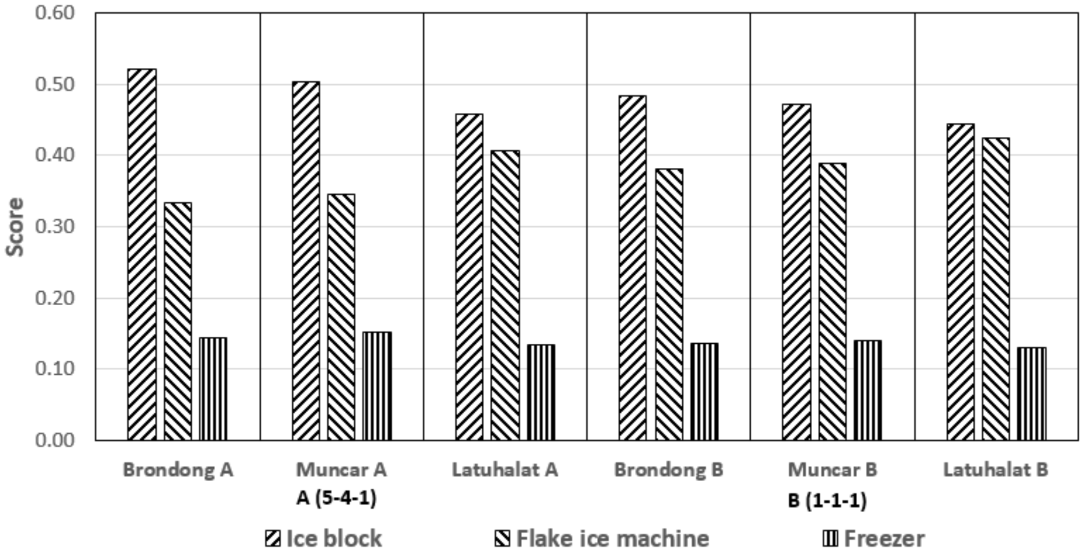


Figure 7.26 AHP results for fish preservation systems for the three selected communities

blocks to become the most appropriate fish preservation method for the three selected fishing communities.

7.6 Concluding Remarks

In this chapter, four groups of technologies that are possible to be employed in fishing vessels in Indonesia have been assessed in term of their social acceptability, the economic viability and their impact to the environment. The order for the most appropriate technologies associated with each of the pillars of sustainability vary for each pillar and each fishing community. Based on the results, the most preferred technologies for local fishers in three selected fishing communities were not the cheapest technologies concerning their operational cost when the long term of service life of the technologies was considered. According to the cost analysis result, the technologies that were the top rank in the social acceptability assessment mostly have the lowest cost in term of their initial investment. This result confirms that the lack of financial support has affected local fishers' preferences on the technologies for their boats.

The result also emphasise that local fishers have less concern to the environmental aspect when considering the technologies for their boat. The environmental impact of current technologies on-board is still the important issue that needs to be handled, since most of these technologies have the highest environmental impact when compared to other alternative technologies based on the result in this study.

The outcome of AHP decision making for two differences levels of importance shows that the attempt to develop sustainable fishing vessel by giving more attention to the environment aspect requires the transformation of local fishers’ preferences on the technologies for their fishing vessels. Government support in financial terms and in the development of local fishers’ knowledge and competencies is required. Additionally the development of environmentally-friendly infrastructure in the form of the development of a centralised renewable power supply for supporting fishing activities, would greatly improve the environmental impact of current practices.

Chapter 8. The Aesthetic Aspects of Traditional Fishing Vessels and Its Relation to the Acceptability of New Designs to Fishers

8.1 Introduction

In order to identify the basic design requirements for the proposed fishing vessel, input was gathered from discussion with local fishers and observations of their current fishing boats. In addition to the technical aspects of the vessels, the aesthetic aspects of boats are also an important input that needs to be considered during the design process.

In fact, a visually attractive appearance is essential for every type of vessel in service worldwide (Guiton, 1971). It is not only for pleasure vessels that there is a need to prioritise their appearance in order to attract people's attention and admiration, but also for working vessels, such as the fishing boats, although at a fundamentally different level. In order to make the boat pleasing to the eye, the correct proportions with regards to the hull and superstructures are required. Furthermore, the appropriate ratio for the bow freeboard to the stern freeboard, and the preferred proportions for the bow and stern angles are important geometrical shapes (Guiton, 1971; Brewer, 1994). In addition to the proportions of several related parts of the vessel, as mentioned above, several features have a significant impact on the appearance of the vessel. The sheer line for instance, can communicate the "grace and personality" of the boat; therefore the sheer line is very often visually emphasised by other objects on the boat, which could be the shape of the railing, or the motif of paint on the hull (Guiton, 1971). However, it is important to ensure that attempts to achieve a good-looking vessel do not distract from the vessel's proper function and safe operation (Brewer, 1994).

Regarding traditional fishing vessels in Indonesia, in order to have an overview in relation to the characteristics of the local fishing vessels in the three selected fishing communities, this chapter presents the result of the many observations on the current local fishing vessels regarding their aesthetic aspects. Moreover, local fishers' opinions concerning the aesthetic aspects of their fishing vessels and on how their preferences on this aspect will influence their acceptance of the new design are also discussed.

8.2 Methodology

As described in Chapter 4, observations of the traditional fishing boats have been undertaken at three selected fishing communities. Any specific and unique features that complement the technical function of the vessels and also the ornaments that decorate the vessels have been identified and documented.

Furthermore, discussions have been undertaken with local fishers in order to understand the various reasons for the attractive decorations on local fishing vessels and how the appearance and the presence of these ornaments influence local fishers preferences and decisions that are relevant to the design of the new fishing vessels. The discussions about these issues was part of an in-depth interview in the second session of the field study regarding fishers' requirements for the design of the proposed fishing vessel as describe in Chapter 1 (Figure 1.1).

Based on the observations and the results of discussions, a few local fishing vessels that have operated in the Bali Straits and to the south of the East Java region were selected as the basis vessels. The main dimensions of these vessels, together with the angle of the bow, the height of the freeboard forward, the sheer and other detail that result in the typical silhouette of the vessels, have been identified. The result of this identification process is subsequently used as an input for the preliminary design of the proposed new fishing vessel in the next chapter.

8.3 Ornamentation on a Traditional Indonesian Boat: A Legacy from the Ancestors

The Indonesian archipelago that consists of thousands of islands is currently inhabited by approximately 1331 tribes (BPS, 2016). Despite the differences in their ethnicities, most of these tribes have some similarities in their connections to the sea. The current traditional vessels, in addition to many artefacts and ancient literatures, have revealed that there is a strong connection between the sea, the people that inhabit the archipelago and the rich cultures of the communities.

The ancestors of these ethnic groups that spread across the islands of Indonesia were migrants that came to Indonesia in many groups and at different times. The earliest inhabitants in Indonesia are believed to have come on foot from Australia and Mainland Asia before the end of the last Ice Age, roughly 40,000 to 17,000 years ago, when most of the islands in the archipelago were still part of Mainland Asia and Australia (Forshee, 2006). Subsequently, other significant migrations occurred from 4,000 B.C. to 1,500 B.C., when people migrated from Southern China by sea to Taiwan and the Philippines. These people then continued to travel, over generations, to eastern Indonesia and finally to the western Indonesian islands and Southeast Asia. This group of migrants are known as the *Malay-Polynesian* people or Austronesians. The next group that moved and settled in New Guinea and on numerous islands to the northeast of New Guinea are known as the Polynesians (Shaffer, 1996)

The ancestors of the Malay-Polynesians came to the Indonesian archipelago with skills in agriculture, metallurgy and boatbuilding (Shaffer, 1996; Bellwood, 1997). These skills, in addition to the existence of main commodities used for international commerce such as herbs and spices, supported the vast development of the maritime trading sector in this region that involved traders from several places, such as China, India, the Middle East and also traders from Europe (Reid, 1993; Shaffer, 1996).

Moreover, the strategic geographical position of the Indonesian archipelago has another benefit. The so-called "land below the wind" is the familiar expression that was used by seafarers in sailing ship in the past regarding the islands to the south of the typhoon belt which runs along the Philippines. This expression emphasised the Chinese and Indian traders' practice of using various islands in Southeast Asia as the main hub during their quite lengthy trade voyages. Traders from China, India and other places were highly dependent on the favourable winds in order to sail; therefore the characteristics of the numerous islands in Indonesia with their warm waters and very few storms were good places to use as temporary shelters while waiting for a better wind (Reid, 1993).

Over time, this commerce brought more people to Indonesia together with new civilisations, ideas and religions. It is believed that Hinduism, Buddhism and Islam were initially introduced and developed through commerce and the interaction between local people and traders from India, China and the Middle East, and this subsequently greatly influenced local culture (Bellwood, 1997). In addition to the influences in culture, commerce also increased the skill and competencies of coastal communities along the Indonesian archipelago in association with sailing and boat building. There were highly skilled wood craftsmen available along the Sumatera and Java coasts, to fulfil the demands of freight ships, especially during the period of dominance of Javanese shipping in Southeast Asian waters in the sixteenth century (Bellwood, 1997; Forshee, 2006).

Local types of vessels called "*Perahu"* and the well-known and larger freight vessels known locally as the "*Jong*", which could carry 400 tonnes of goods on-board, demonstrated the superior skills of the local boat builders in relation to constructing wooden sailing boats (Reid, 1993). The hull was constructed from a massive keel connected to the planks by wooden dowels. The same type of joint was used between the longitudinal planks on the bottom and side shell, without any nails and frames attached to these planks. A quarter-rudder, which looked like the blade of an oar, was positioned on both sides of the vessels and the vessel was propelled by a rectangular lateen–rigged sail, while the shapes of the stem and stern were relatively identical (Reid, 1993). Later, the influence of new building techniques brought over from China introduced iron for fastening that subsequently complemented the use of wooden dowels and thus strengthened the local vessels (Reid, 1993).

However, in addition to the influence of the Austronesian and Polynesian people's ancestors from Southern China, it is assumed that the earliest inhabitants of the Indonesian archipelago already had good seafaring and boatbuilding skills. Their skills were developed in conjunction with the steady growth of a marine oriented culture, as the result of their attempts to adapt and survive in their environment, particularly when the sea levels rose at the end of Ice Age and which resulted in the formation of numerous islands and extensive coastal areas (Thiel, 1987; Clark, 1991).

In the past, boats have already been used for many purposes in Indonesian coastal communities. In addition to being the main modes of transportation, boats were also used to fulfil their many other needs including catching fish, trading goods with other communities, hunting for new wealth and invading new lands (DeJonge and Dijk, 2012). To achieve successful voyages, coastal communities in the past believed that

Figure 8.1 Traditional dugout canoe from Papua, Indonesia with ornaments and animal features on the bow
(Photo: http://www.nativeindonesia.com/mengenal-sejarah-kelautan-di-museum-bahari-jakarta/)

their ancestors' souls, represented by animal characters replicated on the stem post for example, guided them safely and acted as the real skipper of the boat. In many communities, such as in Aru, Maluku Province, this animal ornament would be taken home and kept there until the next trip (DeJonge and Dijk, 2012). A similar concept can be noted on Papua Island, as illustrated in Figure 8.1

Furthermore, in order to demonstrate their achievements with regards to their voyages and to show their personal pride, the status and superiority of their community, therefore coastal communities often decorated their boats attractively especially the stem-post of their boats with various ornaments (Manguin, 2001; DeJonge and Dijk, 2012).

The culture of decorating boats in the Indonesian archipelago, and in many other regions in Southeast Asia, is believed to grown more during the periods of the spread of Hinduism, Buddhism, and Islam. The plant and animal motifs are believed to be the influence of Hinduism and Buddhism, and consequently changed the earlier motifs, which was typically in the form of a simple geometric shape. Subsequently, Islam introduced motifs created from Arabic calligraphy, in addition to geometric and plant motifs in boat decorations (Wahab *et al.*, 2013). This culture of decorating boats, including fishing boats, can still be observed in many coastal communities in Southeast Asia. Figure 8.2 illustrates, for example, a current fishing boat in Kelantan, Malaysia, extensively decorated with a motif of flowers and leaves. This type of motif is quite

Figure 8.2 Motif of flowers and leaves on the bow of a fishing boat in Kelantan, Malaysia
(Source: http://www.expatgo.com/my/2016/03/07/16-reasons-love-kelantan/)

similar to the decorated hulls found in Brondong, Muncar and other fishing communities in East Java.

Similar motifs can also be seen in Bali, Indonesia, where Hinduism remains the religion of most Balinese. Motifs of flowers and leaves adorning vines are applied on many objects in Bali, from houses to ornaments in temples, as a reflection of the owners views and expressions in relation to beauty and devotion (Hartanti and Nediari, 2014). An example of this form of motif can also be found on traditional Balinese doors, as shown in Figure 8.3. This decoration is further evidence that the religion and culture of the communities have a considerable influence on the type of ornament that the communities extensively use on many objects.

The strong emotional connections between the coastal communities and their boats is not only presented in how the communities decorate their wooden boats, but also in how the “shape” of the “boat” is used in numerous daily activities, both physically or as a powerful symbol in various forms. The huge benefits that the boats offer the communities, as described above, in addition to remembering their ancestors, are believed to be the main reasons why boats have been presented in many activities throughout coastal communities in Indonesia. For instance, the shape of the roof of a traditional house in Toraja, South Sulawesi imitates the shape of the boat (Julistiono and Arifin, 2005). In Tanimbar, Maluku Province, a wide stage made of stone in a boat shape was placed in the middle of the village as an assembling place for villagers to

Figure 8.3 Wood engraving with a motif of flowers and leaves used on a Balinese door (http://www.badungbalitrading.com/)

(a) (b)

Figure 8.4 The application of the boat shape in traditional structures in Indonesian.
a) A boat shaped roof in a traditional house in Toraja, Sulawesi; b) A boat shaped stone stage in the middle of the village in Tanimbar, Maluku (Source: http://travel.detik.com/)

meet during special occasion in the past (Ririmasse, 2012). Both these examples can be seen in Figure 8.4.

However, Manguin (2001) believed that there were additional reasons why boats have appeared in many aspects of coastal community life in Indonesia, including many rituals associated with the progressive stages of human life, from birth to the death. Some philosophies that can be taken from boats and their purposes have evidently influenced coastal communities to apply the boat shape in many aspects of their daily life. The concept of the boat as a mode of transportation is believed to be the reason for the boat shaped coffins found in South Nias, North Sumatera Province, and other parts of Indonesia, in order to transport the dead to their final destination (Manguin, 2001; Ballard *et al.*, 2003; Wiryomartono, 2014).

The hierarchy of the crew on board and how the crew respect their skipper has also been adapted as a philosophy for the organisation of the communities and also in the small family units. The concept of "*there are no two skippers in one single boat"* has been used for years in Indonesia to demonstrate how this particular organisation should be managed (Manguin, 2001).

The long history of connections between the coastal communities, their boats and their maritime culture, as described above, make it reasonable that these connections are still in practice until quite recently in many coastal communities in Indonesia. The striking colours and ornaments in the traditional boats can still be observed in many regions in Indonesia. Moreover many rituals that related to the expression of gratitude and the wish for continued protection and large catches are made to God and to the power that is believed to rule the sea, are still preserved to this day (Sartini, 2012).

8.4 Aesthetic Characteristics of Traditional Fishing Vessels in Selected Communities

In order to understand the aesthetic characteristics of traditional fishing vessels in the three selected fishing communities, the following sub-sections discuss the results of the observations on local fishing vessels collected during the field study. The discussion includes the aesthetic characteristic of the hull, cabin, and other specific features of the traditional boats in these communities.

8.4.1 The hull

The hull of a vessel has a reasonably dominant influence on the overall aesthetic characteristics of traditional fishing vessels in the three selected fishing communities as discussed below.

Regarding the types of fishing boats in Muncar, the most dominant type is the "*Golekan"*, or also known as the "*Pakesan"* boat, as shown in Figure 8.5. This sort of wooden boat originates from the Madura Islands, located north of Java Island (Samodra, 2009). The size of the boat varies from a small boat, of up to 11 metres in length, to larger vessels, of up to 24 metres in length. The breadth of the boats correspondingly varies from 2 metres to 6 metres. The draught of this boat is relatively low in order to deal with the shallow water in Muncar fishing harbour (Samodra, 2009).

Figure 8.5 A Pakesan boat in Muncar fishing harbour
(Photo by the Author)

Figure 8.6 A Payang boat in Grajagan fish landing, south of Muncar fishing harbour
(Photo courtesy of Professor R. Birmingham).

The second type of fishing vessel that is operated out of Muncar is the "*Payang*" boat. This traditional fishing boat, as illustrated in Figure 8.6, is the typical fishing boat operated in the south of East Java (Samodra, 2009). The length of the boats is 18 metres on average, and the breadth about 6 metres on average. The specific characteristics of the Payang boat are its high bow and the sharp incline of the sheer line from the mid-ship to the bow peak. The height of the deck at the stern area is relatively low, in order to make hauling the nets on-board considerably more straightforward, whereas the high bow is apparently intended to cope with the surf waves when the boats leave the port or the fish landing area. Figure 8.7 illustrates other types of Payang boats and of how they attempt to cut through the waves when they head out on a fishing trip.

In the Brondong fishing community, there are two dominant types of fishing boats, as illustrated in Figure 8.8. Local fishers call these two type of boats "*Perahu"* and "*Ijon-*

Figure 8.7 The high bow of the Payang boat helps to cope with the surf waves
(Source: http://www2.jawapos.com/baca/artikel/18851/sehari-empat-perahu-terbalik-di-plawangan).

Figure 8.8 The two dominant types of traditional fishing boats found in Brondong
The Perahu (*left*) and the Ijon-ijon (*right*) (Photo by the Author)

ijon". Both these types of traditional fishing boats have reasonably similar shaped hulls. The slight differences are related to the shape of their stem-posts, as the post on the Perahu is higher and tapered, while the Ijon-ijon has a truncated and shorter stem-post. Moreover, the stem-post on the Perahu has a ladder attached to it, which provides the skipper or a crew member with a higher viewing place.

Both the Perahu and Ijon-ijon hulls are constructed with high block coefficients, with a value of the length-beam ratio (L/B) of approximately 2:1 on average, as illustrated in Figure 8.9. With a high block coefficient and a low L/B ratio, this type of fishing boat is also known locally as the "*sigarsemongko*" (Samodra, 2009), which means "half a watermelon". According to the respondents, this "half a watermelon" shape is mainly to increase the fish hold capacity, in addition to providing greater stability for the boats.

Figure 8.9 The shape of the hull on an "Ijon-ijon" in Brondong
(Photo by the Author)

Figure 8.10 Body bobo fishing boat that operates purse seine in Latuhalat
(Photo by the Author).

In contrast to the fishing boats in Brondong and Muncar, the shape of the current fishing boat in Latuhalat has more of a modern look, as illustrated in Figure 8.10. It does not follow the shape of the Austronesian style of boat, which has a reasonably similar shape to the stem and stern forms of the boats found in the two other fishing communities. The respondents stated that this fishing boat, which is called the "*Body Bobo"* boat, was introduced a few years after outboard engines were first installed in local dugout canoes in the 1970s. This type of boat has 17 metres in length on average and up to 3 metres in width.

With regards to the ornamentations on the hulls, almost every fishing region has its own specific pattern; some only play with the colours, but others have more complicated forms of ornamentation. In Muncar, the most dominant pattern that is used to decorate the hull of the Pakesan boat is a hull painted to a selected colour, and decorated with a few parallel white lines that follow the curve of the sheer strake, as illustrated in Figure 8.11.

Figure 8.11 The dominant pattern used to paint the hulls on Pakesan boats in Muncar
(Photo courtesy of Professor R. Birmingham)

Figure 8.12 Identical tribal arts on the stem-post of Pakesan boats in Muncar
(Photo by the Author)

Although there are different colours of the hull and the overall decorations on the Pakesan boats, one identical white *tribal art* pattern is painted on the stem and stern-posts of each of the Pakesan boats, as illustrated in Figure 8.12. According to respondents in Muncar, there is no particular meaning or interpretation in relation to this specific tribal pattern, and it is only used to visually identify this specific type of fishing boat in Muncar.

Regarding the Payang boat in Muncar, there are two types of ornamentations for the hull. The first type of ornamentations comprises a few lines, mostly with different colours that are painted relatively parallel to the sheer line, as seen in Figure 8.6. While the second type of ornament uses the motif of flowers and leaves on the side shell and on the stem-post of the boats. The pattern of vines on the side shell is in the form of lines that run parallel to the sheer line and serves to emphasise the shape of the sheer line, as illustrated in Figure 8.13.

Figure 8.13 The vine motifs painted on Payang fishing boats in Muncar
(Photo courtesy of Professor R. Birmingham)

Figure 8.14 The motif of flowers and leaves on a traditional fishing boat in Brondong (Photo by the Author)

The ornamentations on the hull of both Ijon-ijon and Perahu boats in Brondong are relatively similar in design. A bold motif of flowers and leaves decorates most of the hull above the water line. Although there are different colours that are applied for the flowers and leaves, there is a similarity regarding the patterns of the bold vine stem on the bow and on the stern of both the Perahu and Ijon-ijon boats, as seen in Figure 8.8 and Figure 8.14.

Similar to the tribal art established on the Pakesan boats in Muncar, Ijon-ijon boats in Brondong also have specific tribal art that is painted on their stem and stern-posts, as illustrated in Figure 8.15. As in Muncar, according to respondents there is no specific meaning of the tribal art in Ijon-ijon boats in Brondong.

(a) (b)

Figure 8.15 Tribal art on an Ijon-ijon fishing boat in Brondong
a) tribal art on the stem-post; b) identical tribal art on the stern-post

Figure 8.16 The hull decoration for “body bobo” fishing boats in Latuhalat
(Photo by the Author)

In contrast with the other two traditional fishing vessels in East Java, the hull decorations on the fishing vessels in Latuhalat are reasonably modest and simple, as seen in Figure 8.16. The fishing vessels in Latuhalat do not have motifs of leaves and flowers, as seen on fishing vessels in East Java. There are only a few lines with vaguely painted patterns, which follow the form of the sheer line.

8.4.2 Cabin

In addition to functioning as a shelter for the crew and as a wheelhouse, the cabins on traditional fishing boats have also become the media, the canvas, for local fishers to explore their artistic creativities. In contrast to the hull, the embellishments of the cabins tend to have more varied motifs. For example, Figure 8.17 illustrates the shape of a wheelhouse on a Payang fishing boat in the south and east of East Java, which is extremely attractive in the form its shape and decorations. In addition to motifs of flora and of simple geometric shapes, as seen in Figure 8.18, some cabin decorations use

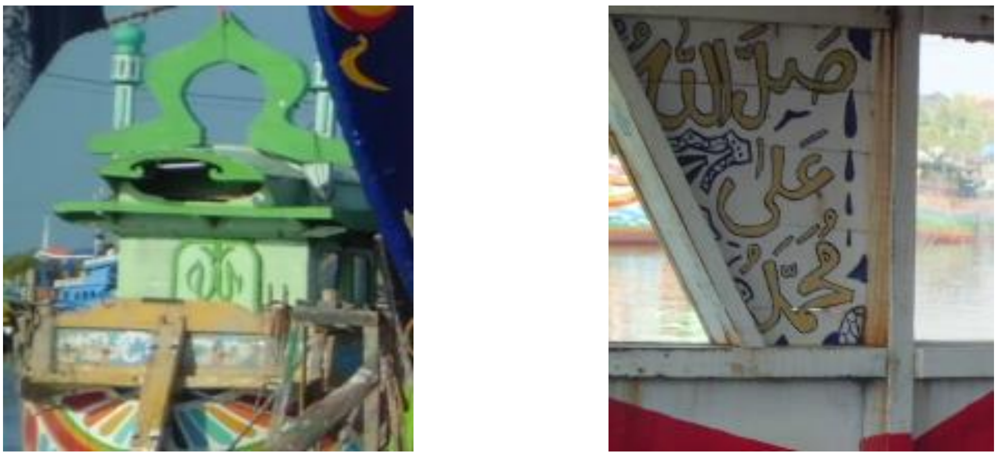
Figure 8.17 Typical wheelhouses for Payang boats in south and east of East Java
(Photo by the Author).

(a) (b)

Figure 8.18 Ornaments on the sides and top of the cabins on boats in Brondong
a) The ornament with flora motif (Photo by the Author); b) Simple geometric pattern on cabin side (Photo by the Author).

Arabic calligraphy and several ornaments that represent the form of a mosque, given that almost all of the fishers in these communities are Muslim, as illustrated in Figure 8.19. Miniature mosque domes or towers are quite common features used as ornaments on the top of cabins in Brondong and Muncar.

Based on the above descriptions, it is clear that the choice of ornaments on the cabins of vessels is predominantly related to the local home port culture that has been inherited for generations, in addition to the local religion. However, the vast development of many aspects of modern life in the three fishing communities, including information technology, has also affected local fishers' decoration choices for their vessels. For example, a considerable number of the local boat owners in Muncar and Brondong



(a) (b)

Figure 8.19 A community's religious identity on the boat cabin
a) Ornamental outline of a mosque dome on top of a cabin (Photo by the Author);b) Arabic calligraphy on a cabin wall (Photo by the Author)

(a) (b)

Figure 8.20 Symbols from modern culture combined with traditional ornaments
a) The logo of Juventus FC on Ijon-ijon boat in Brondong (Photo by the Author);
b) The logo of Manchester United FC on Payang fishing boat in Muncar (Photo courtesy of Professor R. Birmingham).

decorate their boats with the logos of their favourite international football club (FC), in addition to the local traditional ornaments on their cabins and other parts of the deckhouse, as illustrated in Figure 8.20.

8.4.3 Other specific features and ornaments

The decorations on traditional fishing vessels are not only applied to their hulls and the cabins. Almost every part of the vessels are artistically and creatively decorated by local fishers and boat builders, even those related to technical aspects, so as to make their

(a) (b) (c)

Figure 8.21 Different ornaments on "fish finder seats" in Muncar
a) On a Pakesan boat (Photo by the Author); b) On a Payang boat (Photo courtesy of Professor R. Birmingham); c) On a Tubanan boat (Photo by the Author)

boats look more attractive. However, this practice is completely based on the owners' preferences and the boat builder's creativity regarding how attractive the ornaments are on the craft. For example, Figure 8.21 depicts the features that can be found on fishing vessels in Muncar that actually have a similar function on-board. In Chapter 6 this feature is described as the "fish finder seat", which is used by the skipper or a crew member to search for schools of fish. Although they have a similar function, the ornaments attached to this feature are entirely different. The simple chair in Figure 8.21(c) can be discovered on "Tubanan" boats that originally came from Tuban, North of Java and use Muncar as their temporary home port.

There are also a few more attractive ornaments that can be observed on Pakesan boats in Muncar. These include an ornament that resembles a crown attached to the top of the boat's mast, as illustrated in Figure 8.22. This ornament is called a "*Jambulan*" locally (Parastu *et al.*, 2013), which means "topknot" in English. In addition to resembling a crown, the shape of the Jambulan also imitates the shape of butterfly wings or a combination of a replica of a dome on a mosque.

A further recognisable feature of the Pakesan boats are the bamboo bars called "*Landangan*" (Parastu *et al.*, 2013), that are positioned longitudinally on the centreline of the vessels, as seen in Figure 8.23 and Figure 8.5. This feature is made of 3 – 6 bamboo branches decorated in geometric patterns. Based on the observations, in addition to being used as decoration for the vessels, the bamboo bars also have a number of technical functions. Fishers set lamps on the bamboo bars that employ strong

Figure 8.22 Ornament on the top of the mast of a Pakesan boat in Muncar
(Photo by the Author)

Figure 8.23 A bamboo bar called “Landangan” on a Pakesan boat in Muncar
(Photo by the Author)

lights in order to attract the fish. Moreover, in order to ensure that the outboard engine is not accidentally detached from its engine bed and falls into the sea during fishing operation, a rope is attached from the engine to a bamboo bar, as seen in Figure 8.23.

8.5 Local Fishers’ Opinions Regarding Aesthetic Aspects of the Vessels

In view of the fact that the proposed fishing vessel is designed for the Muncar fishing community, the aesthetic aspects of the local fishing vessels was one of the issues discussed with the local fishers. Based on the interview results, most local fishers in Muncar are really concerned about the appearance of their vessels, especially if they have a solid financial background available to support their wish to have attractive fishing vessels.

According to respondents, in addition to the aesthetic reasons, the attractive decorations on traditional fishing vessels in Muncar are actually a form of communication for local fishers. In the past, when communication devices, such as radios and mobile phones, were not available locally, the boat owners, fish workers and fish traders at the fishing port used the ornamentations on the boats to recognise and anticipate the imminent arrival of their boat when it was approaching the harbour. Hence, the owner and his group who owned the vessel had enough time to prepare baskets for the fish catches and everything as necessary in the harbour before the vessel landed, or if necessary to launch a “Taxi” boat in case the vessel was, for some reason, anchored further out from the harbour. This kind of taxi boats are still employed until now, as seen in Figure 8.24.

(a) (b)

Figure 8.24 The small Golekan boat as a taxi in Muncar fishing harbour (Photos by the Author)

Apparently this technical purpose encouraged the boat owners to decorate their boats more attractively and brightly, so as to make them visually distinctive from other boats. Consequently, it is not only about the technical purpose or attractive appearance of the vessels, but also related to the pride and prestige of boat owners and their group who operate the vessels.

How the aesthetic aspect is important to the local fishers in Muncar can be inferred from the respondents' opinions related to the group of fishing boats that were granted by the Indonesian government, and have been abandoned since it was granted in 2012. In addition to technical aspects, respondents also criticised the shape of the boats and the simple colours, as seen in Figure 8.25. Of course colours can be changed by simply repainting the hulls and deck structures, however the lines cannot be changed.

Figure 8.25 The 30GT FRP fishing vessel donated by the Indonesian government (Photo by the Author)

Figure 8.26 FRP long boat with similar decorations to the Pakesan boats
(Photo by the Author)

Local fishers' concerns regarding the aesthetic appearance of their vessels can be revealed as well in Figure 8.26. This figure shows how some local fishers who operate FRP long boats with outriggers, which are relatively newly established in this area, have adopted part of the embellishments of the Pakesan boat for their fishing boats. This style of ornamentations on the FRP long boat with the outriggers did not exist when the first field study was undertaken in 2013, however the image in Figure 8.26 was taken during the focus group discussions in 2015.

The interview also revealed that the reason behind the ornamentations has shifted from the intention that is associated with ancient myths about the vessel to the more recent needs that exclusively pertain to the local fishers' satisfaction, pride, status and identity. According to the respondents' responses, local fishers in Muncar rarely understand the initial historically based philosophies behind the decoration of their boats. During the interviews, most of the respondents said that the decorations are merely part of the aesthetic reason to make their boats more beautiful. However, two respondents remarked that their ancestor's beliefs, that their fishing boat had a soul; hence it required proper clothes just like a person, were the main reason for the ornamentation of their boats, in the earlier years.

8.6 Basis Vessels

By considering the results of the interviews and the observations of local fishing vessels, the visual appearance of the vessel is significant for local fishers in Muncar, and therefore affects their acceptance of the new design of the fishing vessels. For that

Figure 8.27 The silhouette obtained from one type of local fishing boat in Muncar (Photo courtesy of Professor Birmingham)

reason, the design of the proposed fishing vessel for this community appropriately considered the aesthetic aspects of the boat, in addition to its technical aspects. In order to increase the acceptability of the proposed design, the characteristics of local vessels were adopted and carefully modified as necessary, with the aim of fulfilling the local fishers' requirements in terms of both technical and aesthetic aspects.

As discussed previously, several features of the boat, such as the sheer line and the shape of the bow, significantly affect the appearance of the vessel. Furthermore, the combination of these features will help to shape the aesthetic characteristics of the new vessel. In order to have an overview regarding the aesthetic characteristics of the local fishing vessels in Muncar, a simple silhouette of the vessels was identified from the basis vessels that were selected among the traditional fishing vessels in Muncar. The example of this silhouette is illustrated in Figure 8.27 from the local Payang boats.

As the proposed fishing boat is targeted to be able to operate in the seas further to the south of East Java and Bali Island, the basis vessels were selected from the current local

Table 8.1 References from the basis fishing vessels

Basis Vessels	L_B (m)	B_B (m)	D_B (m)	T_B (m)	$Fb_{B.fore}$ (m)	$Fb_{B.Aft}$ (m)	$Fb_{B.mid}$ (m)	Bow Height (m)	Stern Height (m)	Bow slope	Height & position of mast	Length & position of cabin
	17	5	2.1	0.7	3.0	0.7	1.4	4.6	1.7	60^0	6m; 47% Loa from bow	2m; 0m from stern
	19	6	1.8	0.8	2.3	0.7	1.0	3.6	1.7	50^0	No mast	2m; 1.75m from stern
	19	6	1.7	0.9	2.6	1.0	0.8	4.0	2.4	50^0	5m; 18% Loa from bow	3m; 1.5m from stern
	16	5	1.7	0.7	1.5	0.5	1.0	2.7	1.5	45^0	5m; 38% Loa from bow	2m; 2m from stern

fishing boats that frequently operate in these areas. In order to be able to cope with the waves in many fish landing areas in FMA 573, local fishing boats that have relatively high bows were selected to be the basis vessels. Four local fishing vessels that have quite similar shape were selected, as seen in Table 8.1.

In order to have a profile of the proposed design that is relatively close to the local designs, some references are required from the basis vessels. These references include the height of the freeboard at the aft, at mid-ship and at the bow of the local boat; the position of the cabin and mast, including their size; and the ratio of the boat’s length and height. The identification of these references from the basis vessels has been undertaken and the results are presented in Table 8.1.

8.7 Concluding Remarks

The lengthy history of interconnections among the Indonesian coastal communities and the sea has established maritime cultures that continues to influence the interaction of the coastal community with their fishing boats. Although there is a progressive slight change in motivation in relation to how local fishers treat their boats in contrast to the ways of their ancestors, particularly as an influence on their current beliefs and religions, a number of the practices including the appreciation of the aesthetic aspects of the vessels still exist.

The local fishers’ concerns on the subject of the appearance of their fishing boats have resulted in various decorative styles that are typical of each fishing community. This variety has given each fishing community a local identity that can reveal the local fishers’ preferences with regards to the aesthetic aspects of the vessels. By understanding the characteristics of the aesthetic aspects of the local fishing vessels, the proposed new fishing vessels for specific fishing communities can be designed to be consistent with these characteristics. With this approach, acceptability of the proposed design is believed to be high.

Given that the proposed vessel is targeted to be operated in the fishing community of Muncar, four local fishing vessels have been selected as basis vessels, in order to obtain the specific aesthetic characteristics of local vessels that can be adapted for the new design. The characteristics of the local vessels in associated with aesthetic aspects have been identified and are used as the primary input for commencement of the preliminary design stage.

Chapter 9. Designing a Sustainable Fishing Vessel for Specific Fishing Community – a Case Study

9.1 Introduction

An in-depth case study into implementing the concept of sustainable development in the design process of a fishing vessel, was undertaken in the fishing community of Muncar in East Java, Indonesia. This case study was undertaken in order to gain a better understanding and clarification of the more general procedure that is required to develop sustainable fishing vessels for specific fishing communities in Indonesia. The outcomes that are expected from this case study are a prototype design of a fishing vessel which can improve the quality and operations of fishing fleets throughout coastal communities in Indonesia. Furthermore, a further significant outcome from this case study is a proposed rational approach and method that can be employed to design fishing vessels for other specific fishing communities in Indonesia, which can both increase the acceptability of the new designs and simultaneously produce a superior fishing vessel that can support the sustainability of fisheries.

Muncar was selected from among the three fishing communities where the full field study was conducted for a number of reasons. A transformation from one day fishing to undertaking fishing trips that are longer in duration is required by this particular community, given that there is an evident decline in the fish stocks in their local traditional fishing grounds in the Bali Strait. Additionally, based on observations made in the local fishing harbour, there are various types of fishing vessels that regularly come from other regions of Indonesia, which use Muncar as a temporary home port. For that reason, the local fishers are reasonably familiar with the shapes and characteristics of other fishing vessels besides their own traditional Pakesan fishing vessels. Moreover, among the three fishing communities, Muncar was originally granted 4 units of FRP fishing vessels, specifically 2 units of 15GT and 2 units of 30GT, by the Indonesian government. The reason why these vessels have been abandoned has been determined and used as input considerations for the proposed new design.

This chapter describes how the design process for the proposed new fishing vessel was conducted. Furthermore, the proposed steps discussed in Chapter 3 were implemented. The selected items of technology that could possibly be implemented in Indonesian fishing vessels, as discussed in Chapter 5, and which were assessed in terms of achieving the goals of the three pillars of sustainability, as discussed in Chapter 7, have been applied in the development of the proposed design. Other aspects relating to the local fishing community, as discussed in Chapter 6, and the varied aesthetic aspects related to the local design discussed in Chapter 8, and which could in some way influence the design of the vessel, were also considered.

9.2 Methodology

The design process of the proposed fishing vessel followed the logic of the design spiral concept described previously in Chapter 3. It began by defining the primary goal of the design process in association with a sustainable fishing vessel. Subsequently, this sustainable goal was used to control every stage in the spiral design, in order to ensure that the design process followed the concepts of sustainable development.

In view of the fact that the vessel was being specifically designed for the fishing community in Muncar, East Java, many of the design requirements were elicited from this particular fishing community by interviewing the local fishers concerning their requirements related to new fishing vessels. Subsequently, every aspect of the local fishers' requirements were examined in association with various national regulations related to fishing vessels and moreover other recommendations from international bodies pertaining to the appropriate operation and safety of fishing vessels.

Based on the results of the initial observations on local fishing vessels, in addition to the result of interviews and the sustainable goal of the proposed design, various traditional fishing boats found on the waterfront at Muncar were selected as becoming the basis vessels for starting the new design. These basis vessels were subsequently used as a benchmark to acquire the preliminary main dimensions of the proposed vessel. Moreover, any characteristics specific to the local design were identified, including the shape of the hull, the deck layout and the arrangement of the cabin, the choice of fishing gear and their arrangement on deck. These technical aspects of local vessels in conjunction with the aesthetic features of the boats have been used as guidelines with respect to designing the prime features of the proposed vessels.

By considering the fishers' requirements and input from the basis vessels, the initial General Arrangement (GA) was sketched. From this, a rough calculation of the overall weight of the boat was obtained as an input for the initial design of the lines plan in the next stage. For the lines plan stage, MAXSURF Modeller software was employed.

Before the final GA was provisionally developed, decisions were made in terms of the selected main engine, fish preservation and other technologies to be employed in the proposed vessel based on the result of the technologies assessment in Chapter 7. Moreover, the layout of the vessel was finalised considering the results of final lines plan and selection of technologies to be applied on-board.

Once the final GA was completed, more details pertaining to the boat's structure was designed in sequence. For this purpose, rules concerning the acceptance requirements of the structure of the boat were acquired from the Indonesian Classification Bureau (Biro Klasifikasi Indonesia, BKI). More precise weight and centre of gravity calculations were then obtained in relation to the boat and its outfit. Based on this revised weight calculation, the stability of the proposed fishing vessel could be assessed.

In order to ensure that the design of the proposed fishing vessel fulfils the needs of local fishers, Focus Group Discussions (FGDs) were conducted in the targeted fishing community. A small group of local fishers were involved in the discussion reviewing the proposed design. Based on the results of the FGD, several adjustment and modifications were made to the proposed design. Some of the requirements from local fishers cannot be fulfilled because of mandatory aspects, such as safety regulations. These have been analysed, in order to establish appropriate solutions that can be applied on-board. Any supporting measures to overcome the differences between fishers' requirements and the final design have also been included.

9.3 Sustainable Goal

The Brundtland Report suggests that sustainable development requires equal consideration of each of the three pillars of sustainability during the implementation, as this will ensure obtaining more effective support for the achievement of sustainability. However, addressing each of the three pillars on an effectively equal level is an immense challenge. There is always some degree of conflict concerning the requirements that need to be satisfied in connection with each of the three pillars (Sneddon *et al.*, 2006). For instance, an increase in the economic aspect that supports the welfare of communities, as a part of the social aspect, frequently has a negative impact on the environmental aspect. Therefore, conflict will constantly arise depending on how complicated the problems are in the communities in relation to the three pillars. Thus there is always a trade-off in the implementation of sustainable development (Hueting, 1990).

Indonesia faces similar circumstances regarding the development of its fishing fleet, in order to facilitate the overall sustainability of its fisheries sector in general. In the case of the development of the Indonesian fishing fleet, conflict has the potential to arise when considering the current conditions of the local fishers and the attempt to achieve sustainable developments specifically in local fishing vessels. As most of the fishers in Indonesia are individually involved in small-scale fisheries, the pressures to increase the standard of living in their relatively poor communities becomes the principal incentive for the local fishers to pay more attention to the economic aspects in contrast to the environmental issues.

Thus the sustainability goal for the design of the proposed new fishing vessel is to produce a fishing vessel specifically for a selected fishing community in Indonesia, which could provide a balanced solution for any potential challenges during the vessel's life cycle in association with the more complex economic, social and environmental aspects in the fisheries sector.

However, by considering the potential conflicts among the measures taken to develop sustainable fishing vessels, it is important to recognise which is the main priority among the three pillars for a specific fishing community. For that reason, by considering the condition of the local fishers in Muncar, a priority in the design of the proposed fishing vessel for this fishing community pertains heavily on the social aspect of the vessel, particularly related to the socially acceptable condition of the proposed fishing vessel itself. Nevertheless, in order to achieve the environmental aspects of sustainable development, both compromises and adjustments are required in the new design to encourage local fishers to ensure that their fishing activities are more environmental-friendly.

9.4 Design Requirements for the Proposed Design

According to Fyson (1985), there are two starting points related to obtaining the requirements necessary for designing a fishing vessel. The first starting point is to completely follow the owner's requirements and ideas in all aspects, while the second starting point is based on requirements that reflect the designer's concepts related to the boat (Fyson, 1985). Regarding the design of fishing vessels in terms of fisheries development in a specific fishing community, a compromise between these two approaches could be possible. Therefore, the success of introducing a new design will be affected by how much the prospective owners, in this case the local fishers, are involved in the decision making within the design process.

By considering the need to significantly involve local fishers during the design process, the design requirements for the proposed fishing vessel were elicited from local fishers in Muncar. However, as the objective of designing the proposed vessel is to develop sustainable fishing vessel, the fishers' requirements need to be fully considered. This includes considering any potential improvement of the new vessel and also potential conflictions between fishers' requirements with any mandatory regulations associated with the fishing vessels.

9.4.1 Local fishers' requirements

As explained in Chapter 4, in-depth interviews regarding the design requirements were undertaken with 10 local fishers, who were a skipper and the owners or former owners of several types of traditional local fishing vessels in Muncar.

Moreover, in order to gain a better understanding concerning the fishers' requirements and to assist and encourage the participants to clearly explain and clarify their opinions and preferences, a number of images of local fishing vessels, as well as of the grant aid fishing vessels provided earlier by the Indonesian government, were employed as interview aids. Figure 9.1 illustrates how part of the in-depth interview was undertaken in Muncar.

In order to establish the final decision for each element of the design requirements, the designer's response, or in this case, the researcher's reasonable response to the fishers'

Figure 9.1 Interview to elicit fishers' requirements for the new design of the fishing vessels (Photo by the Author)

requirements is presented. As it is believed that the new design must be an improvement in as many ways as possible on the current boats the proposed design does not totally follow the local fishers' requirements. An additional study was conducted in order to understand the rationale behind the local requirements, so as to identify alternative equally viable solutions to any problems regarding the requirements, especially for those that are in conflict with the official regulations or standards associated with fishing vessels and their operation.

The results of the interviews regarding the fishers' requirements can be explained as follows:

a) Target fishing ground

- *Fishers' requirements*

The traditional fishing grounds for local fishers in Muncar are clustered around the Bali Strait that separates Java Island and Bali Island, as seen in Figure 9.2. The Bali Strait is a narrow strait, which is only a mile wide in the northern part, with a water depth of approximately 50 metres, while the southern part is a quite deep sea and approximately 28 miles wide. Additionally, to the south of the Strait is the vast Indian Ocean.

It is worth noting that local fishers will go fishing over a further distance to the south of Bali Island, especially when there is information in relation to there being schools of fish in this more distant fishing ground. In this case, they will land their catches at Jimbaran fish market in Bali, which is located more than 60 miles from the Muncar home port.

Figure 9.2 Traditional fishing grounds of the Muncar fishing community (Adapted from https://www.google.co.id/maps/)

Table 9.1 The permitted fishing grounds for fishing vessels in Indonesia

No	Fishing Ground	Regions (from shore line)	Capacity of Vessel
1	Fishing Ground 1	≤ 4 miles	≤ 10GT
2	Fishing Ground 2	> 4 miles to ≤ 12 miles	> 10GT to ≤ 30GT
3	Fishing Ground 3	> 12 miles	>10GT

- *Final design requirements*

In order to reduce exploitation pressure on the traditional fishing grounds in the Bali Strait, and in line with the Indonesian government's plan to encourage local fishers to go fishing further out at sea, the proposed vessel is planned to be able to travel to the south of Java Island and also to the southeast of Bali Island or in Fisheries Management Area (FMA) 573.

Other references for this design process regarding the possible targeted fishing grounds is the regulations related to the permitted fishing grounds for fishing vessels of a specific size. Ministerial regulation no. PER.02/MEN/2011 regulates the size of fishing vessels that are allowed to operate certain distances from the shoreline in any of Indonesia's FMAs (MMAF, 2011b), as seen in Table 9.1. Based on this regulation, the proposed vessel is targeted to be operated in Fishing Ground 2 and 3.

b) Fish target

- *Fishers' requirements*

The Bali Strait is the migration pathway of the *Sardinella Lemuru*, a small pelagic fish, and which has become the primary target for the local fishing communities. As a result, Muncar has become extremely famous in connection with canned sardine producers in Indonesia. However, since there has been a significant decline in sardine stocks in the Bali Strait over the last decade, local fishers have somewhat revised their fish targets in order to incorporate other species of fish, especially since every sort of fish that is landed in Muncar has value in the local market. Based on the interview, there is no specific singular fish target for local fishers and they will catch any types of fish that are available, especially depending on the harvest season for each species.

- *Final design requirements*

Based on the fishers' requirements above, the fish target for the proposed design is for a multi species fish catch activity. However, by estimating potential fish stocks in FMA

573, the fish target for the proposed design is pelagic fish, of both small and large type (MMAF, 2011a).

Although specific regulations corresponding to the combination of size and the species of the fish that are allowed to be caught have not been promulgated yet in Indonesia, in order to ensure that the proposed vessel supports the implementation of sustainable fishing practices, the design of the fishing gear instead was considered, for example the size of the mesh on the nets.

c) Fishing gear

- *Fishers' requirements*

The fishers' choice pertaining to the types of fishing gear depends on their anticipated fish target. According to the local Marine Affairs and Fisheries Agency, numerous types of fishing gear are commonly operated by local fishers in Muncar. Among the types of fishing gear, the highest number are gillnets, followed by handlines and then purse seine nets. However, as the purse seine requires a large number of crew on-board in order to operate it, the number of fishers that are involved in this fishing method is greater than those who operate other types of fishing gear.

According to the respondents, there are two primary reasons why local fishers select their particular fishing gear. The first reason is related to the type of fish target. The second reason is related to the cost of the fishing gear, both for procuring the gear and for operating them. Fishers with limited financial support mostly operate gillnets and handlines, seeing as they are less expensive to acquire and require fewer crew on board.

- *Final design requirements*

One of the very basic requirements for ensuring responsible fishing practice is the implementation of more environmentally-friendly fishing gears including non-destructive fishing gear. To ensure that appropriate fishing gear is applied in the proposed vessels, national regulations have been used as guidelines.

By considering the local fishers' requirements, the proposed fishing vessel is designed to be a multi-purpose fishing craft. Therefore, it is designed to be able to operate a number of types of fishing gear based on the seasons and the fishers' changing needs. Moreover, Ministerial Regulation no PER.02/MEN/2011, which regulates the type of fishing gear that is allowed to be operated in certain FMAs, has been used in order to select the fishing gear to be operated. Passive fishing gear, such as gillnets, handlines and long lines are clearly allowed to be employed in FMA 573. While for the purse seine, according to the regulation, only nets with a mesh size of ≥ 3 inches are allowed in this FMA. In addition, other active fishing equipment specifically trawl and seine nets are not permitted in FMA 573 (MMAF, 2011b); therefore, it is recommended that these two types of active fishing are not operated on the proposed vessel.

d) Expected catches capacity

- *Fishers' requirements*

According to respondents' responses, in the last few years the maximum catch for fishing vessels that operate purse seine is typically approximately 5 tonnes, while handlines and gillnets generally achieve smaller catches, on average approximately 1 tonne per trip, although they are predominantly more valuable fish. In contrast to the average catches landed recently, the respondents were still expecting to have a maximum capacity of 20 tonnes provided for in the new design, which is the same capacity as most of the current larger (20 meters) fishing boats have in Muncar.

- *Final design requirement.*

The maximum catch over the last few years for purse seine fishing has been only 5 tonnes. Thus, in order to minimise the excess capacity of the fish hold, the fish hold for the proposed fishing vessel is designed to be able to carry a maximum of 10 tonnes of fish in bulk, in conjunction with 5 tonnes of crushed ice.

e) Duration of fishing trip,

- *Fishers' requirements*

The average length of a local fishing trip in Muncar is less than 24 hours. Fishers leave the home port in the afternoon and land their catches early in the next day in Muncar harbour. However, those who fish south of Bali Island regularly leave home for a maximum of three days round trip. They land their catches and load the provisions, each day of their trip, in Jimbaran, Bali. According to respondents, they do not mind if they go fishing for longer durations, if it provides better results.

- *Final design requirement*

In view of the fact that the target fishing grounds are a further distance away from Muncar, a longer fishing trip is thus required, which will be potentially more beneficial than if the vessel returns to the home port on a daily basis. The proposed fishing vessel is thus designed to be able to be operated for a maximum duration of 7 days, without any refuelling from the nearest fishing port. The consequences of this are an increase in tank capacity regarding fuel, fresh water, provisions and moreover, the design of proper accommodation on-board.

f) Accommodation and deck layout,

- *Fishers' requirements*

Most local fishing vessels in Muncar have no proper shelter on board, typically only a tarpaulin draped over bamboo bars is used as a temporary shelter on many of the fishing vessels. Local fishers argued that as they only go fishing for a 24 hour period or less, they do not require any shelter, as they will be working for most of the time that they are on-board. However, if the fishing duration is more than one day, most respondents agreed that some form of proper more permanent shelter is required. For that reason, the requirement for accommodation is that of a simple shelter that does not restrict access and movement and still provides adequate working area for casting and hauling the nets.

It should also be mentioned that the respondents believe that a proper toilet and galley facilities are not required on board. They argue that if they need to go to the toilet during their fishing trip they can simply use the side of the deck as a temporary natural toilet. With regards to the galley, given that local fishers only go fishing for less than one day, most of them take a prepared meal from home; consequently a galley is not required. However, based on the respondents' responses, they would not mind if there are both a toilet and galley for the longer trip available on-board.

Concerning the working deck layout with respect to local fishing vessels, it is affected by the type of fishing gear that is to be operated on-board. Fishers that operate purse seine prefer to store their nets on the port-side of the weather deck, so it will be easy for them to deploy the nets as soon as they detect a school of fish, while fishers who operate gillnets and handlines, have no specific position for storing their fishing gear seeing as these are passive equipment. However, based on the interviews, many fishers prefer to store the gear on the forward areas of the deck.

- *Final design requirement*

One of the design requirements for sustainable fishing vessels is that of a safe and healthy working environment on-board. This can be fulfilled by providing reasonable accommodation and sanitary facilities, in addition to designing an appropriate deck layout both for the working areas and other general activities on-board.

Considering that the duration of a fishing trip for the proposed fishing vessel is of up to 7 days, proper accommodation is included in the new design. It is completed with an appropriate simple galley and toilet. Additionally, other features related to the protection of the crew on deck have been considered and provided, such as a proper railing on deck side and handrail along the cabin wall.

As the proposed boat is designed to be a multi-purpose fishing vessel, the local common fishing practices for handling and operating difference types of fishing gear were used as input to the design of the layout for the main deck. As the result, a compartment is required for storing the fishing gear, and space made available in areas next to the fish hold hatchway**,** in order that local fishers can use this area to store their nets. Further assessment regarding the stability of the vessels, when the fishing gear is stored on deck, is required for this case.

g) Number of crew

- *Fishers' requirements*

According to the respondents, single fishing boat that operate purse seine and employ line haulers on-board to assist with hauling the nets, will require a minimum of nine crew members on-board to lift the nets back on to the deck. Due to the hauling time and the amount of load for each crew member, respondents commented that a purse seine will require 15 crew members on-board, although current single purse seining boats in Muncar predominantly employ 25 – 30 crew. Fishing boats that operate handlines or gillnets require s smaller crew; for example small vessels of up to 10 metres in length and that operate these passive fishing gears only have approximately 3 – 5 crew on board.

- *Final design requirement*

In view of the fact that the proposed vessel is designed as a multi-purpose fishing boat, the number of crew on-board will be influenced by the type of fishing gears operated by the fishers. However, based on respondents' opinions concerning the more appropriate number of crew for single purse seine, the design of the accommodation and volumes of consumable tanks are intended to cater for a maximum of 15 crew members on-board.

h) Construction material,

- *Fishers' requirements*

With regards to the construction material for the vessels, wood is by far the most common material used for fishing vessels in Muncar. However, long boats made of FRP with outriggers have become increasingly popular in Muncar recently. With the handling advantage of it being a lightweight boat, FRP has become more attractive for local fishers that operate small fishing vessels of up to 10 metres in length.

- *Final design requirement*

By considering the fishers requirements and the result of the assessment of alternative construction materials, as discussed in Chapter 7, the selected construction material for the proposed fishing vessel is wood. However, seeing as there is increasing interest among the fishers pertaining to FRP, and, furthermore, based on the assessment of the materials that FRP is the second choice after wood, the proposed fishing vessel is also designed in to be built in FRP. Further discussion about the selection of construction materials for the proposed boat, including their scantlings are discussed in sub-section 9.5.7, in relation to detailed construction aspects.

i) Powering

- *Fishers' requirements*

Most local fishing vessels in Muncar use outboard non-marine diesel engines for propulsive power, in conjunction with a long shaft driven propeller which can be tilted, especially for use in fishing vessels that operate a purse seine. According to respondents, the main reason for this choice is because there is a potential risk that the purse seine net can drift on the sea current and subsequently get caught in the shaft or propeller during the casting process. However, an outboard engine with a long shaft propeller enables the crew to avoid the net being caught on the propeller by simply lifting it out of the water when they deploy the net. According to the respondents, in term of practical experiences and competencies, local fishers essentially have no difficulties in operating an inboard engine. A number of respondents admitted that they have experience of operating fishing vessels with an inboard engine, particularly when they work as crew on fishing vessels from other regions that operate handlines. Many of the fishing vessels that are found in Muncar fishing harbour and have inboard engines, operate handlines or gillnets.

- *Final design requirement*

From among the few alternatives available for the main engines, an inboard diesel marine engine is suggested for the proposed vessel. The decision rationale is described further in sub-section 9.5.5 with respect to the range of technologies applied on-board.

j) Fish preservation

- *Fishers' requirements*

The most common method employed locally to preserve fish on-board is by using block ice that is crushed when required into flakes and used to cover the fish in the fish hold. The result of the in-depth interviews with local fishers on the subject of alternative technologies for fish preservation confirmed that simple block ice continues to be the main choice for fish preservation.

- *Final design requirements*

With regards to fish preservation on the proposed fishing vessel, a similar method to that used by the current local fishing vessels is employed, which is ice stored in a block shape and crushed into small size when it is needed to cover the fish. However, further improvements in the preservation system are proposed and discussed in sub-section 9.5.5 concerning the technologies applied on-board.

k) Electricity sources

- *Fishers' requirements*

The requirement for electricity sources is largely based on the fishing gear that is operated on-board. Fishing vessels that use lighting in order to attract fish to their location require a large supply of electricity on board. To fulfil this requirement, local fishing boats in Muncar use alternators that are coupled to a separated diesel engine.

- *Final design requirements*

It is suggested that solar panels complemented by batteries are employed in order to store electricity on-board the proposed vessel. However, if more electricity is required, it is suggested that an electricity generator run on LPG could be installed on-board. A more detailed description concerning the selection of a suitable electricity source for the proposed design is presented in sub-section 9.5.5 in relation to the technologies applied on-board.

l) Navigation devices,

- *Fishers' requirements*

Navigation devices such as the Global Positioning System (GPS) are considered to be not necessary for local fishers according to the respondents. Their traditional fishing grounds that are mainly situated reasonably close to land are the main reason respondents have no interest in using GPS, and they argue that visual recognition of natural landmarks is precise enough to be utilises as guidance for local fishers. However, if they need to go fishing further out at sea, most respondents do not deny that they need devices that would assist them to return home safely and also in bad weather, although one respondent claimed that quite a lot of local fishers still understand how to use natural signs, such as their knowledge of astronomy and the predominant direction of the waves, to navigate back home.

- *Final design requirements*

The proposed vessel is targeted to go fishing further out at sea; therefore it is highly possible that the new fishing grounds will be far enough away from land such that the fishers cannot rely solely on landmarks situated on the mainland, in order to navigate their vessels. Furthermore, by considering the benefit that the GPS can offer for fishing activities and the safety of fishing trip, therefore, it is recommended that a GPS is employed in the proposed vessel.

m) Electronic devices for fishing aids,

- *Fishers' requirements*

Local fishers have little or no experience of using modern electronic devices as fishing aids, such as a fish finder. The lack of knowledge and information regarding such devices, in addition to a potential problem in terms of equity issues among the local fishers, principally on the issue of equal access to limited fish resources, have limited the introduction of such devices. According to the respondents, local fishers' skills learned from their ancestors are precise enough at detecting and locating the fish; therefore, utilising electronic devices as fishing aids is not required.

- *Final design requirements*

By considering the respondents' responses in relation to an electronic fish finder, the simple physical elevated "fish finder seat" that is found on local vessels and which the skipper employs for his visual observations will be retained for the new design. This is for the simple reason that it is more beneficial to have the skipper in a high position above the water to look for shoals of fish compared to fish finder, as the skipper is able to search quickly and easily over a wider radius from the vessel. Respondents said that they can often detect the presence of fish schooling hundreds of metres away from the boats. However, there is still the possibility of incorporating a fish finder and other fishing aids on local fishing boats at some time in the future, with the aim of complementing current practices in locating shoals of fish.

n) Local culture and aesthetic aspects,

- *Fishers' requirements*

As described in Chapter 8, the ornaments and decorations on the fishing vessels are local culture heritages that have existed for a great many years. Colourful fishing vessels with attractive ornaments visually demonstrate the identity of the vessels and also add to the status of the vessel owners. Each type of boat has its own type and style of decorations, hence, according to some respondents, it is not necessary for the newly designed fishing boat to have ornamentation specific to local designs; nevertheless, colour and decorations are one of the principal aspects that need to be available on the fishing vessels, given that local fishers are very concerned with the appearance of their crafts.

- *Final design requirements*

Based on the respondents responses regarding the aesthetic aspect of fishing vessels and moreover, supported by the discussion in Chapter 8, the aesthetic aspect is being seriously considered for the proposed vessel. Hence, the aesthetic characteristics found in local fishing vessels are adopted and adapted for incorporation as physically relevant in the new design. A more detailed discussion pertaining to the implementation of this aspect in the proposed design is presented in sub-section 9.5.2 regarding local features and aesthetic aspects.

9.4.2 Other requirements and considerations

As described in Chapter 6, local fishers in Muncar have a number of shortcomings, including the relatively low level of formal education, a relatively low level of financial support, and also a minimal level of awareness regarding practical safety consideration and the complexities of the environment as well. These limitations will evidently influence some aspects of the design of the proposed fishing vessel; therefore, they need to be considered during design process. For instance, the technologies applied on-board should not be over complicated for local fishers to operate.

In order to support the implementation of alternative technologies, the availability of a robust supply chain for the purchasing of technologies and their spare parts for repair and maintenance are important with respect to the successful implementation of alternative technologies. According to local suppliers of engines and other machinery for fishing activities in Muncar, very few difficulties are encountered in relation to providing various types of engines and equipment, as long as there is sufficient demand from the large number of local fishers.

Regarding the prevention of pollution potentially produced by fishing activities on-board, there are no specific national regulations that control the prevention of marine pollution from fishing activities. Instead, there is Government Regulation no. 21/2010 on the subject of the protection of the marine environment, which regulates the prevention of marine pollution from ships in general. The articles that are relevant for fishing vessels include: 1) marine environment protection can be conducted through the prevention and mitigation of the pollution caused by the operation of the ship (Chapter I, Article 2.2); and 2) marine environment protection related to preventing the discharge of waste disposal into the water area (Chapter I, Article 2.3).

9.5 Designing Proposed New Fishing Vessels

In this section, the design process of the proposed fishing vessel is presented. As explained in the methodology section above, the design stages that are discussed in this section include: the identification of the main dimensions for the proposed design; the local aesthetic characteristics to be adapted; the design of the preliminary general arrangement (GA); the development of the lines plan and associated hydrostatics; the selection of technologies applied on-board; the design of the final arrangement; the design of the detailed structure, and the stability assessment of the proposed vessel.

9.5.1 Main dimensions identification

The initial stage of designing a vessel is the identification of the boat's main dimensions. In order to ensure the acceptability of the proposed design, the ratio of the main dimension found in traditional fishing vessels was used as a reference. It is important to have the correct ratio of dimension based on the basis vessels, in order to give the local fishers the feeling that the proposed design bears some similarity and operational capabilities to the traditional fishing vessels.

Since the proposed vessel will be operating south of Java Island, the Payang boat, as illustrated in Figure 8.6 (Chapter 8), that commonly operates in this water is used as the basis vessel. Moreover, given that the proposed fishing vessel will be required to operate at sea for more than one day, and hence needs a proper cabin, the Payang boat, which can be fitted with a cabin, was used as the basis vessel, instead of the local Pakesan boat, as seen in Figure 8.5 (Chapter 8). Given that the lengths of the Payang boats in south of East Java waters are usually from 16 – 20m, then the first estimate of the length of the proposed fishing vessel is designed to be within this specific length range.

By checking the volumes that are required for the fish hold of the target capacity and the fishing gear storage compartment of the proposed design, and by comparing these volumes with the ones in the basis boats, the design length can be estimated. However, since there was not enough information in relation to the actual volumes of the fish hold of the local fishing boats, hence the fishing vessels that were donated to local fishers by the Indonesian government were used as a comparative measures to obtain the designed length of the new design. This was simply to obtain the initial length of the new vessel based on the volumes of the fish hold and fishing gear storage available in the comparative vessels and the length of the vessels themselves.

As reviewed above, the proposed vessel will bring home a maximum of 15 tonnes of fish in bulk together with ice. By considering that the stowage rate for sardines in bulk with ice is approximately 0.65tonnes/m^3 (Shawyer and Pizzali, 2003), this load therefore needs a fish hold that is 23 m^3 in volume. Furthermore, based on the observations of local fishing boats that operate purse seine, the volume required for storing the nets was also identified. A minimum of 6 m^3 is required if the purse seine nets are to be stored below the weather deck. Hence, a minimum volume of 29 m3 is required for the combined fish hold and storage of fishing gears in the proposed vessel. Based on this required volume, and by making a comparison with the granted vessels which are 18.5 metres in length, it was decided that the provisional design length for the proposed vessel should be 18 metres.

Table 9.2 Main dimension identification

Basis Vessels	**L_B (m)**	**B_B (m)**	**D_B (m)**	**T_B (m)**	**L/B**	**B/D**	**T/D**	**Barkla's Scaling based**				**Ratio based**			
								L_D	**B_D**	**D_D**	**T_D**	**L_D**	**B_D**	**D_D**	**T_D**
	17	5	1.9	0.7	3.4	2.4	0.4	18	5.20	1.98	0.73	18	5.29	2.01	0.74
	19	6	1.8	0.8	3.2	3.3	0.4	18	5.78	1.73	0.77	18	5.68	1.71	0.76
	19	6	1.7	0.9	3.2	3.5	0.5	18	5.78	1.64	0.87	18	5.68	1.61	0.85
	16	5	1.7	0.7	3.2	2.9	0.4	18	5.43	1.85	0.76	18	5.63	1.91	0.79

Based on the selection of the initial designed length, the other main dimensions of the proposed vessel; the beam, height and draught, were obtained by means of Barkla's scaling factor and the main dimension ratios of the basis vessels, as can be seen in Table 9.2 In order to determine the main dimensions of the new vessel, the related main dimension of the basis vessel is multiplied by Barkla's scaling factor, which is $L^{0.70}$. "L" in this variable is obtained by dividing the length of the design vessel with the length of the basis vessel (Larsson and Eliasson, 2007). For this proposed design, as a comparison of the result from Barkla's scaling method, a simple method using the ratio of the basis vessels main dimensions is applied as well, as shown in Table 9.2.

By considering the results of identification of main dimension based on Barkla's scaling method and the ratio of the basis vessels main dimensions, as shown in Table 9.2, the initial dimensions of the proposed fishing vessels as the input for the next stage are as follows:

- Length overall (Loa) = 18 metres
- Beam moulded (B) = 5.5 metres
- Depth (D) = 1.7 metres
- Draught (T) = 0.8 metres

9.5.2 Local features and aesthetic aspects

Based on the discussions during the in-depth interview in Muncar, the appearance of the fishing boat is of critical importance for the local fishers. The observation of local fishing boats has confirmed that profile, colours and ornamentations are the basic aspects that need to be considered when designing fishing boats for the Muncar fishing community. Consequently, in order to increase the fishers' acceptance of the proposed design, the aesthetic characteristics of local vessels must be adopted and adapted in support of the new design development process.

As described in Chapter 8, the silhouettes of the basis vessels of the proposed design have been identified. These references pertaining to boat profiles, with particular reference to the sheer and angle of the bow and transom, were subsequently adopted. They were modified to a degree however in order to accommodate improvements in the proposed design. In addition to considering the silhouette of local fishing vessels in relation to designing the shape of the proposed design, several decorations were also created for the new design. The ornamentations with motif of flowers and leaves, which are frequently found on local fishing vessels, were adapted for the proposed craft. Figure 9.3 below illustrates a few free-hand sketches of the ornamentations that were designed for the proposed fishing vessel.

A number of technical features for the new vessel were also embellished with various decorations placed on them also shown in Figure 9.3. In addition, Figure 9.4(a) reveals a radar reflector that will be installed on the proposed vessel. By considering local fishers preferences regarding ornamentations, this radar reflector is designed to be decorated so that it can be part of the decoration on-board without reducing in any way its technical function.

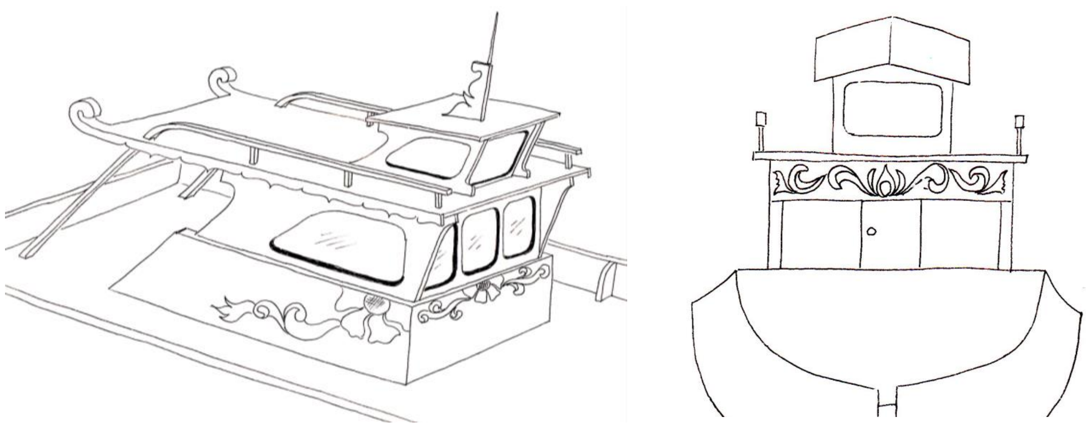
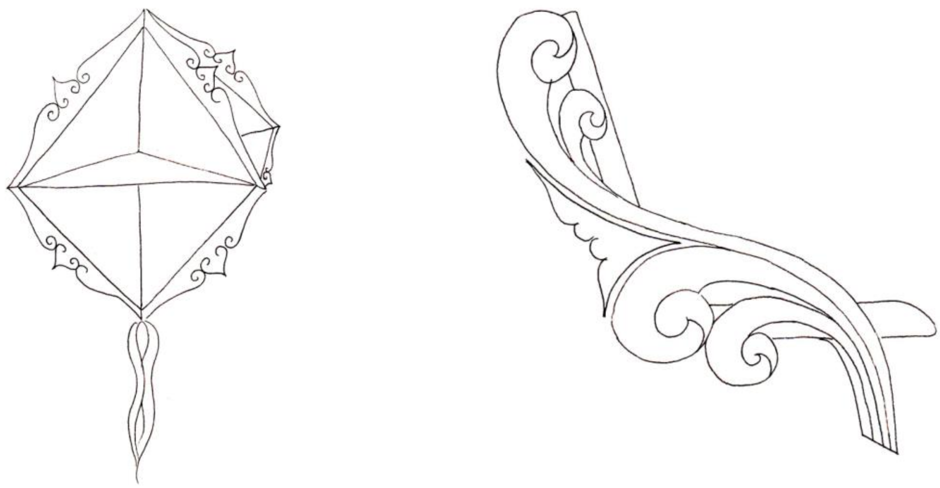


Figure 9.3 Illustrative sketches of various possible decorations for the cabin design



(a) (b)

Figure 9.4 Illustrative design of ornamentations for the technical features
a) Ornamentation on the radar reflector; b) Ornamentation on the fish finder seat

Moreover, based on the observation and discussions with local fishers, features will be retained where their function supports local fishers fishing activities and which are not to be substituted by other alternatives. These features include the existence of the fish finder seat for the skipper and moreover, the bamboo or wood bar between the cabin and foremast that is used to hang the nets when fishing, or for repairing the nets. With examples from local boats, both features were designed with proper consideration concerning aesthetic aspects, including how these features are connected with other parts of the vessel. For example, the trend of a curved line for the bamboo bars that followed the trend line of the dominant part of the cabin (for instance the trend line on the second deck) provides a visual continuity along the profile of the vessel. Moreover, for the same reason and as with the radar reflector, the fish finder's seat that is attached to the foremast is also decorated, as can be seen in the sketch in Figure 9.4(b).

9.5.3 Preliminary General Arrangement

Preliminary General Arrangement (GA) is the initial planning for the distribution of the compartments and components along the vessel in conjunction with the initial design for the deck layout. By using the anticipated main dimensions as input and by thinking about local fishers' general requirements and their common fishing practices, a preliminary GA was created and sketched, as illustrated in Figure 9.5.

The local fishers' preferences concerning the deck layout and their common fishing practices, including those concerning the position of fishing gear and its storage, working areas, and the position of the line hauler, have been used as input for this stage.

The basis vessels that were selected from local traditional fishing boats have also been used as references for this preliminary GA with the aim of putting the cabin, mast and other dominant features in appropriate relative positions. However, seeing as there are several potential improvements regarding the proposed design that have to be accommodated, for example, the need for an appropriate cabin in conjunction with a proper galley and toilet; the layout of the proposed design does not completely follow the basis vessels.

At the initial stage it was decided to split the fish holds into six compartments, as seen in Figure 9.5, in order to minimise the potential for free surface movement from the fish and melted ice in the fish hold. Furthermore, the consumables tanks are devised to be located at the aft of the boat, below the weather deck. The separated fuel tanks are designed to be located inside the engine room, while the main fresh water tank is placed behind the aft bulkhead of the engine room. A separate tank for daily fresh water is also situated on the second deck, so that the distribution to the galley and other parts of the vessel only relies on the simple gravitation feed method.

The proposed vessel is targeted to be a multi-purpose fishing boat, which can operate purse seines, gillnets and handlines. However, during any single fishing trip only one type of fishing gear will be intended to be used. Hence, different alternatives are provided with regards to the storage of fishing gears. The storage for the nets situated in

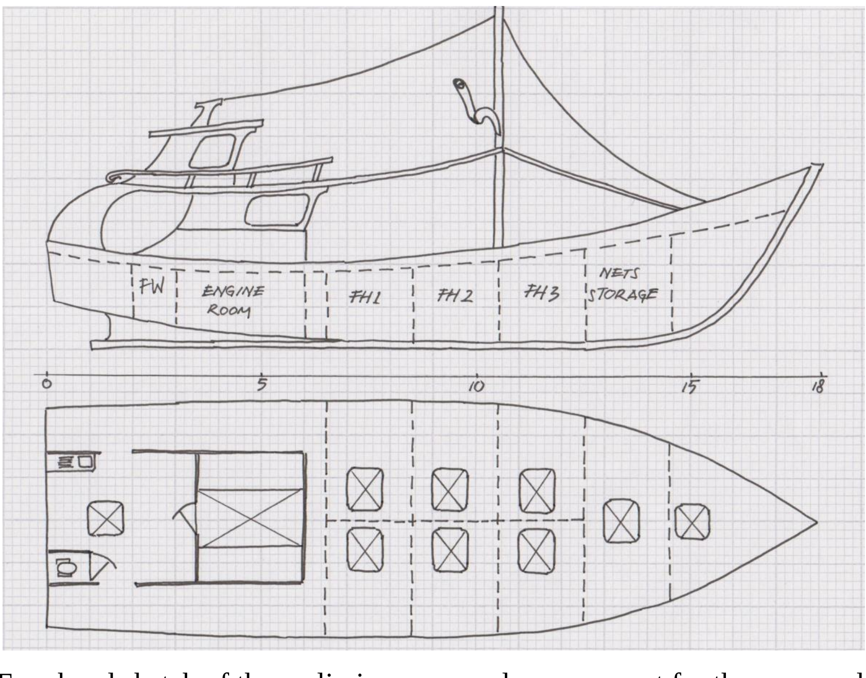


Figure 9.5 Free-hand sketch of the preliminary general arrangement for the proposed fishing vessel

front of the fish hold is prepared for gillnets or handlines, while more space between the bulwark and fish hold hatchway is organised for the purse seine nets, in case the fishers prefer to store the nets in this particular space.

9.5.4 Lines plan

The proposed vessel is targeted to be operated further out into the FMA 573, which is located south of Java and Bali Islands. For that reason, the basic shape of the local fishing boats that are commonly operated in this area was adopted for the proposed design. The high bows with a moderate slope of the stem-post of the Payang fishing boat, which is effective when passing through surf waves, was applied. Moreover, the trend of the sheer line from the same type of vessels was applied for the proposed design to mimic the aesthetic aspect of the basis vessel, in addition to obtaining the requirement of a relatively low deck at the aft of the proposed boat to accommodate the effective fishing activities, particularly for hauling the nets.

As an input for the design process regarding the lines plan, the total weight of the vessel was initially estimated with the intention of identifying the required displacement for the proposed vessel. This preliminary weight calculation is the best weight estimation pertaining to the vessel's structure, main engine and general equipment, fishing

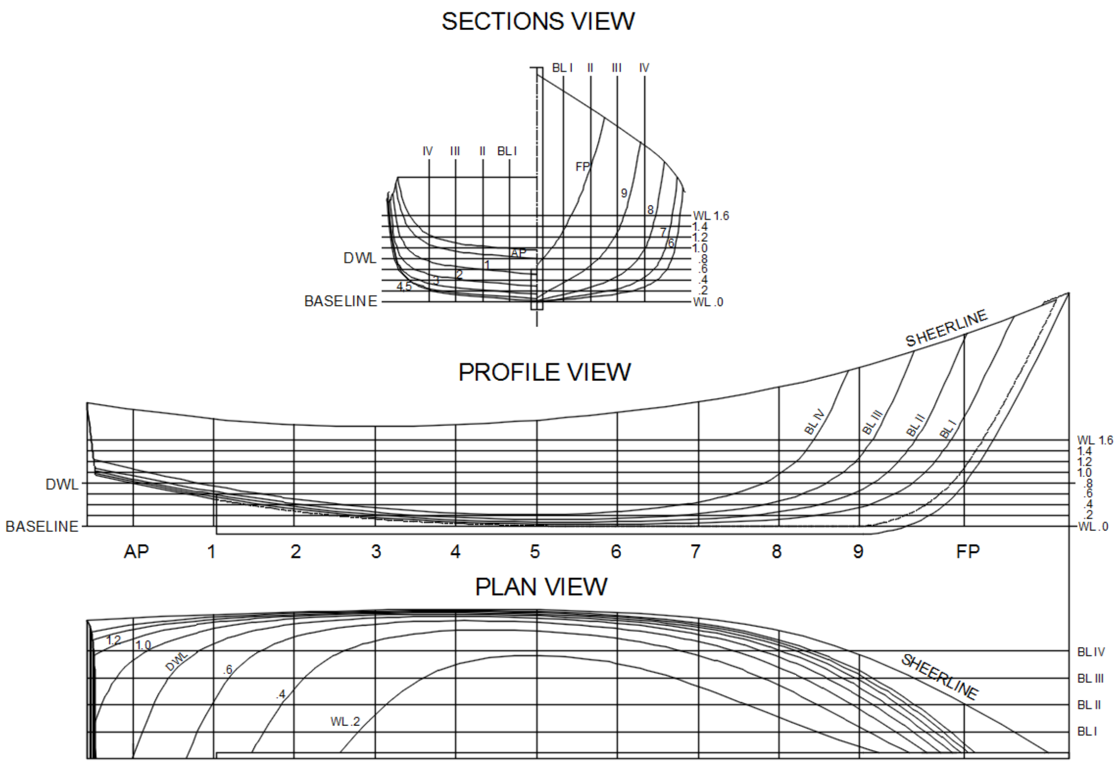


Figure 9.6 Lines plan of the proposed fishing vessel

equipment, crew and their luggage, consumables (both fuel and fresh water) and maximum anticipated fish catches. The initial estimation in relation to the total weight of the proposed design was based on the assumption that the craft will be operated by 15 crew members, fishing for a limit of 7 days, with a maximum catch of 10 tonnes of fish. Additionally, the calculation of the weight of the vessel's structure considered wood as being the most appropriate construction material.

The rough calculation for the estimated weight of the proposed vessel established that the heaviest weight condition occurs during the start of the return to the home port condition. In this case, the fish holds are filled with 10 tonnes of fish in bulk with 5 tonnes of ice, while consumables remain at 20% of the total outward-bound demand for a 7 day trip. Thus, the total weight for this particular condition is 30.4 tonnes.

By using the free hand sketch of the hull in the preliminary GA as an input, the lines plan of the proposed vessels was developed by using the modelling software known as MAXSURF Modeller. The result of this stage is presented in Figure 9.6, while the drawing containing the proper scale is attached in *Appendix C-2.*

By using MAXSURF Stability software, the hydrostatic data of the proposed design for several draught conditions were obtained and can be noted in Table 9.3. This

Table 9.3 Hydrostatic data for the proposed fishing vessel

No	Measurement	Draught Amidships (m)			
		0.200	0.400	0.600	0.800
1	Displacement (tonnes)	3.221	10.440	20.440	32.480
2	WL Length (m)	13.229	13.513	14.303	15.458
3	Beam max. extents on WL (m)	3.842	4.784	5.122	5.277
4	Wetted Area (m^2)	32.442	51.006	64.104	75.660
5	Waterplane area (m^2)	26.112	42.918	54.201	62.809
6	Prismatic coefficient (Cp)	0.492	0.558	0.598	0.610
7	Block coefficient (Cb)	0.177	0.286	0.363	0.409
8	Max. Section area coeff. (Cm)	0.363	0.519	0.616	0.678
9	Waterplane area coeff. (Cwp)	0.514	0.664	0.740	0.770
10	LCG from zero point (m)	7.261	7.261	7.261	7.261
11	LCB from zero point (m)	8.308	8.048	7.793	7.551
12	LCF from zero point (m)	8.203	7.729	7.331	6.963
13	KB (m)	0.104	0.245	0.372	0.494
14	KG (m)	1.205	1.205	1.205	1.205
15	BMt (m)	6.820	5.941	4.604	3.658
16	BML (m)	48.674	36.029	30.502	27.315
17	GMt (m)	5.719	4.981	3.771	2.947
18	GML (m)	47.573	35.069	29.669	26.605
19	KMt (m)	6.924	6.186	4.976	4.152
20	KML (m)	48.778	36.274	30.874	27.810
21	TPc (tonne/cm)	0.268	0.440	0.556	0.644
22	MTc (tonne.m)	0.099	0.237	0.393	0.560

hydrostatic data indicates that the displacement of the proposed vessel is 32.46 tonnes at its designed load line, 0.8 meters, and it fulfils the minimum requirement regarding the displacement to cover the maximum weight of the vessel during its operation.

9.5.5 Technologies incorporated on-board

By considering the results from the selection of sustainable technologies for the selected fishing community in Chapter 7, in addition to the results of the fishers' requirements and the observation of local conditions, the selected technologies for the proposed design regarding the main engine, electricity sources and fish preservation are as follows:

a) Main engine

The results of the assessment concerning powering, as discussed in Chapter 7, if the social aspect is prioritised, demonstrated that the ranking for the alternative main engines in Muncar are respectively: non-marine diesel engine, an engine operated on LPG, electric hybrid motor, and marine diesel engine. However, if the three aspects of sustainability are considered at the same level, the ranking will be in the following order: electric hybrid motor, an engine run on LPG, marine diesel engine, and non-marine diesel engine.

It is suggested that whatever type of engine is selected, that an inboard engine type will be installed, in preference to an outboard engine with a long shaft propeller, as are used in existing local boats. In addition to the efficiency aspect, as a more effective thrust to the vessel can be obtained with a more appropriate propeller shaft angle, reasons associated with the stability and safety of the vessel and also the impact of the heavy weight of the engine high up on the hull structure justify the decision to install an inboard engine instead of an outboard engine coupled with a long shaft propeller. In order to overcome the local fishers concern about the nets getting caught in the propeller, a watertight access to the propeller from the after peak compartment was provided, to enable the propeller to be freed from inboard.

In terms of the actual type of engine to be employed on the proposed vessel, by considering the efficiency and feasibility of the local supply chain for alternative main engines and possible improvements and adaptations, which can be achieved by experience based capacity building by local fishers in the near future, it is considered that an inboard marine diesel engine could be installed. Moreover, based on the results of the cost analysis and environmental impact assessment, the marine diesel engine was the second on the rank.

The engine power required for the fishing vessel is influenced by the type of fishing gear that is operated on-board. According to local fishers, vessels that operate purse seine require a minimum speed of 8 knots in order to chase shoals of fish, while boats with passive fishing gears can be operated at a slower speed simply in order to reach the fishing ground. Based on these references, the proposed craft is targeted to have a normal operating speed of 10 knots. The MAXSURF Resistance software revealed that in order to achieve that particular speed, the proposed vessel should have a minimum power of 80hp. Considering that 80hp, which is required for the proposed vessel, is normally referenced to 80% of the Maximum Continuous Rating of the engine, then a 115hp Yanmar engine 6CHE3 was selected to be installed in the proposed vessel.

b) Sources of electricity

For electricity power for the proposed design, if the vessel requires only a little power for the cabin, for lighting in working areas and for navigation lights, then based on the results of the assessment, solar panels are the most appropriate option when considering the three pillars of sustainability. Therefore, for this circumstance, the electricity in this vessel is supplied by 3 solar panels of 100WP each the output of which is stored in 4 battery units of 200Ah 12 volts. This system will provide 100 watts, on average, of electricity for lighting and other basic electronic devices on-board, for roughly 10 hours per 24 hour period.

According to the results of the assessment on alternative larger electricity sources, discussed in Chapter 7, for the both assumptions of levels of important, an electricity generator that runs on LPG is the main choice for Muncar, followed by an alternator coupled with a diesel engine and finally a genset operating on petrol.

By taking into account the fact that the electricity generator that functions on LPG has become available on the Indonesian market at an affordable price and moreover, that this is in line with the government’s programme to convert petrol fuel powered machinery to LPG, it is suggested that a generator run on LPG be also employed on the proposed vessel. However, the local government will need to ensure that there is no problem with the LPG supply chain or of its cost in the local region.

c) Fish preservation

The results of the assessment of the alternative fish preservation methods, as discussed in Chapter 7, demonstrated that, for the both assumptions of levels of important, block ice is still the principal choice on-board, followed by an ice machine on-board and then a freezer. For that reason, fish preservation method with block ice is employed for the proposed vessel. Additionally, in order to have an enhanced fish preservations systems, the design of the fish holds for the proposed fishing vessel was completed with proper insulations and partitions.

The weakness of the existing fishing boats concerning their fish preservation is mainly related to the poor level of insulation that reduces the shelf life of the ice. In order to maintain the low temperature in the fish hold and reduce the percentage of melted block ice, a minimum of 100mm of polyurethane insulation will be attached between the hull structure and the fish hold (Fyson, 1985)

Furthermore, a drawback of the typical fish hold in existing fishing vessels is that the hold space extends between the port and starboard side. The risk of a relatively large free surface, due to fish or melted ice reducing the stability of the vessel is high. Although the fishers will continuously reduce the amount of water inside the fish hold by simply pumping it out, there is still the danger from the fish itself. Therefore in order to reduce this free surface problem, the fish holds were divided by a centreline longitudinal bulkhead into a starboard fish hold and a port fish hold, thus resulting in 6 individual fish holds as seen in Figure 9.7.

9.5.6 General Arrangement

For the General Arrangement (GA) design stage, three slightly different GAs were designed, all using an identical hull. The differences among these three designs are regarding the layout and the form of the cabins and the wheelhouse. The three different types of cabin and wheelhouse along with the layout gave the local fishers more choices in connection with the proposed designs. One design of the proposed GA can be seen in Figure 9.7, while the final GA design prepared on a proper scale can be seen in *Appendix C-2*

The final developed volume regarding the combined fish hold compartments is 16.7 m^3. It can carry a load of 15 tonnes of mixed fish and ice flakes in a ratio of 2:1. The total volume of the fuel tank is 5.3 m^3, which represents 4.5 tonnes of diesel fuel. This is

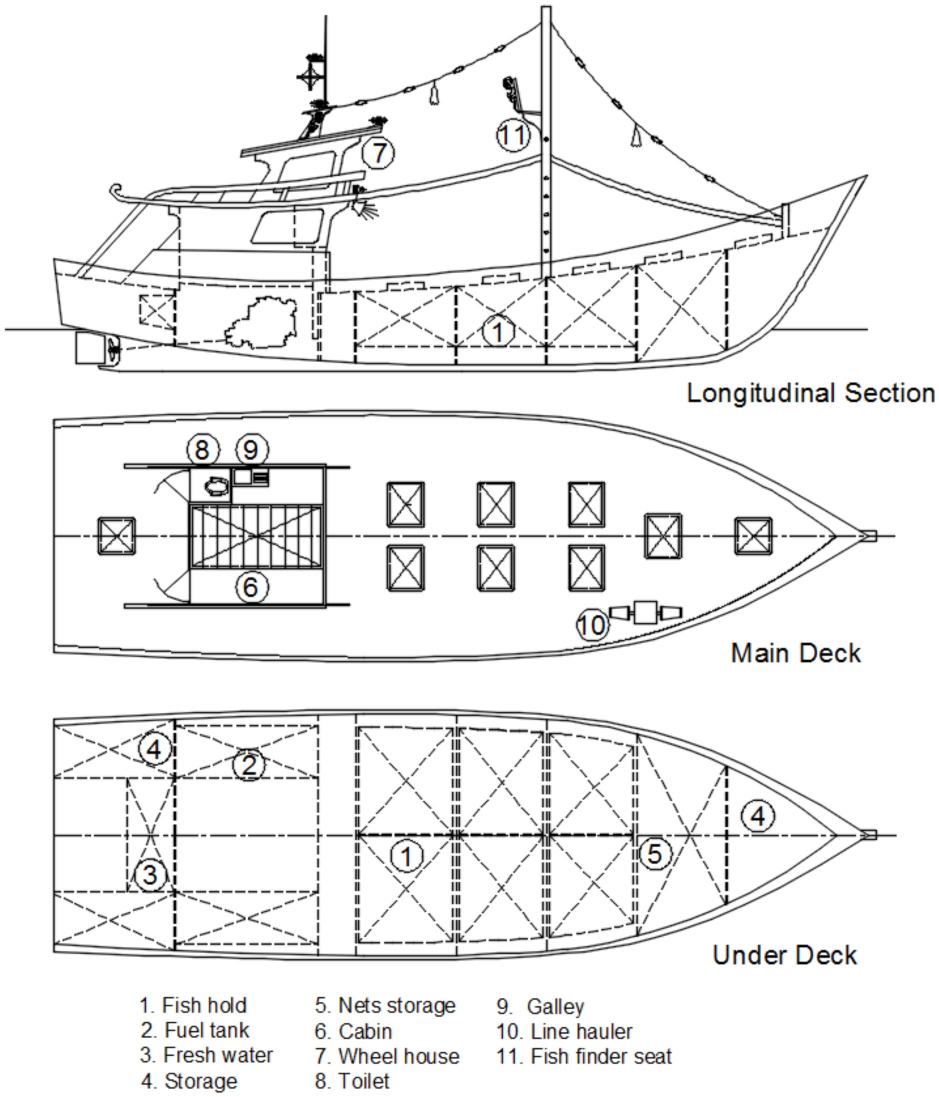


Figure 9.7 One of the General Arrangement of the proposed design

more than sufficient for a 7 day fishing trip for which approximately 3.4 tonnes of fuel is required. While the main fresh water tank has a volume of 1.5 m^3 and can thus hold 1.5 tonnes of water where roughly 1.2 tonnes of fresh water is required for a 7 day fishing trip. Of this amount, 1 tonne of fresh water will be carried in the main tank, while an additional 0.2 tonnes will be stored in a small daily tank that is situated on the second deck.

The following three figures, Figure 9.8 to Figure 9.10, illustrate the three different topside designs of the proposed fishing boat. The colouring on these proposed 3D designs was added merely to provide the local fishers with a graphic overview of the final appearance of the proposed designs and are not necessarily the colours of the final design.

Figure 9.8 The first design version of the proposed fishing vessel

The first design, as seen in Figure 9.8, copied the profile of the wheelhouse and the stern part from the current local Payang fishing boats. The wheelhouse is placed towards the aft end of the cabin top and, similar to the local design, access to this wheelhouse is from the forward side. In this first proposed design there is no direct access from the wheelhouse down to the inside of the cabin underneath; access down to the main deck is via the ladder adjacent to the cabin top. The galley and the toilet are situated in the open area at the aft end of the stern. The galley is in relative open space; nevertheless, it is protected from the sun and the rain by its position below the second deck. It is the same with regards to the toilet, which is located next to the galley and covered by a partition that is approximately a metre in height.

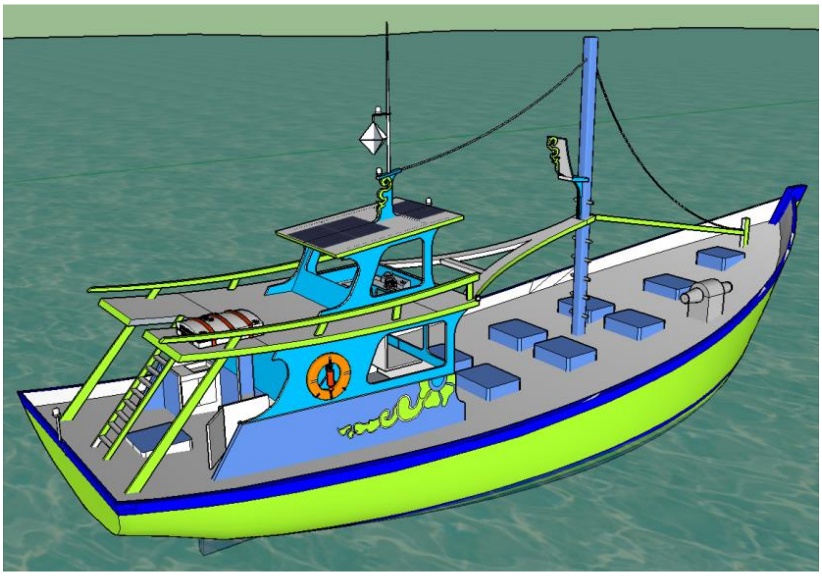


Figure 9.9 The second design version of the proposed fishing vessel

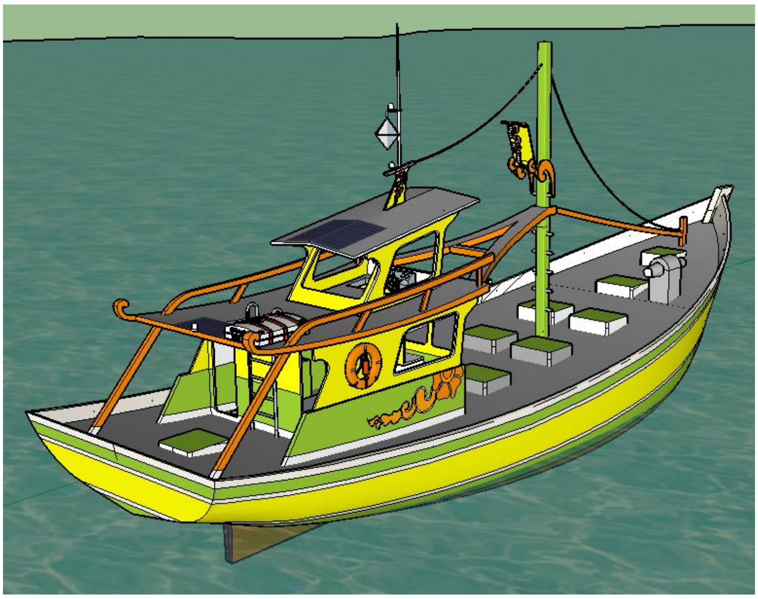


Figure 9.10 The third design version of the proposed fishing vessel

For the second alternative design, as illustrated in Figure 9.9, the wheelhouse is placed at the front end of the second deck, and offers the skipper an improved view of the working deck area. The idea for this wheelhouse was adopted and modified from a traditional fishing vessel in Brondong, East Java. With this design of wheelhouse, the skipper is able to stand on the platform that is fitted inside the cabin, at a position of roughly half the cabin height from the main deck. With this arrangement, the skipper has easy access to the cabin underneath. The galley and the toilet are placed at the stern, adjacent to the back door of the cabin.

The third proposed design, as illustrated in Figure 9.10, has a wheelhouse in a similar position to the second design and is connected to the inside cabin below. Furthermore, instead of placing the galley and toilet outside the cabin, the third design has both the toilet and galley located inside the cabin.

9.5.7 Construction details

A problem inherent in traditional wooden fishing vessels, as described in the previous chapter, is related to the relative poor structures of the current vessels (Dijkstra and Schutter, 1995; Rosyid and Johnson, 2005; Davy, 2006; Savins and Lee, 2006). Moreover, given that the structures of the traditional fishing vessels are built on hereditary knowledge; thus, there is no formal standard that is used with regards to the scantlings of the vessels’ component structures. In order to obtain an appropriate level of integrity of the hull structure that ensures the strength, water tightness and safety of the vessels, the proposed structure of the fishing vessel has been designed based on the

Indonesian Classification Bureau (Biro Klasifikasi Indonesia, BKI) guidelines. However, as suggested by the *Code of Conduct for Responsible Fisheries* of the FAO, other established formal standards can be adopted if the criterion is not available locally; therefore, for those structures and components that are not covered by the BKI, the UK standard issued by the Sea Fish Industry Authority (SFIA) regarding fishing vessels from 15 to 24 metres in length has been adopted.

As described in the previous section, the construction material that is to be used for this proposed design is wood. Nevertheless, seeing as there is a relatively high potential for implementing FRP for the hull in the future in Muncar fishing community, the proposed design also has an alternative FRP structure as well. The rules applied for the proposed structures are BKI Volume VI/1996 for wooden boats and BKI Volume VII/2013 for small vessels up to 24 metres in length for FRP boats.

Compared to the structure of the current local fishing vessels, the construction of the proposed new design applied a modern structural arrangement standard for boats that have proper transverse and longitudinal internal structural. Although most local boat builders have no competencies in building such a wholly different structural form and moreover, have no experience of constructing boats based on a formal design drawing that is to be followed, there is still an opportunity to apply the modern structure approach with regards to the proposed design. The observations made during the field study revealed that over the last few years, a number of local boat builders have been involved in a government project in constructing 30GT wooden fishing boats in a relatively modern boat yard, approximately 15 km from Muncar village. This group of local boat builders has been trained to construct boats using more modern methods and structures, based on the design drawings. According to the boatyard, the excellent skills of traditional boat builders in working with wood, for example in bending the wood planking, meant that there were relatively no difficulties in relation to this transfer of skills to the new technology.

Nonetheless, there are several problems that may occur pertaining to the alternative proposed FRP fishing vessel. There are no boatyards capable to build FRP boats in Muncar and the competencies that are required to construct such vessels are entirely different to the skills of local wooden boat builders. With respect to this problem, local boatyards and boat builders require considerable capacity building in order to construct FRP boats.

Table 9.4 Summary of the scantling for the structure for the proposed wooden fishing vessel

No	Structural Member	Scantling	Remarks
1	***Keel*** - Total sectional area (cm^2) - Siding (mm) - Moulded (mm) ***Keelson*** - Siding (mm) - Moulded (mm)	 831 200 250 400 100	- Rule: BKI 1996, Sec.4.1 - Minimum density of wood 0.7 tonnes/m^3
2	***Stem-post*** - Siding (mm) - Moulded (mm)	 200 300	- Rule: BKI 1996, Sec.4.2 - Minimum density of wood 0.7 tonnes/m^3
3	***Stern-post*** - Siding (mm) - Moulded (mm)	 200 320	- Rule: BKI 1996, Sec.4.2 - Minimum density of wood 0.7 tonnes/m^3
4	***Transverse frame*** - Spacing (mm) - Siding (mm) - Moulded (mm)	 400 90 135	- Rule: BKI 1996, Sec.4.3 - Minimum density of wood 0.70 tonnes/m^3
5	***Floor*** - Minimum height of floor (mm) - Thickness	 200 90	- Rule: BKI 1996, Sec.4.4 - Minimum density of wood 0.70 tonnes/m^3 - The height of the floor is measured from the top side of the keel - The length of the floor is a minimum of 0.4 x breadth at related position)
6	***Bilge stringers*** - Siding (mm) - Moulded (mm)	 260 70	- Rule: BKI 1996, Sec.4.5 - Minimum density of wood 0.45 tonnes/m^3
7	***Beam stringers*** - Total sectional area (cm^2) Main beam stringer - Siding (mm) - Moulded (mm) Lower beam stringer - Siding (mm) - Moulded (mm)	 295.5 80 250 60 120	- Rule: BKI 1996, Sec.4.6 - Minimum density of wood 0.56 tonnes/m^3
8	***Hull planking*** Side plank and bottom plank - Thickness (mm) - Width (mm) Garboard and sheer strake - Thickness (mm)	 50 200 60	- Rule: BKI 1996, Sec.4.8 - Minimum density of wood 0.56 tonnes/m^3 - Minimum width of the garboard is 521 mm
9	***Deck beam*** - Spacing (mm) - Siding (mm) - Moulded (mm) For engine casing position - Siding (mm) - Moulded (mm)	 400 90 130 180 150	- Rule: BKI 1996, Sec.4.7 - Minimum density of wood 0.56 tonnes/m^3
10	***Deck planking*** Deck plank - Thickness (mm) - Width (mm) Margin plank - Thickness (mm)	 50 100 60	- Rule: BKI 1996, Sec.4.9 - Minimum density of wood 0.45 tonnes/m^3 - Minimum width of the margin plank is 260 mm

Based on the selected main dimensions of the proposed design, the scantling of the designed structure were identified. A summary of the scantling for the wooden boat structural members is presented in Table 9.4, while the summary of the design and scantling of the FRP boat structure and the method used to calculate the scantling are attached in *Appendix C-1*.

By considering the above minimum required scantlings, the boat structure has been designed. Figure 9.16 in section 9.7 showing the final proposed design illustrates the transverse section of the mid-ship structures for the proposed wooden fishing vessels, whereas the other structures in wood and FRP are presented in *Appendix C-2.*

9.5.8 Intact stability

In order to ensure that the proposed fishing vessel can perform its mission tasks safely in every type of condition during its fishing trips, the stability of the proposed vessel has been assessed. For this purpose, design software known as MAXSURF Stability was employed to assess the stability of the proposed craft. The inputs for this assessment are the lines plan of the proposed vessel as designed by MAXSURF modeller in the previous stage and a selection of loading scenarios that represent potential fishing conditions regarding the proposed vessel.

Subsequently, in order to justify whether or not the proposed vessel fulfils the criterion necessary to guarantee the stability of the fishing vessels, the stability criteria for decked fishing vessels based on the FAO/ILO/IMO Voluntary Guidelines for the Design, Construction and Equipment of Small Fishing Vessels, 2005, was applied as an authoritative reference.

The loading scenarios for the stability assessment of the proposed vessel are based on the assumption that the vessel goes out fishing for 7 days and that it is operated by 15 crew members. The purse seine nets is employed on-board and is stored when not being used on the portside of the weather deck following local practice. Based on these assumptions, four different loading scenarios are established, which include the vessel proceeding out to the fishing ground; the boat returning with full catches to the home port; the craft cruising in a light displacement condition and the boat hauling in the nets. The distribution of weights on-board along the length of the proposed vessel for the four scenarios can be seen in Figure 9.11.

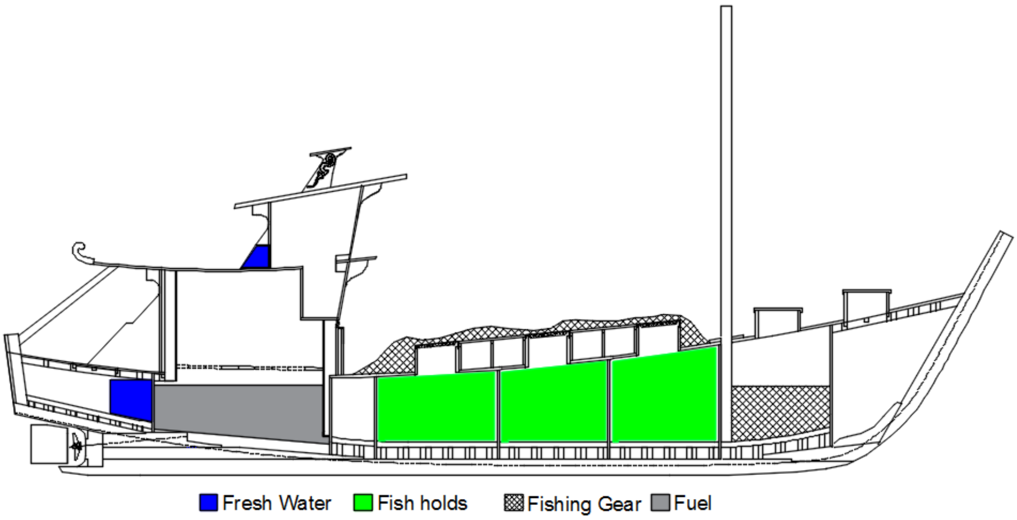


Figure 9.11 Load distributions in the proposed fishing vessel

In the first scenario, the vessel is leaving the home port with 100% consumables in the storage tanks. At the same time the fish holds are filled with 10 tonnes of block ice spread relatively evenly in the three fish holds. In this case, the blocks of ice are assumed to be in a solid condition; consequently, for this scenario, the water Free Surface Moment (FSM) in the fish holds is neglected. The weight and distribution of the load for the first scenario can be observed in Table 9.5.

The returning to home port scenario is based on the assumption that the proposed vessel will leave the fishing ground with the fish holds filled with the maximum target capacity of 10 tonnes of fish, which is mixed with a residual mass of 5 tonnes of crushed ice. The effect of the free surface in the fish holds, as the effect of fish and melted ice, was considered in this scenario. Furthermore, the consumables for this scenario are assumed to be down to 20% of the departure conditions. The load distribution for the second scenario can be seen in Table 9.6.

Table 9.5 Load distribution for on departure condition

No	Item Name	Quantity	Unit Mass (tonne)	Total Mass (tonne)	Long. Arm (m)	Trans. Arm (m)	Vert. Arm (m)	Total FSM (tonne.m)
1	Lightship	1	14.167	14.167	7.261	0.040	1.202	0.000
2	Fish hold	1	10.000	10.000	8.796	0.000	0.519	0.000
3	Fuel	1	3.400	3.400	3.501	0.000	0.980	0.622
4	Fresh water	1	1.400	1.400	1.749	0.000	1.474	0.281
5	Crew	15	0.060	0.900	2.829	0.085	2.301	0.000
6	Fishing gears	1	0.500	0.500	8.912	-2.250	1.800	0.000
7	Luggage	15	0.002	0.030	4.842	0.000	2.000	0.000
8	Provisions	15	0.010	0.150	1.182	1.900	1.150	0.000
	Total			**30.579**	**6.959**	**-0.006**	**1.008**	**0.903**
	FS correction						**0.030**	
	VCG fluid						**1.038**	

Table 9.6 Load distribution for beginning the return to the fishing port

No	Item Name	Quantity	Unit Mass (tonne)	Total Mass (tonne)	Long. Arm (m)	Trans. Arm (m)	Vert. Arm (m)	Total FSM (tonne.m)
1	Lightship	1	14.167	14.167	7.261	0.040	1.202	0.000
2	Fish hold	1	15.000	15.000	8.556	0.000	1.041	3.429
3	Fuel	1	0.680	0.680	3.667	0.000	0.707	0.360
4	Fresh water	1	0.280	0.280	1.483	0.000	0.843	0.244
5	Crew	15	0.060	0.900	2.829	0.085	2.301	0.000
6	Fishing gears	1	0.500	0.500	8.912	-2.250	1.800	0.000
7	Luggage	15	0.002	0.030	4.842	0.000	2.000	0.000
8	Provisions	15	0.002	0.030	1.182	1.900	1.150	0.000
	Total			**31.631**	**7.640**	**-0.013**	**1.153**	**4.033**
	FS correction						**0.128**	
	VCG fluid						**1.281**	

The central activities during the middle of a fishing trip are setting and hauling in the nets; for that reason, the third scenario is related to these activities. In this third scenario, the vessel is assumed to be in the hauling process with a total load of 1 tonnes; which represents the nets with the fish catches, hung between the crane and the bulwark. Furthermore, the fish holds have already loaded to 90% of the maximum catches targeted and with only 20% of fuel and fresh water still remaining in the storage tanks. Seeing as the boat is in the hauling state, all 15 crew members will be on one side of the vessel. The list of loads and their distribution for the third scenario can be seen in Table 9.7.

The final scenario selected for the stability assessment regarding the proposed vessel is the light displacement condition. In this scenario, the proposed vessel cruises with no load in the fish holds and only carries fuel, fresh water and provisions amounting to 20%. Table 9.8 demonstrates the load and its distribution for the last scenario.

Table 9.7 Load distribution during hauling the net

No	Item Name	Quantity	Unit Mass (tonne)	Total Mass (tonne)	Long. Arm (m)	Trans. Arm (m)	Vert. Arm (m)	Total FSM (tonne.m)
1	Lightship	1	14.167	14.167	7.261	0.040	1.202	0.000
2	Fish hold	1	13.515	13.515	8.276	0.000	1.046	3.303
3	Fuel	1	0.680	0.680	3.667	0.000	0.707	0.360
4	Fresh water	1	0.280	0.280	1.483	0.000	0.843	0.244
5	Crew	15	0.060	0.900	9.029	-2.332	2.703	0.000
6	Luggage	15	0.002	0.030	4.842	0.000	2.000	0.000
7	Provisions	15	0.002	0.030	1.182	1.900	1.150	0.000
8	50% load of catches on crane	1	0.500	0.500	9.001	-3.722	4.332	0.000
9	50% load of catches on bulwark	1	0.500	0.500	9.001	-2.750	1.800	0.000
	Total			**30.602**	**7.693**	**-0.181**	**1.232**	**3.907**
	FS correction						**0.126**	
	VCG fluid						**1.358**	

Table 9.8 Load distribution for lightship condition

No	Item Name	Quantity	Unit Mass (tonne)	Total Mass (tonne)	Long. Arm (m)	Trans. Arm (m)	Vert. Arm (m)	Total FSM (tonne.m)
1	Lightship	1	14.167	14.167	7.261	0.040	1.202	0.000
2	Fish hold	1	0.000	0.000	0.000	0.000	0.000	0.000
3	Fuel	1	0.680	0.680	3.667	0.000	0.707	0.360
4	Fresh water	1	0.280	0.280	1.483	0.000	0.843	0.244
5	Crew	15	0.060	0.900	2.829	0.085	2.301	0.000
6	Fishing gears	1	0.500	0.500	8.912	-2.250	1.800	0.000
7	Luggage	15	0.002	0.030	4.842	0.000	2.000	0.000
8	Provisions	15	0.002	0.030	1.182	1.900	1.150	0.000
	Total			**16.587**	**6.810**	**-0.026**	**1.255**	**0.604**
	FS correction						**0.036**	
	VCG fluid						**1.291**	

These four scenarios pertaining to the loads and their distribution subsequently are used as the input for the individual load case in MAXSURF Stability software. The results of the stability assessment of these four scenarios are illustrated in Figure 9.12 and Table 9.9. Figure 9.12 reveals the righting lever (GZ) curve, where each line in this graph represents the GZ value of each operational scenario for every degree of vessel heeling to starboard.

Based on the GZ curve given in Figure 9.12, the maximum GZ for each scenario and the area under the GZ curve for a certain degree of vessel heeling are identified. The results are subsequently compared to the stability criteria for decked fishing vessels based on the FAO/ILO/IMO Voluntary Guidelines, as presented in Table 9.9.

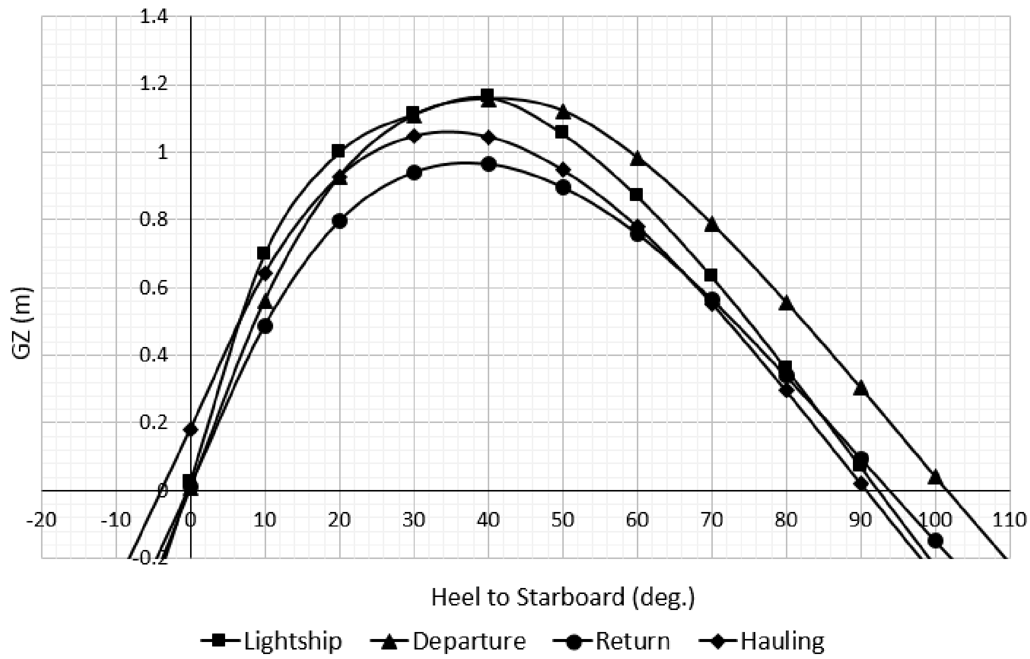


Figure 9.12 GZ curve for the four operational scenarios

Table 9.9 Criteria for the intact stability of small fishing vessels and the results from the proposed vessels stability assessments

No	Stability Value	Criteria	Departure	Return	Hauling	Lightship
1	Area under the curve 0°-30° (m-rad)	≥ 0.055 m-rad	0.364 (Pass)	0.313 (Pass)	0.387 (Pass)	0.405 (Pass)
2	Area under the curve 0°-40° (m-rad)	≥ 0.090 m-rad	0.563 (Pass)	0.481 (Pass)	0.571 (Pass)	0.605 (Pass)
3	Area under the curve 30°-40° (m-rad)	≥ 0.030 m-rad	0.199 (Pass)	0.168 (Pass)	0.184 (Pass)	0.200 (Pass)
4	GZ at angle of heel ≥ 30^0	≥ 0.200 m	1.107 (Pass)	0.939 (Pass)	1.045 (Pass)	1.112 (Pass)
5	GZ max (m)		1.157	0.957	1.058	1.163
6	Angle where GZ max occurs	≥ 25^0	40.9^0 (Pass)	37.3^0 (Pass)	34.5^0 (Pass)	39.1^0 (Pass)
7	Initial metacentric height (GM)	≥ 0.350 m	3.387 (Pass)	2.894 (Pass)	2.838 (Pass)	4.503 (Pass)
8	The point of vanishing stability	> 70^0	102^0 (Pass)	94^0 (Pass)	91^0 (Pass)	92^0 (Pass)

By considering the result given in Table 9.9, it can be concluded that the stability of the proposed fishing vessel fulfils the minimum criteria.

9.6 Focus Group Discussion on the Proposed Designs

As described in Chapter 4, in order to obtain the fishers' opinions and feedback related to the proposed vessels prior to finalising the arrangement of the design, Focus Group Discussions (FGDs) were conducted in both the Muncar and Brondong fishing communities. Three groups of fishers were involved during the discussion in Muncar, while only one group of fishers participated during the FGD in Brondong. Additionally, mock-ups of the three proposed designs, as illustrated in Figure 9.13, were built to

Figure 9.13 Mock-up of three proposed designs for the FGD

Figure 9.14 FGD participants in Muncar using the scaled models to discuss the layout of the deck and associated equipment

provide the participants with a better physical idea regarding the shape and layout of the vessel.

In each FGD conducted in Muncar and Brondong, the participants were actively involved in reviewing and commenting on the proposed vessels. The discussions were very constructive and were greatly assisted by the mock-up boats, as seen in Figure 9.14.

The results of the FGD showed positive responses from the participants related to the proposed designs. In Muncar, all the FGD participants agreed that the shape of the hull was appropriate for both their traditional and potential new fishing grounds. According to the participants, the main profile of the proposed vessel, including the slope of the bow, the shape of the deck sheer line, in addition to the shape of the stern are excellent. They also liked the design of the wheelhouses, in particular the wheelhouse that has access to the main cabin and a good view of the working areas (Figure 9.9 and Figure 9.10). Additionally, the respondents offered feedback during the FGD, in order to enhance the proposed design.

The feedback included the following suggestions below:

1. FGD participants commented that they require more space for the working area and storage of the nets between the deck side and the fish hold hatchway, if they operate purse seine. Therefore, they suggested that there is only one line of hatchways in the centreline of the deck, thus giving more easy movement and more working space.

2. Participants confirmed that they require a fish finder seat. The proposed fish finder seat is ideal for the skipper; its height from the main deck is adequate, and it only needs a simple roof to avoid the strong sun and rain during fishing trips.
3. The size of the cabin and wheelhouse is faultless; nevertheless, participants would like more access to the cabin, principally to provide the skipper with easy access from the wheelhouse to the working area. Moreover, participants proposed a sliding window in order to ventilate the cabin more and to provide the skipper with a better view of the main deck from the wheelhouse.
4. The participants insisted that the height of the bulwark should not be more than 200mm, if they operate purse seine, particularly in the areas for hauling and deploying the nets. The height of the bulwark could be higher, however, if the boat operates only passive fishing gears such as gillnets or handlines.
5. All the participants accepted the presence of the galley and toilet on-board. However, they prefer to have the galley and toilet located outside the main cabin and with a reasonable amount of open space.
6. There was a debate regarding what type of engine should be incorporated in the proposed design. Several participants suggested that an outboard engine with a long shaft propeller was installed for the proposed design, if the vessel operates purse seine; whereas a number of participants that have experience of inboard engines believed that an inboard engine would be more appropriate for the proposed design.

Surprisingly, FGD participants in Brondong also demonstrated a positive response to the proposed design, even though the initial design of the proposed design had not involved local fishers from this community. The hull shape of the proposed design is entirely different to the local Ijon-ijon design, which has a high block coefficient form. However, the local fishers' interest in the recently introduced fishing vessels from

Figure 9.15 Newly introduced fishing vessel from Kalimantan (left) and locally designed Ijon-ijon from Brondong (right)

Kalimantan Island, as shown in Figure 9.15, affected the Brondong respondents' responses in relation to the proposed design. Local fishers in Brondong found that the shape of the hull of the fishing vessels from Kalimantan Island, which is slimmer than the local design, made the vessel faster and consumed less fuel. Respondents' positive response to the proposed design was as a result of their interest in the slimmer hull shape.

For the FGD participants in Brondong, the arrangement of the cabin and wheelhouse is another attraction relating to the proposed design; in fact the arrangement of the wheelhouse in the proposed design (Figure 9.9 and Figure 9.10) was actually modified from the concept of the wheelhouse in one of the local designs seen in Brondong.

Regarding the choice of main engine, and in contrast to the preferences of the participants in Muncar, and given that the inboard engine has been implemented in local Brondong boats for several decades, no particulars comments were made concerning the inboard engine that is installed in the proposed design.

According to participants in Brondong, the only aspect that is not necessary for their needs in the proposed boat is the fish-finder seat for the skipper. Local fishers have never used this feature in order to detect shoals of fish; instead the application of an electronic fish finder device is relatively common in this community.

At the conclusion of the FGD in Brondong, based on the current situation in their fishing community regarding the increase in operational costs pertaining to fishing, participants believed that the proposed design will have the potential to be implemented in their region in the future.

9.7 Final Proposed Design

The three proposed designs were presented to local fishers in Muncar, where the final recommended new fishing boat is targeted to be operated. Positive responses were demonstrated by the FGD participants and considerable feedback was obtained, with the intention of refining and enhancing the final design. As the main concern for developing the proposed vessel is in ensuring the acceptability of the boat, participants' feedback during the FGD in Muncar was used to revise the proposed design. However, by considering potential improvements to the current fishing vessels, in addition to the attempt to increase the implementation of responsible fishing practices among the local

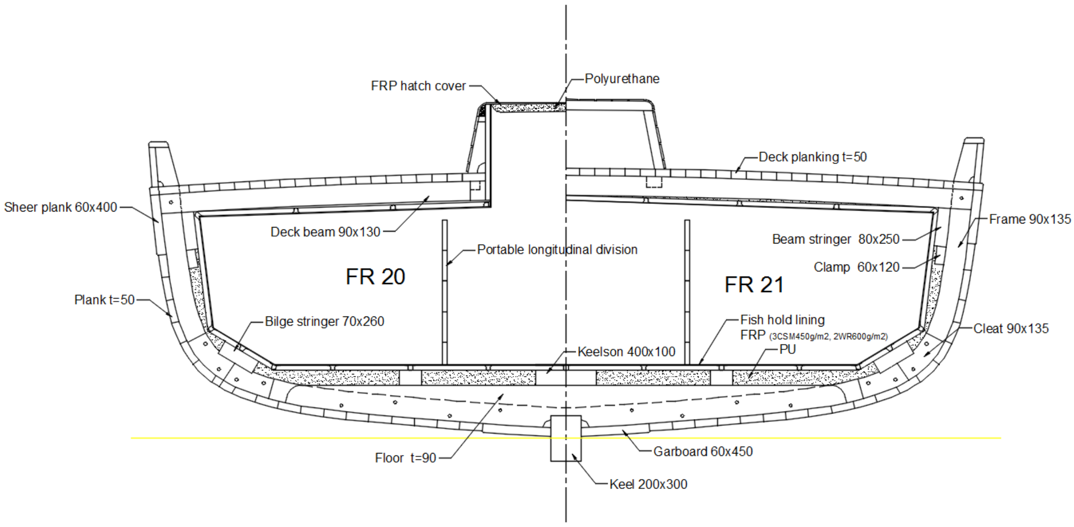


Figure 9.16 The final structure of the mid-ship section of the proposed wooden fishing vessel

fishers in Muncar, many aspects were taken into account when the proposed boat was being revised.

Participants' concern with regard to adding more space in the working area and their suggestion to have only one line of hatchways have been implemented by rearranging the fish holds. The previous longitudinal bulkhead along the centreline of the overall fish hold to create port and starboard side holds has been removed in order to allow a single hatchway positioned on the centreline of the main deck. However, to minimise the effect of free surface in the larger fish holds, as a consequence of the removal of the longitudinal bulkhead, two portable longitudinal divisions are attached, as seen in Figure 9.16. In practice, the space between the partitions in the centreline of the fish

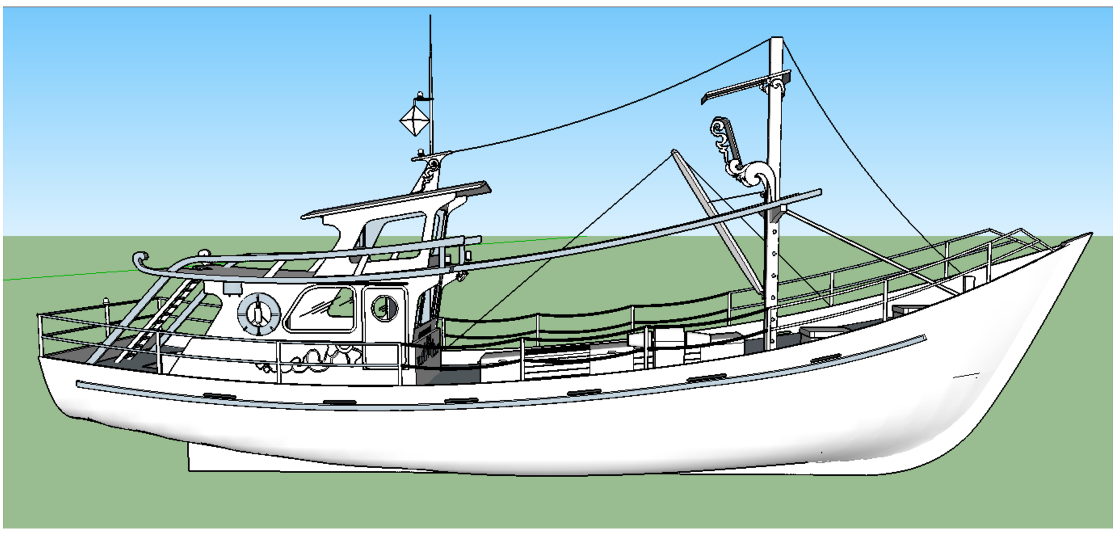


Figure 9.17 Final design of the recommended fishing vessel for the Muncar fishing community

hold also functions as a working space to load the catches into both side compartments of the fish hold, prior to this space in the centreline then being filled with fish.

Concerning the fish finder seat for the skipper, in order to protect the skipper from the strong sun and rain, a folding roof is attached to the main mast above the fish finder seat, as seen in Figure 9.17.

It is worth mentioning that the fishers asked for more access to the cabin; consequently, two sliding doors were added one on each side of the cabin, in addition to a single access to the galley area on the stern part of the vessel, as seen in Figure 9.17. By considering the standard in relation to the height of coamings for access to the cabin form the weather deck, the height of the coaming for these sliding doors is 460 mm.

The fishers' request to have hatchway coamings with a lower height is based on their concerns that the nets can easily become stuck in the hatchway if it is too high. According to SFIA guidelines, a lower hatchway coaming height can be implemented as long as the water-tightness of the hatch cover can be ensured. By considering the local fishers' awareness of safety on-board, the idea to employ lower hatchway coamings with a watertight cover system could be incorrectly maintained by local fishers. Therefore, a hatchway with the standard minimum coaming height of 460 mm was employed. However, in order to minimise the possibility of the nets becoming jammed in the hatchway, the spaces between the hatchways are covered by wood gratings that permit the nets to slide past these spaces, yet still allows the water to pass through the wood grating. Moreover, the sharp edges of the hatch-covers are reduced by making them more rounded, as shown in Figure 9.18.

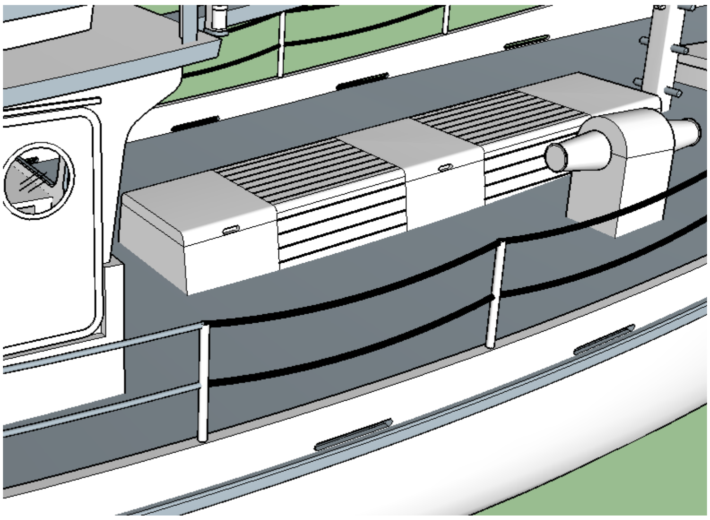


Figure 9.18 New arrangement of the hatchways and gratings for the final proposed design

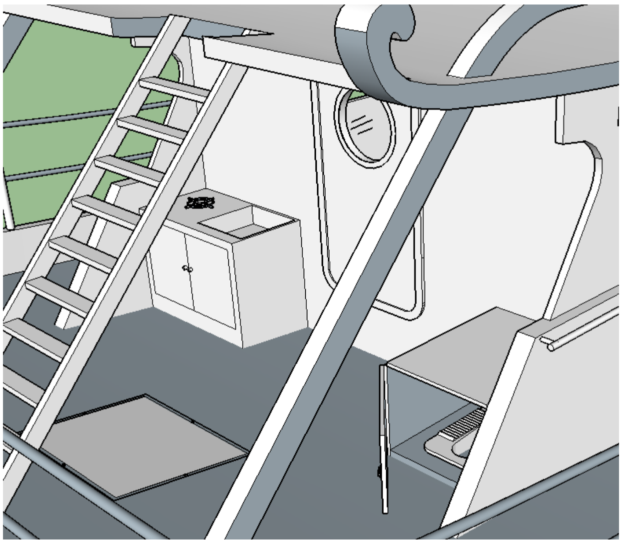


Figure 9.19 Arrangement of the galley and toilet for the final proposed design

By considering the participants' preferences regarding the on-board galley and toilet, Figure 9.19 following shows the arrangement for both these facilities in the proposed design. The toilet is a simple squat toilet that is covered by partition side measuring 1.1 metres in height. This partition can be folded and secured; therefore, the entire part of toilet can be closed when it is not in use. This arrangement and the relatively open space of the galley has the result that the stern area of the vessel has more space for crew activities to take place.

9.8 Concluding Remark

The sustainable goal of the fishing vessel development for Muncar fishing community was to design fishing vessel with potential solutions for any possible challenges in term of social, economic and environmental aspects in the future. By considering the current condition of local fishers and in order to increase the acceptability of the vessel, more concerns were prioritised regarding the social aspects of the proposed design.

Therefore, the local fishers were involved during the preliminary and final stage of the design process of the proposed vessel. The in-depth interviews that are related to the design requirements in initial stage of the design process and the FGD that delivered feedback in order to complete the final design engaged the local fishers in Muncar fishing community.

By considering the local fishers' requirements, in addition to some adjustment and compromises in order to accommodate the standard for implementing the responsible fishing practices and the potential improvement for the vessel in the future, a final proposed design for Muncar fishing community has been completed. Good responses from the FGD respondents in Muncar to the proposed new fishing vessel justified that the engagement of local fishers in the preliminary design of the vessel in order to identify the design requirements has increased the local fishers' acceptance to the proposed design.

However, the final design of the proposed fishing vessel revealed that there are follow-up measures required to implement a sustainable fishing vessel for the Muncar fishing community, and other communities in Indonesia. Alterations to improve some aspect of the proposed new vessel should take account of the gap between the proposed improvement of the vessel and the condition of local fishers regarding their competencies, awareness and willingness to implemented responsible fishing practices.

Chapter 10. Discussion and Conclusions

10.1 Discussion

10.1.1 Sustainable fishing vessels and the importance of stakeholders engagement

Chapters 1 and 2 of this thesis have described the numerous potential roles of the fisheries sector in Indonesia, especially for guaranteeing food security and the alleviation of poverty among the coastal communities. However, there are many challenges that need to be overcome if the sustainability of this sector is to be secured in the future, including how to implement responsible fishing practices among the local fishers in the enormous number of fishing communities in Indonesia.

As the main tool for fishing activities the fishing vessels themselves must be sustainable. This, together with responsible fishing practices could eventually lend to the achievement of sustainability in the fisheries sector. Chapter 3 of this thesis defines a sustainable fishing vessel as one that address all issues concerning the social, economic and environmental aspects of fishing practices. For that reason, the concept of sustainable development that embraces all the three pillars of sustainability needs to be applied throughout the life cycle of the vessel, from its manufacture to its final disposal, and including the design process.

In order to consider the complex social aspects, an understanding on the conditions of the local fishers and their communities is important, given that the performance of fishing boats, and the implementation of responsible fishing practices, clearly depends on the behaviour of all stakeholders involved in the operation of the boats. These stakeholders are: the fishers as the main operators of the boats; the local boatyards who are intimately involved in manufacturing and maintaining or repairing the boats; the many suppliers that provide the consumables and spare parts for the technologies that are applied and incorporated on board; and also fisheries agencies and government bodies who manage and control the sector through promulgation of proper policies and regulations.

The outcomes of the in-depth interviews that were undertaken in the three selected fishing communities in this study, and supported by personal observation of the local current fishing boats, have emphasised how the characteristics and status of local fishers and their communities have influenced the operation of local fishing vessels and the conditions of the local fisheries sectors. For example, the relatively low level of awareness of the local fishers concerning the sustainability of fish resources in their traditional fishing grounds, which was exacerbated by their belief that the abundance of the fish in the sea is unlimited, has resulted in a decline of fish stocks in many fishing grounds.

Therefore, in order to develop a sustainable fishing vessel, it requires the full participations of all the related stakeholders, and not only the local fishers. It is emphasised by the Code of Conduct for Responsible Fisheries of the FAO, as discussed in Chapter 2, that any policy and development related to the fisheries sector that affects local fishers and their communities' livelihood should positively involve the local fishers and their fishing communities in any way possible. This includes the involvement in any developments that introduce and implement new technologies related to the fishing vessels in local communities.

Furthermore, by learning from the negative experiences of earlier government financial programmes to supply vessels, and by considering the results from this case study to design a proposed new fishing vessel for a specific fishing community in Indonesia, it can be seen that the engagement of the local fishers in the design process of the vessel that they will subsequently operate is a sound approach to increase the level of acceptability and so the success of the introduction of a new vessel.

10.1.2 Potential obstacles to developing sustainable fishing vessels for Indonesia

Almost every fishing community in Indonesia is unique, and each has their own characteristics and specific fishing practices that can influence the requirements for the fishing vessels that they want to operate. The understanding of the characteristics and the needs of the local fishers and their fishing communities in relation to the fishing vessels is an enormous challenge when developing fishing vessels for specific fishing communities in Indonesia.

The challenges will become more complex when considering the requirements to apply the concepts of sustainable development proposed by Brundtland Reports. The compulsory requirement to give more concern to the environmental impact of the fishing vessel may conflict with the social aspects of the fishing communities.

According to the results of the in-depth interviews in the three selected communities and the observations on their current traditional fishing vessels, as described in Chapter

6, some common problems in the three selected communities are possibly becoming obstacles for the development of sustainable fishing vessels in Indonesia.

These obstacles include the relatively low level of the local fishers' basic education that eventually affects their competencies and their levels of acceptance of the alternative technologies for their fishing boats. Therefore, it will be hard to introduce new and sophisticated technology to these communities. This condition was exacerbated by the minimum information previously given to local fishers about the alternative technologies.

The respondents' responses during the in-depth interviews also revealed the relatively low level of local fishers' awareness of how to implement responsible fishing practices. The employment of destructive fishing gear, which causes damage to the sea bed or results in catching juvenile and untargeted fish, is still common in these communities. The fishers tend to be more concerned about how effective the fishing equipment is in catching fish rather than in whether or not the gear will have a detrimental impact on the environment.

Concerning the implementation of responsible fishing practices, the issues related to ensuring adequate health and safety in the working environment is another challenge that is relatively difficult to overcome. The lack of fishers' awareness of health and safety issues is the main problem in implementing and creating a robust health and safety operating environment on-board vessels and throughout each fishing trip. In contrast to local fishers understanding in relation to the risks associated with their job, their willingness to use various items of safety equipment and applying safety standards, to avoid for example potential injuries, is still very low.

The relatively low level of financial support is another obstacle. Local fishers prefer to employ technologies that have low initial cost for their boats. Unfortunately, based on the technologies assessment in chapter 7, these preferred types of technology tend to have relatively high operational costs throughout the service life of the vessel. Additionally, for some technologies, they also have a high impact on the environment.

The challenges related to social issues in many cases is even more complex. Advanced technologies incorporated in fishing vessels often aims to reduce the number of crew that are required to sail the vessel and to operate the equipment on-board. This condition is suitable for developed countries where the cost of the crews' salaries is high.

However, in the case of the Indonesian fisheries, using advanced technologies that reduce crew numbers on-board will decrease the opportunities for local fishing communities to sustain their employment levels. Moreover, the implementation of advanced and effective technologies potentially generates a social conflict among the community members if there are only a few fishers within the communities that can operate the technologies, and who appear, to others, to have an unfair advantage.

In addition to the challenges related to fishers and their fishing communities, other problems are related to various technical issues in developing fishing vessels in regions of the country. These include the availability of a robust and first-rate support infrastructure, especially for the more remote areas noting the geographical characteristic of Indonesia and its many islands. The price gap for fuel and spare parts for technologies on-board in Latuhalat and other areas in Java Island, or the problems in the continuity of the supply chain for LPG fuel in Muncar and Latuhalat, are examples of the rudimentary nature of the infrastructures limiting the choice of alternative technologies in remote areas. This has reduced the local fishers' interest in alternative superior technologies.

A further problem with the infrastructure is that the local boatyards used for construction, maintenance and repair, do not have proper capabilities for manufacturing high-quality vessels. Based on observations in the three selected fishing communities, most local boatyards use wood and apply long established traditional methods in the construction of the vessels, which are based on the knowledge and skills that have been transferred from generation to generation. Regardless of their excellent skills in constructing local fishing craft, their lack of ability to build other types of vessels based on technical drawings inhibits the introduction of new designs for local fishing communities. Moreover, boatyards that have the capabilities to build adequate quality fishing vessels with other construction materials, such as an FRP boat, is still very rare.

With regard to national regulations, there is currently a problem in the availability of comprehensive regulations related specifically to fishing boats. For instance, national regulations or standards concerned with the safety of fishing vessels, especially for small fishing vessels that are up to 24 metres in length, are not yet available (Suwardjo *et al.*, 2010). In addition, there is a problem in the actual enforcement of some current regulations related to fisheries and fishing vessels. The strict enforcement of several regulations, particularly for artisanal fisheries, is believed to be causing a few social problems and creating a degree of anxiety among the local fishers concerning the continuity of their income. For example, according to fisheries officers and harbour masters in Muncar and Brondong, the enforcement of the provision of safety equipment on board which is a mandatory requirement for obtaining port clearance prior to leaving a port has meant that fishers have been unable to go fishing since there are no fishing vessels with standard safety equipment on-board.

All of the aforementioned obstacles have made the efforts to develop sustainable fishing vessels for fishing communities in Indonesia to be challenging, it is therefore necessary that they are all carefully considered during the development of the vessel.

10.1.3 Proposed procedure to develop sustainable fishing vessels for Indonesia

The design of a proposed fishing vessel that has been undertaken in this research project has demonstrated that in order to develop fishing vessels that can support the achievement of sustainable fisheries an approach that manages the many obstacles and challenges is required. In particular the fishers, being the main actors in the operations of the vessels, must be closely engaged in the process.

In Chapter 3 of this thesis, an adapted conceptual design spiral has been proposed in order to have the appropriate sequential steps to design a fishing vessel for a specific fishing community in Indonesia. This spiral considers the three pillars of sustainability throughout the design process. Furthermore, a list of design requirements that also reflects the essence of the three pillars has been identified as an input for the initial stages of the design spiral.

However, a more comprehensive procedure is required in order to provide guidelines to develop sustainable fishing vessels for specific fishing communities in Indonesia. This procedure needs to include how the inputs for the design requirements and the information for the design process are obtained, and how the stakeholders' engagement should be employed during the development of the vessel. Based on the case study that has been undertaken in designing a fishing vessel for a specific fishing community in Indonesia, and by considering the diverse potential challenges that have been discussed above, a proposed procedure to develop sustainable fishing vessels for Indonesia is illustrated in Figure 10.1.

The flowchart in Figure 10.1 shows that in order to develop sustainable fishing vessels for specific fishing communities in Indonesia, the main inputs should be obtained from the targeted fishing communities from where the vessels will be based and operated, in order that the input is relevant and precise. This input consist of information about the fishers' requirements, the characteristics of the local existing fishing vessels, and the conditions of the local supporting infrastructures. In order to have valid data about these inputs, the engagement of local stakeholders is important.

The in-depth discussions with local fishers should also elicit their views on the requirements for the fishing vessels and the technologies to be applied on-board. The input from the local boatyards is needed in order to have a more factual understanding of the existing fishing vessels and the yards capabilities to support any improvements in fishing vessel development. The discussions with local fisheries agencies or government bodies and with local suppliers for technologies, are to gather information about the conditions of the local infrastructure, including the supply chain for supporting technologies for the fishing vessels in their region. Regarding the availability and the enforcement of regulations related to fishing vessels and their operations, the input from local government and/or the local fisheries agencies is also needed.

The results of the design process of the proposed fishing vessel as developed in this study have confirmed how the engagement with local fishers at the initial stage and at the final stage of the design spiral have influenced the acceptability of the proposed vessel.

Based on the experience gained in undertaking this study, using the features of local vessels as the starting point for the design process can increase the acceptability of the final design. The attempt to adopt and to adapt specific common features in local designs that are important for local fishers should be part of the design process, but achieved without diminishing the potential improvements to the new vessel. Moreover, the problems of the supporting infrastructures, especially for the more remote areas, need to be considered at the initial stage of the design process, given that it will affect the choice of technologies that can be employed in the new fishing vessel.

The development of sustainable fishing vessels requires the implementation of the three pillars of sustainability to equal levels. However, the overall conditions of the local fishers in many fishing communities in Indonesia has resulted in a relative ignorance of the environmental aspects of their vessels. Consideration of the local fishers' requirements and their limitations is most important in the design process of the vessel, however, it should not ignore the main goal of the vessel's development, which is to

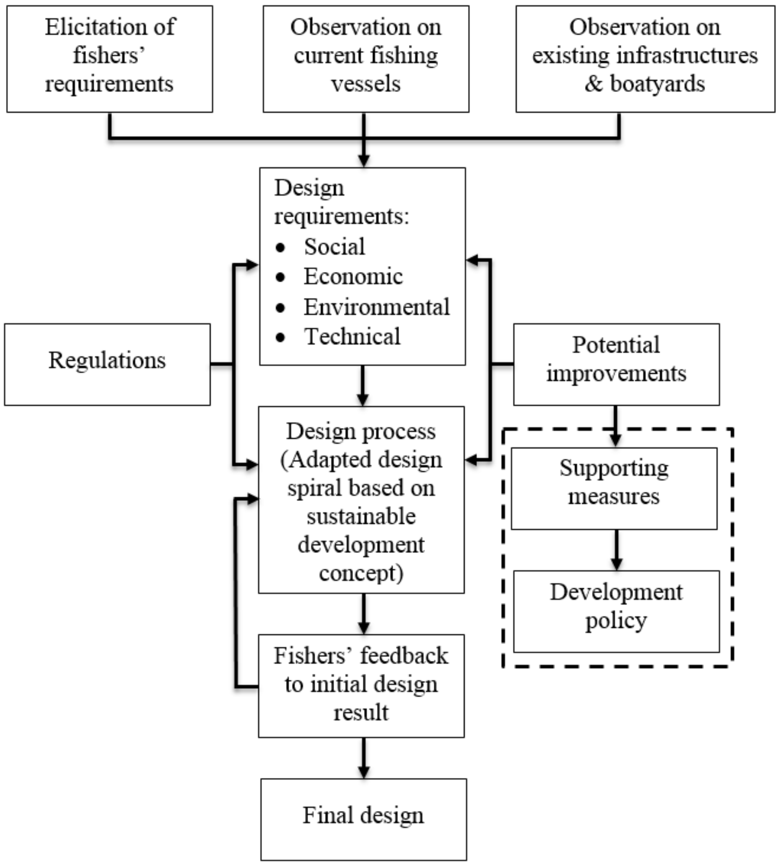


Figure 10.1 Proposed procedure to develop sustainable fishing vessel in Indonesia

achieve a sustainable fishing vessel. Taking measures to eliminate or minimise the various obstacles that inhibit the implementation of all of the three pillars equally is the only route to achieve true sustainability. Therefore, the input to the design process should also include the identification of potential improvements for the new fishing vessel, as seen in Figure 10.1, in order to facilitate gradually transforming the current fishing vessels into the more sustainable fishing vessels.

Potential improvements of the vessel include: improvements in a healthy and safe working environment on-board; improvement of the technologies that are employed on-board, which are more efficient and have a reduce impact to the environment, and fulfill the economic viability; and improvement of the performance of the vessel itself.

In order to ensure that the improvements to the vessel will be such that it can function well and can support the transformation of a traditional fishing fleet to meet the future needs, the identification of potential improvements for the new design should be followed by the measures to overcome any obstacles that inhibit the development of sustainable fishing vessels. In Figure 10.1, this task is bounded by the dotted line that includes the identification of supporting measures for the improvement of the vessels and followed by the identification of a development policy that needs to be established by the Indonesian government in order to support the fishing vessel's development.

By considering the potential obstacles to the development of new fishing vessels in Indonesia, the improvements required are not only on the vessel itself but also to the understanding of the fishers who operate the vessels, and the infrastructure necessary to support the operations. Therefore the supporting measures can be in the form of capacity building for local fishers and their communities and in the form of infrastructure development for the local community. The capacity building for local fishers and their communities is in line with the Code of Conduct for Responsible Fisheries recommendations that "*States should enhance through education and training programmes the education and skills of fishers and, where appropriate, their professional qualifications*". This capacity building includes increasing local fishers' awareness in implementing responsible fishing practices, and also by increasing local fishers' competencies in operating more environmentally-friendly technologies on-board.

A simple example can illustrate this: providing better and comprehensive safety equipment on board will be ineffective without any improvement being imparted in the crews' knowledge and in their willingness to use such equipment, and also their accountability in implementing health and safety standards in their own working environment.

The efforts to introduce new alternative technologies that are more environmentally-friendly need to be continuously carried out and should be supported by the related stakeholders, especially the government. For example, the implementation of renewable energy to supply electricity such as the solar cells and a wind turbine on-board needs to be promoted and popularised. The problems local fishers have in terms of initial investment could be overcome by a grants scheme or other form of financial support from the government. However, if there is still a low level of interest of local fishers in employing these types of technologies on-board, the local government can start to promote the technologies by providing relevant infrastructure. For example, a mini power plant that uses solar panel arrays and/or wind turbines in a fishing harbour will allow local fishers that are using batteries only for lighting can cost effectively recharge their batteries with these facilities, which will reduce the consumption of more expensive and polluting land grid power by using cleaner technology.

Infrastructure development is required to support the full range of operational activities of sustainable fishing vessels, especially for the more remote fishing communities. This includes the development of an improved supply chain in order to minimise or eliminate the price disparity between the areas in Java Island and elsewhere that greatly influence the operational cost of the vessels.

The success of fishing vessel development in Indonesia will also be affected by how effective is the government policies to support any measures necessary to overcome the obstacles aforementioned. The latest Indonesian government policy to build grant fishing vessels for groups of fishers in many fishing communities in Indonesia was designed to support the development of fishing vessels in Indonesia. This programme tried to encourage traditional fishers to go further offshore by assisting the local fishers with financial support in order to have more appropriate vessels. By granting each vessel to be shared by a group of fishers, the government expected that this group of fishers could share both the operational costs and the profit from the operation of their granted vessel. It was also expected that the older vessels owned by the members of group could be disposed of in order to reduce the total number of fishing vessels and reduce the pressure in artisanal fishing grounds. However the failure to involve local fishers properly in developing the design of the granted vessels in many cases resulted in the refusal to use the donated vessels in many fishing communities. Therefore the proposed procedure as outlined in Figure 10.1 the involvement of the local fishers is not only at the initial stages of the vessel design process, but also near to the end of the process in order to have their focused feedback for the final design.

10.1.4 Broader Implementation in Developing Sustainable Fishing Vessels for Developing Countries

According to FAO, approximately 90% of the people working in capture fisheries in the world are involved in small-scale fisheries (FAO, 2016), and their largest populations are found in developing countries (Allison and Ellis, 2001; FAO, 2016). The common problems faced by these huge number of fishers and fish workers including the low level of formal education, lack of financial support, inadequate health and safety working environment, and pollution and environmental degradation (FAO, 2015d).

These circumstances have limited the fishers’ choices for the technologies that are employed in their fishing vessels and eventually influence the overall performance of the vessels. For example, the two-stroke outboard engine is commonly used by artisanal fishers in developing countries since its price is affordable, although the operational cost of this kind of engine is higher compare to the in-board diesel engine (Gulbrandsen, 2012). The results from many FAO programmes in the development of fishing fleets in many developing countries, as discussed in Chapter 2, also show how the aforementioned problems have inhibited the development of better fishing fleets and the implementation of responsible fishing practices in developing countries.

Based on these condition, Article 5 of Code of Conduct for Responsible Fisheries of FAO specifically stated the need for considering the capacity of developing countries to implement the responsible fishing practices as suggested by the Code. According to this Article, any measures to promote the implementation of sustainable fishing practices should be aware of the special circumstances and requirements of developing countries, especially in terms of financial support, technical assistance, transfer of technology and in improving their capability to develop their fisheries sector (FAO, 1995).

Furthermore, according to the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries of FAO, the small-scale fisheries very often have a strong connection with the local communities that engaged in this sector and eventually strengthen the social cohesion among the communities. This interconnection influences the cultures and values of the communities (FAO, 2015d). Therefore this Guideline emphasises the requirement to recognise and to respect the local cultures, including the local practices and knowledge of the communities in any aspects of development.

Based on the above discussion, by considering the obstacles and other aspects that need to be considered when developing the fisheries sector and implementing responsible fishing practices in developing countries, the challenges that are faced by many communities in developing countries are similar to those in Indonesia. Therefore it is reasonable to assume the approach proposed in this thesis to design a fishing vessel that can support the sustainability of fisheries could be applied in other regions. The procedure to develop sustainable fishing vessel as discussed previously and illustrated in Figure 10.1 is therefore applicable to be implemented in fishing communities in other developing countries.

10.2 Research Summary

In order to achieve the aim of this research project, which was to propose a procedure for designing sustainable fishing vessels for specific fishing communities in Indonesia, a number of research questions were set out in Chapter 1 of this thesis. The degree to which these questions have been answered is summarised in this section.

The first research question was concerning the status, level of knowledge and type of qualifications of local fishers and others in their fishing communities, and what are their preferences and requirements related to fishing vessels. Based on the result of the field study that has been conducted in the three selected fishing communities in Indonesia, the question regarding the status of local fishers was responded to in Chapter 6, while the local fishers' preferences and requirements were discussed in Chapters 7 and 9 respectively. Consequently, the answers revealed various weaknesses that the local fishers have, including their low level of awareness in terms of sustainable fishing practices and regulations, their limited knowledge, and their economic circumstances have affected local fishers' fishing practices and subsequently influenced their preferences and requirements regarding fishing vessels including the choices related to technologies applied on-board.

The second research question was regarding the design requirements and other aspects that need to be considered in order to design sustainable fishing vessels for specific communities in Indonesia. For this question, the concept of sustainable development and how this concept can be implemented in fisheries and fishing vessels is discussed in Chapter 2. Subsequently, the list of design requirements has been identified in Chapter 3, in conjunction with a modified design spiral in order to provide guidelines for designing a sustainable fishing vessel. The primary issue concerning the design requirements and the design spiral for sustainable fishing vessels is how to implement the three pillars of sustainability (social, economic and environmental) at each relevant stage of the development of the design.

The third research question was related to the most recent and established technologies found on fishing boats in world-wide service that could be applied in Indonesia. By considering the total cost for procuring and operating each of the technologies, their current acceptability by local fishers in Indonesia and the viability of the technology in the communities, the list of technologies that have potential and are possible to be employed in fishing vessels in Indonesia have been selected, as discussed in Chapter 5. The result demonstrates that many of the established alternative technologies available in worldwide fishing practices cannot be implemented directly onto fishing boats in Indonesia owing to their sophistication and high cost. An understanding is required of the limitations that the local fishers in each community have in order to employ the alternative technologies.

The next research question was associated with the most appropriate technologies that can be applied on-board fishing vessels in Indonesia, which fulfil the requirements concerning the social, economic and environmental aspects. With regard to this research question, groups of potential alternative technologies that could be employed in fishing vessels in Indonesia have been assessed regarding their social acceptability, economic viability and their environmental impact. The results of assessments are presented in Chapter 7, and revealed that the level of importance of each pillar of sustainability will influence the choice of the most appropriate alternative technologies for each fishing community.

The final research question was related to the obstacles that need to be overcome and the strategies required with the intention of developing fishing vessels that are sustainable in Indonesia. In order to identify the obstacles and to formulate a proper procedure to develop a sustainable fishing vessel, a case study in which a sustainable vessel designed for one selected fishing community in Indonesia has been conducted. The results are presented in Chapter 9.

Based on this case study, the obstacles and the proposed procedure to develop a sustainable fishing vessel for specific fishing communities in Indonesia are discussed in this final chapter. By considering that the potential obstacles to developing such vessels are mostly related to the limitations that the local fishers and their communities have, the initial step in the proposed procedure to develop a sustainable fishing vessel is related to obtaining inputs from targeted communities that affect the development of the vessel, especially through a proper engagement with related stakeholders.

10.3 Recommendation for Future Work

This study has not included any in-depth analyses on the performances of the existing local fishing vessels in each of the selected fishing communities in terms of their hydrodynamic resistance, stability during all operations, and seakeeping, since the focus of this study was in preparing the comprehensive procedure to develop a sustainable fishing vessel for a specific fishing community in Indonesia, and the selection of technologies that are possible to be employed in the fishing vessels in Indonesia as a whole. There were a huge number of types and variations of fishing vessels in

Indonesia. Some of them are distributed in relatively wide areas from their origin and have apparently experienced relatively little adaptation or modification from local fishers in the new areas. One such example is the “Sekoci” type of hull from Sulawesi Island, mostly used to operate handlines, which subsequently spread to a large number of fishing communities in other islands in Indonesia. It shows that some of these traditional fishing vessels have achieved an optimum overall performance that satisfies the local fishers in many communities.

It will be very useful for the development and improvement of fishing vessels in the future if further study is conducted on the many type of hulls available in traditional fishing vessels. These traditional vessels have been evolving and refining in detail for centuries, but have no supporting drawings and have had no technical assessments in term of their resistance, stability and seakeeping. Having a good and well-arranged database about these numerous types of vessels will be useful for the future development of fishing vessels in Indonesia

10.4 Conclusion

The enormous potential of the fish resources in the Indonesian waters must be exploited wisely in order to ensure its sustainability for both current and future generations. Undertaking responsible fishing practices and developing a fishing vessel in a way that the vessel itself is sustainable, are among the efforts that must be undertaken with respect to achieving this objective. By considering the current conditions of the local fishers and their communities in most coastal areas in Indonesia and based on the characteristics of existing traditional fishing vessels, there are huge challenges to develop fishing vessels for these communities according to the concept of sustainable development.

In this thesis, the difficulties of developing sustainable fishing vessels for specific fishing communities in Indonesia are addressed. A strategy to overcome the challenges is generated. In order to implement the concept of sustainable development, the three pillars of sustainability are reflected in each relevant stage of the design process of the vessel, therefore more comprehensive design requirements that represent social, economic, and environmental aspects of fishing vessels have been developed. It is suggested that there is proper engagement with the related stakeholders at the initial and the final stages of the design process. Moreover, the appropriate selection of the potential technologies to be employed on-board, which accomplish the three pillars of sustainability, is recommended as a part of the design process. It is believed that these approaches are able to generate solutions for the social, economic and environmental issues concerning the sustainability of the fishing vessel in Indonesia.

In order to demonstrate the potential of this method, a case study has been conducted which has examined the entire proposed procedure. Based on this case study, a further approach for designing fishing vessels for specific fishing communities in Indonesia is to use traditional fishing vessels as a starting point in the preliminary design stage. Retaining and adapting features on traditional vessels that have evolved as the most suitable solutions for local problems, ensures that local identity and familiarity is maintained, and is thus likely to increase local fishers' acceptance. The result from this case study has ended up with the design of a proposed fishing vessel which reflects both the value of local fishers and their community, and moreover, the potential for sustainable achievement.

The design process developed in this thesis is a significant contribution to the creation of a sustainable fisheries sector in the developing world. However this can only be effectively achieved if other complementary measures are also taken, including capacity and competency building in the fishers' communities, the enactment and enforcement of relevant regulations, and the development of more robust supply and support infrastructures. All these measures will enable the development of truly sustainable fishing vessels for Indonesia.

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Appendix A

Field Study Results

A.1 Example of characteristic of local fishing vessels

A-2 Example of in-depth interview results

A.3 Example of flyer for in-depth interviews

A.1 *Example of characteristic of local fishing vessels*

Respondents	A.F.05	B.F.08	B.F.11
General			
Age (years)	54	35	40
Experience (years)	26	20	20
Latest education	Elementary school	Elementary School	Senior High School
Owner/Skipper/Crew	Skipper	Skipper	Skipper
Others job	No	No	Trader
Boat Length	17 m	8 m	15 m
Boat Breadth	3.40 m	4.5 m	6 m
Number of crew	14	9	14
Fish landing	PPI Erie, Latukolon	Brondong	Brondong
Fishing ground	Banda Sea (5-10 miles)	Sulawesi, Makassar, Kalimantan (500 miles)	Masalembu (200 miles)
Length of fishing	5 hours	10 days	12 - 13 days
Hull material	Wood (Gofasa)	Wood (Teak)	Wood (Teak)
Main engine			
- Type of engine	Outboard, Yamaha (Kerosene), 2 unit	Yanmar, 3 unit	Mitsubishi, 3 unit
- Engine power	2 X 40 HP	2x23HP, 30HP	3 x 120HP
- Fuel consumption	100 liters (kerosene)	1000 liters (diesel)	2400 liters (diesel)
Electrical			
- Electric power	660 watt	60 watt	100 watt
- Purpose	lighting	lighting	lighting
- Electrical sources	Genset Honda 2kW	Battery, Alternator	Battery, Alternator
- Fuel consumption	10 liters (gasoline)	-	-
Fishing Gear			
- Type of fishing gear	Purse seine	Hand line	Trawl
- Line/net hauler	NA	NA	Hauler for rope
Fish preservation			
- Fish hold capacity	NA	3 tonnes	10 tonnes
- Preservation system	No preservation	Block ice	Block ice
- Consumption for one trip	-	70 block ice (2.1 tons)	400 block ice (12 tons)
Electronic devices	NA	GPS, Fish finder	GPS

A.2 Example of result of in-depth interview

Respondents: B.F.06

1. General Information

Q : What is your name?

A : -

Q : And if you don't mind me asking, would you tell me how old you are?

A : 60 years old

Q : What is your position on board?

A : As a crew

Q : Do you have any other job apart from this?

A : Sometimes I work as a fish trader,

Q : What was your last education?

A : Junior high school, however, I didn't pass it

Q : Could you please tell me how long you have been a fisherman?

A : About 13 years

Q : Could you please tell me what size of boat you use?

A : It's about 15 m length, 6 m breadth and the fishing gear in use is "Payang" (seine net)

Q : Is the use of seine net fishing boat quite common in Brondong?

A : Nowadays the majority of fishing boats in Brondong uses seine net.

Q : With regards to fish; what kind of fish do you usually catch?

A : A lot of different varieties of fish; we do not really stick to certain varieties.

Q : How many crews do you normally carry on your boat?

A : 13-14 crews in general and that would include a Skipper, 2 Engine Masters, and 1 Chef

Q : Where is the landing port?

A : As a rule, we land at Brondong fishing harbour, we have never landed at other ports.

Q : Where is your fishing ground?

A : Masalembu Island and Matasiri Island

Q : On average, how long do you go for one fishing trip?

A : It really depends on the amount of fish we get. If we manage to catch a colossal amount of fish, we will normally go fishing for a week and then we will travel back home. We will have 2-3 days of rest and also use the time to re-supply the consumable then we set off for our next trip. The longest time we would spend on fishing will be about 18 days; however that is not advisable as we need to consider the freshness of the fish until landing.

2. Current Technologies

Q : Would you tell me what kind of material you use for your boat?

A : Wood, but now we use plenty other types of timber beside teak, we also use mahogany.

Q : Have you ever encountered any issues by using wood as your boat material?

A : No problem at all, it is good to use wood for fishing boat

Q : What kind of maintenance do you regularly conduct?

A : Repainting, caulking, also cleaning the fouling on the hull. The maintenance can be finished in one day so we can go fishing in the next day. We have already applied anti-fouling for coating the hull.

Q : What kind of engine do you install on board?

A : At the moment, we use 3 units of Mitsubishi PS 125HP, one for the line hauler and two for the main engine

Q : How many litres of fuel do you bring on average for one trip?

A : 15 drums of fuel, 1 drum contains about 200 litres.

Q : Have there been any problems with the existing engines?

A : There are always many problems if we use second hand engines. If it is new, it is quite unlikely to have a problem. Every time we finish unloading our catches, the engines are always checked and serviced if there is a broken part.

Q : Do you maintain the engine by yourself?

A : Yes, we do it by ourselves. However, if we come across difficulties in the process, we usually ask for a technician to give us a hand.

Q : How about the spare parts? Is it quite accessible around here?

A : Yes, it is easy to find the spare part here, but sometimes we have to go to Surabaya for specific spare parts.

Q : How about the electricity on the boat? What functions does it hold?

A : For lighting and pumping water

Q : How many watts are required for the lighting?

A : About 800-1000 watts

Q : Do you use light to attract fish?

A : No, we don’t. We fish during the daytime

Q : What kind of electricity source do you use?

A : Dynamo alternator that is connected to the main engine

Q : Do you use batteries on board?

A : Yes, we bring 2 units for back up of dynamo alternator.

Q : Do you have navigation lights on board?

A : Yes, there are navigation lights with battery as electrical sources.

Q : Are the 15 drums of fuel also used for electricity?

A : Yes, but for the purpose of pumping water, we bring about 30 litres of gasoline for one trip.

Q : Have there been any problems with the dynamo alternator?

A : There is no problem with dynamo alternator, however, we always have 1 or 2 unit alternators for our backup.

Q : Please describe the shape of "Payang" as your fishing gear?

A : It looks like a Trawl, but it is smaller. The boat is still running while we pull the net. It catches demersal fish, but the net doesn't reach the reef or bottom of the sea. Sometimes it does, but very rarely.

Q : Have you ever operated other kinds of fishing gear?

A : No, we always use "Payang"

Q : What size is your net?

A : The net is about 50 meters length and the rope is 1500 meters length each side. The smallest mesh is 2-3 cm and the largest mesh is about 30 cm.

Q : How many hauling do you carry out in a day?

A : Between 10-12 times a day, from dawn to 3-4 PM. If there is no fish, we work overtime till late; sometimes it could be 15 times of hauling the net. It takes about 1.5-2 hours for one hauling.

Q : How many fish can you get for one haul?

A : Sometimes 1-3 tonnes, but some other time we just get a little.

Q : Do you use "Rumpon" (Fish Aggregating Devices) for fishing?

A : No, we don't.

Q : How about the line hauler?

A : We use line hauler, the engine for the hauler is Mitsubishi PS engine

Q : Have there been any problems with the existing fishing gear?

A : Sometimes it is stuck on reef and it gets damaged. Or when it accidentally catches big fish, such as sharks or dolphins, it will get broken. Sometimes we have to rip the net off so the big fish can be released to the sea, because it has no value in fish market.

Q : Have there been any problems with the line hauler?

A : No, we haven't been in that situation yet. However the net line should be carefully managed on deck, otherwise it could jeopardise the crews during deployment and hauling the net. Crews should avoid wear long sleeves as well as long gloves. I almost had an accident with the hauler. My gloves were stuck on the hauler so I pulled my hands. I was quite fortunate that nothing bad happened. The safety of the hauler is not good; it still rotates for few times even after the engine shutdown.

Q : Now it is about the fish storage. How many blocks of ice do you bring for one trip?

A : About 300-500 blocks of ice, and it will be crushed once the fish are caught.

Q : How many fish can your boat hold?

A : There are quite a few fish holds. If one fish tank contains 65 blocks of ice, it can store about 1.5 tonnes of fish. If it contains 40 blocks of ice, it can store about 1 tonne of fish.

Q : How do you arrange between fish and ice on the fish holding tanks?

A : It is arranged layer by layer, first layer is ice, then fish, then covered by ice. It is not added with salt because the fish is for export.

Q : Is sea water added in the fish holding tanks?

A : No, just ice in the holding tanks. The water from melting ice is removed from the fish hold. If the fish tank is filled with water, the fish skin will be defected due to contact with crushed ice.

Q : Your fishing gear catches all kinds of fish. Are there any kinds of fish that are released back to the sea if it has low price at fish market?

A : Yes, there are. Several kinds of fish have quite a low price, rather than filling up the fish holding tanks with low priced fish, it is better that we removed them at the sea.

Q : How many fish holding tanks do you have in your boat?

A : 6 fish holding tanks

Q : Have there been any problems with ice for fish preservation?

A : Yes, there have been. If we go fishing too long, the fish at the bottom of fish tank will be spoiled. The fish will still be fresh if the trip is not more than 10 days.

Q : What kind of electronic device do you use to support your fishing?

A : We use GPS. They are useful for avoid hitting reef or shipwreck because the position of the reef or shipwreck is saved in GPS. Or we also can save the location at the fishing ground that has many fish.

Q : Next questions are about the facilities on your boat. Are there sleeping rooms on board?

A : There is no special room, only a shelter that is also utilised to store a lot of other stuff.

Q : How about dining room?

A : No, there is not.

Q : Is there a galley?

A : Yes. We use an LPG stove for cooking. We bring 20-25 cylinders of LPG 3 kg for one trip. Most fishermen now use LPG instead of kerosene, because kerosene is become more expensive compared to LPG.

Q : How much freshwater do you bring?

A : For drinking we bring 30-35 gallons, and 7 drums of fresh water for cooking and others.

Q : How about toilet facilities; are the facilities available on board?

A : There is no special place for toilet, commonly we use the space behind the shelter at the aft.

Q : Do you use GPS for navigation?

A : Yes, I do

Q : How about radio communication; do you use it?

A : I don't bring radio communication on board, nowadays mostly fishermen use mobile phone for communication, although sometimes there is no signal for some area, except when it is close to the land.

Q : Do you have fire extinguishers on board?

A : No, we don't

Q : Do you have lifebuoys on board?

A : No, we don't

Q : Do you have life jackets on board?

A : Yes, we have them. The number of life jackets depends on the number of crews on board.

Q : How about the first aid box; do you have it on board?

A : Yes, we do

Q : Do you have smoke signal on board?

A : No, we don't.

Q : If you have waste from activities on board what do you do?

A : We dispose the waste directly to the sea

Q : How about the waste lube oil, how do you treat it?

A : We collect it and sell it when we land

Q : If there is water in the engine room, how do you treat it?

A : We dispose directly to the sea by the same devices as the engine cooling system

Q : How about the waste water from fish hold; how is the disposal system?

A : We dispose it directly to the sea as well, we do it once every two days.

Q : How about waste from cooking or bathing; how is the disposal system?

A : It is disposed directly to the sea

Q : How do you fix the broken net?

A : We repair the broken net on board. Usually we bring 4 nets, 3 nets are for back up. The broken net and rope will be stored on board; the reason is if we dispose it to the sea, we are concerned that our net or our propeller could be stuck on the abandoned net.

Q : Is there a note on board to record the catch?

A : Not really, we mainly use our estimation. It is noted in the land

Q : Do you use antifouling for your hull?

A : Yes, the bottom of the boat is repainted every 2 months

3. Preference on the Alternative Technologies

Q : Are you still interested in using wood?

A : Yes, I am still very interested. 10 point

Q : How do you feel about fiberglass?

A : I am really interested, 10 point, however it is too expensive

Q : How do you feel about aluminium?

A : I have never seen it. Aluminium is easily dented if it hits something, wood is more flexible compared to aluminium. I think 6 point.

Q : How do you feel about laminated wood? Are you interested?

A : I have never heard about this material, I don't know, 6 point

Q : Why do you prefer wood as the material for your boat?

A : Because wood is more cost efficient and durable than other materials

Q : Don't you think it is difficult to find wood recently?

A : I don't think so, although recently we have been using more varied kinds of wood; not only teak just like we used to.

Q : For the main engine, are you interested in marine-used engines?

A : I think marine-use engines are better, but it depends on the owner's budget. Our existing engines are second hand engine, the owner said that it is used engine from Singapore; the engine condition was still 75% compared to the new ones.

Q : How about engines that run on LPG; would you consider using them?

A : I never heard about it, it should be good if it makes our job easier, 10 point.

Q : What do you think about electric engines? They need batteries or diesel gensets to supply the electricity.

A : I think it is not strong enough for fishing boats, 6 point.

Q : Do you still use sails?

A : Yes, sometimes. We bring a small sail to support propulsion in case there is trouble with one of the engines, so yes 10 point.

Q : What is your consideration in choosing the main engine?

A : It should be easy to use, fuel efficient, and not expensive. It depends on the boat owner, because the owner tends to prefer the second hand engine, with the same price he could get four used engines compared to the new one.

Q : For the electric source on board, are you interested in using gensets?

A : There are some boats in here that use them

Q : What do you think of gensets that run on LPG?

A : If I have a boat, I will be very interested, 10 point. It simplifies our job and also fuel efficient. I am happy if there is more advanced technology for boats.

Q : Do you still use batteries for electricity?

A : Yes, but only for back up

Q : How about using solar cell as an electric source; do you think you will be interested?

A : I have used 1 unit for lighting, also for back up if there is trouble with the alternator, 10 point.

Q : What do you think about wind turbine for charging battery?

A : I am afraid I am not quite keen on that; it seems that the fishermen here are not keen on it as well, 6 point. And it's the same case with regards to the solar cell I'm afraid, only few fishermen still use it.

Q : What is your consideration in choosing electricity source?

A : It should be fuel efficient, easy to use, and easy to maintain

Q : About the fishing gear, are you interested in other fishing gear?

A : I think I am quite happy with what we use now to be honest; most fishermen here use *Payang* (seine nets), we bring hand line just for extra income for crews

Q : For fish preservation, are you interested in using freezer?

A : I am afraid not, it is too big for my boat, there is no more space on board for freezer, I prefer 6 point.

Q : Would you consider an ice maker on board?

A : There is no space for such machine, there is a shelter above the engine room. Moreover there are nets and net lines in front of the shelter, so 6 point.

Q : Have you had any problems with block ice for fish preservation?

A : Fortunately, we have not had any problems. The important thing is the block ice should be in good quality, so it is not melting easily.

Q : Are you interested in using fish finder?

A : I don't use it, it depends on the owner. But I am personally interested.

Q : Do you use GPS that is equipped with map?

A : Yes, we have already used it. It is very useful

Q : What do you think of tools that send signal to the land if the boat is sunk?

A : That really depends on the owner. I personally would buy it if I was the owner of the boat. The problem is, most boat owners share the budget to buy boat equipment with the crews; they don't use their own money for the equipment.

4. Safety devices

Q : Are you interested to provide fire extinguishers on board?

A : No, I'm not. There is water everywhere.

Q : Would you consider lifebuoys?

A : Yes, they are necessary on board

Q : How do you feel about smoke signal?

A : Yes, I am actually interested, but again, it depends on the owner.

Q : According to you, is the safety equipment required on board?

A : Yes of course, because the risk at sea is very high. I have drowned once, there was a strong wind and I was thrown into the water.

5. Current Condition of Local Fisheries

Q : According to you, what have been changed in fisheries in this area?

A : The fish price is changed, it is not stable. The amount of fish has been declining, and we have to go farther for fishing. In the past, the fishing ground was around Masalembu Island, now the fishing ground is around Matasiri Island, the distance is twice compare to in the past.

Q : What do you think about it in the future?

A : Well, It is totally depend on God's will. In fact, the amount of fish has been declining which resulted in the decrease of the fishermen's income. I'm afraid our children and grandchildren won't get anything from the sea. Suppose that coral reef destruction has never occurred.

Q : What was your initial reason for choosing to be a fisherman?

A : It has been my livelihood for long time.

Q : Have you ever thought about working in land?

A : Yes I do; in fact, I have been a fish trader

Q : Is your son also a fisherman?

A : No, he works in fish canning industry. Actually, he wanted to study in college but I had no money to support him.

Q : Do you want your son to be a fisherman?

A : No, I don't want my son become a fisherman, I don't want them to be poor just like their parents. Working at sea is extremely tough; it puts your life at risk.

Q : According to you, is the young generation here interested to be a fisherman?

A : Yes, especially if they are desperate and could not continue their study. If they have no job, they will choose to be a fisherman. If their family is still able to support them, they will continue their study.

A-3 Example of flyer for in-depth interviews

Solar Panel (Price: >£100)

Solar Panel is a system that harnesses solar power to generate electricity. The electricity is stored into the batteries and supplied for many electric devices on-board

Wind Turbine Generator (Price: >£300)

Wind turbine generator is a system that harnesses the energy of wind to drive the generator in order to produce electricity. The electricity is stored into the batteries and supplied for many electric devices on-board

Appendix B

Result of Technologies Assessment

B-1 NPV of the cost for non-marine diesel engine

B-2 Life Cycle Inventory for construction materials

B-3 Example of Monte Carlo result for comparing alternative technologies

B-4 AHP Analysis for Alternative Construction Materials

Appendix B-1. Example of NPV of the cost for main engines

Yanmar TF 300H (Non-marine diesel engine)

Initial Investment

No	Engine Brand	Price (IDR)	Price (GBP)
1	Yanmar TF 300H	Rp 37,000,000.00	£ 1,850.00

Operational Cost

1) Fuel oil consumption

No	Engine Brand	hp	Fuel consumption (g/HP.h)	Hour/Year	Total fuel/year (liters)	Price/liter (Per January 2015)	Total cost/year
1	Yanmar TF 300H	30	170	3150	16,179.88	£ 0.32	£ 5,177.56

2) Lubrication oil consumption

No	Engine Brand	hp	Lube oil tank capacity (liters)	Number of replacement/year	Total Lubrication/year (liters)	Price/liter (Per January 2015)	Total cost/year
1	Yanmar TF 300H	30	9.8	14	137.20	£ 1.75	£ 240.10

NPV calculation for 20 years operations

Year	Investment Cost (1)	Operational Cost (2)	Other cost (3)	Income (4)	Cash flow (5 =1+2+3+4)	$(1+i)^{-t}$ (6)	PV= Cash flow x $(1+i)^{-t}$ (7 = 5x6)	NPV (Sum 7)
0	£ 1,850.00				-£ 1,850.00	£ 1.00	-£ 1,850.00	-£ 1,850.00
1		£ 5,417.66		£ -	-£ 5,417.66	£ 0.93	-£ 5,063.24	
2		£ 5,742.72		£ -	-£ 5,742.72	£ 0.87	-£ 5,015.92	
3		£ 6,087.29		£ -	-£ 6,087.29	£ 0.82	-£ 4,969.04	
4		£ 6,452.52		£ -	-£ 6,452.52	£ 0.76	-£ 4,922.60	
5		£ 6,839.67		£ -	-£ 6,839.67	£ 0.71	-£ 4,876.59	-£ 26,697.38
6		£ 7,250.05	£ 2,475.72	£ -	-£ 9,725.77	£ 0.67	-£ 6,480.69	
7		£ 7,685.06		£ -	-£ 7,685.06	£ 0.62	-£ 4,785.87	
8		£ 8,146.16		£ -	-£ 8,146.16	£ 0.58	-£ 4,741.14	
9		£ 8,634.93		£ -	-£ 8,634.93	£ 0.54	-£ 4,696.83	
10		£ 9,153.03		£ -	-£ 9,153.03	£ 0.51	-£ 4,652.93	-£ 52,054.85
11		£ 9,702.21	£ 3,313.07	£ -	-£ 13,015.28	£ 0.48	-£ 6,183.46	
12		£ 10,284.34		£ -	-£ 10,284.34	£ 0.44	-£ 4,566.37	
13		£ 10,901.40		£ -	-£ 10,901.40	£ 0.41	-£ 4,523.69	
14		£ 11,555.49		£ -	-£ 11,555.49	£ 0.39	-£ 4,481.42	
15		£ 12,248.81		£ -	-£ 12,248.81	£ 0.36	-£ 4,439.53	-£ 76,249.32
16		£ 12,983.74	£ 4,433.63	£ -	-£ 17,417.38	£ 0.34	-£ 5,899.87	
17		£ 13,762.77		£ -	-£ 13,762.77	£ 0.32	-£ 4,356.94	
18		£ 14,588.53		£ -	-£ 14,588.53	£ 0.30	-£ 4,316.22	
19		£ 15,463.85		£ -	-£ 15,463.85	£ 0.28	-£ 4,275.88	
20		£ 16,391.68		£ -	-£ 16,391.68	£ 0.26	-£ 4,235.92	-£ 99,334.16

Note :

1) The operational cost for year 't' = operational cost year 1 x $(1+f)^t$, where 'f' is inflation rate

2) Other cost is the cost for the replacement of the main engine

Appendix B-2. Life Cycle Inventory for construction materials

Construction material : Wood

No	Inventory	Quantity
	Materials	
1	Steel, unalloyed {GLO}| market for | Alloc Def, S	0.4 ton
2	Sawnwood, hardwood, kiln dried, planed {RoW}| planing, hardwood, kiln dried | Alloc Def, S	32 m3
3	Alkyd paint, white, without solvent, in 60% solution state {GLO}| market for | Alloc Def, S	45 kg
4	Acrylic varnish, without water, in 87.5% solution state {GLO}| market for | Alloc Def, S	31.5 kg
5	Copper oxide {GLO}| market for | Alloc Def, S	27.5 kg
6	Zinc oxide {GLO}| market for | Alloc Def, S	13.75 kg
	Processes	
7	Electricity, high voltage {ID}| market for | Alloc Def, S	1170 kWh
8	Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S	5750 tkm

Construction material : Wood Laminate

No	Inventory	Quantity
	Materials	
1	Sawnwood, hardwood, kiln dried, planed {RoW}| market for | Alloc Def, S	28 m3
2	Epoxy resin, liquid {GLO}| market for | Alloc Def, S	230 kg
3	Alkyd paint, white, without solvent, in 60% solution state {GLO}| market for | Alloc Def, S	45 kg
4	Acrylic varnish, without water, in 87.5% solution state {GLO}| market for | Alloc Def, S	31.5 kg
5	Copper oxide {GLO}| market for | Alloc Def, S	27.5 kg
6	Zinc oxide {GLO}| market for | Alloc Def, S	13.75 kg
	Processes	
7	Transport, freight, lorry 16-32 metric ton, EURO3 {GLO}| market for | Alloc Def, S	5100 tkm
8	Electricity, high voltage {ID}| market for | Alloc Def, S	1463 kWh

Construction material : FRP

No	Inventory	Quantity
	Materials	
1	Glass fibre reinforced plastic, polyester resin, hand lay-up {GLO}| market for | Alloc Def, S	2.5 ton
2	Plywood, for outdoor use {RoW}| market for | Alloc Def, S	2.5 m3
3	Glass fibre {GLO}| market for | Alloc Def, S	4 ton
4	Sawnwood, hardwood, kiln dried, planed {RoW}| market for | Alloc Def, S	3 m3
5	Polyurethane, rigid foam {GLO}| market for | Alloc Def, S	270 kg
6	Zinc oxide {GLO}| market for | Alloc Def, S	13.75 kg
7	Copper oxide {GLO}| market for | Alloc Def, S	27.5 kg
	Processes	
8	Transport, freight, lorry 3.5-7.5 metric ton, EURO5 {GLO}| market for | Alloc Def, S	3000 tkm
9	Electricity, medium voltage {ID}| market for | Alloc Def, S	250 kWh

Construction material : Aluminium Alloy

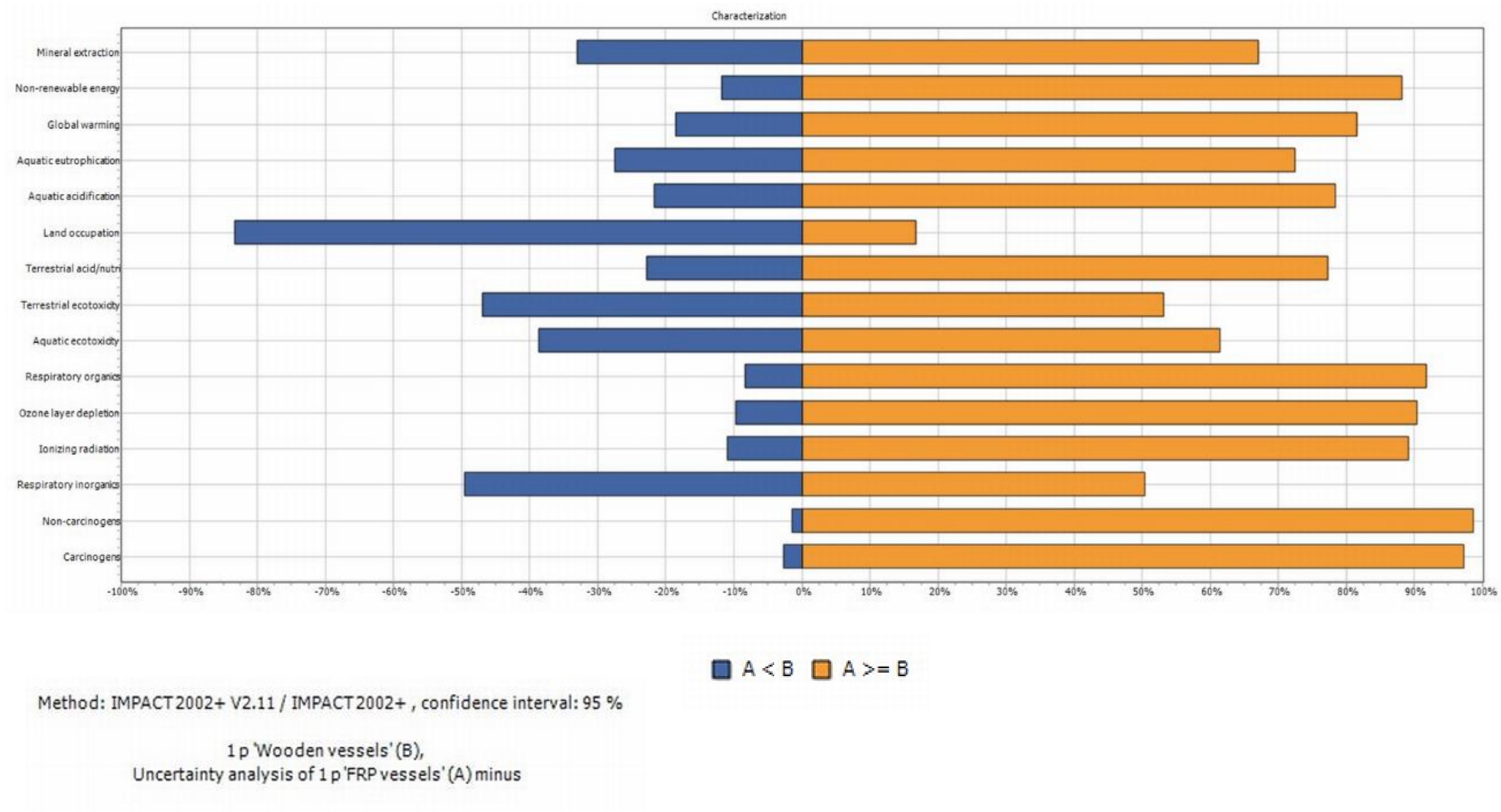
No	Inventory	Quantity
	Materials	
1	Aluminium alloy, AlMg3 {RoW}| production | Alloc Def, S	10 ton
2	Copper oxide {GLO}| market for | Alloc Def, S	27.5 kg
3	Zinc oxide {GLO}| market for | Alloc Def, S	13.75 kg
4	Zinc {GLO}| market for | Alloc Def, S	300 kg
	Processes	
5	Welding, arc, aluminium {GLO}| market for | Alloc Def, S	1500 m
6	Electricity, high voltage {ID}| market for | Alloc Def, S	500 kWh
7	Transport, freight, lorry 7.5-16 metric ton, EURO3 {GLO}| market for | Alloc Def, S	11000 tkm

Construction material : Steel

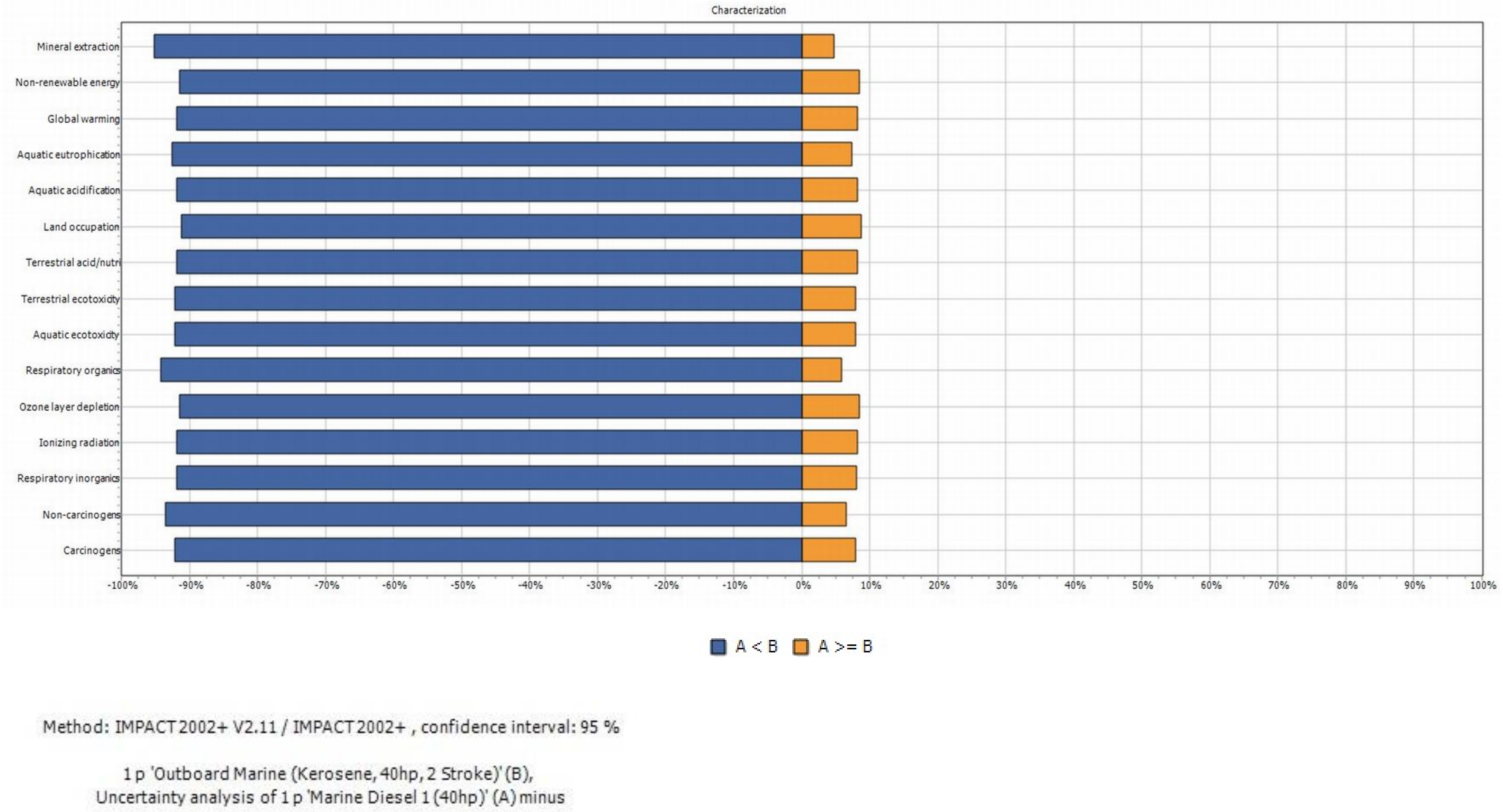
No	Inventory	Quantity
	Materials	
1	Steel, low-alloyed {GLO}| market for | Alloc Def, S	27 ton
2	Sand {GLO}| market for | Alloc Def, S	26 ton
3	Diesel {RoW}| market for | Alloc Def, S	570 kg
4	Alkyd paint, white, without solvent, in 60% solution state {GLO}| market for | Alloc Def, S	105 kg
5	Copper oxide {GLO}| market for | Alloc Def, S	27.5 kg
6	Zinc oxide {GLO}| market for | Alloc Def, S	13.75 kg
	Processes	
7	Welding, arc, steel {GLO}| market for | Alloc Def, S	1250 m
8	Transport, freight, lorry 7.5-16 metric ton, EURO3 {GLO}| market for | Alloc Def, S	33000 tkm
9	Electricity, medium voltage {ID}| market for | Alloc Def, S	5000 kWh

Appendix B-3. Example of Monte Carlo result for comparing alternative technologies

B-3.1 Midpoint impact comparison of wood and FRP constructions materials



B-3.2 Midpoint impact comparison of wood and FRP constructions materials



Appendix B-4. AHP Analysis for Alternative Construction Materials

Step 1. Pairwise comparison for criteria

Pairwise comparison matrix of the main criteria with respect to the goal

	Social	Cost	Environment
Social	1	2	5
Cost	1/2	1	4
Environment	1/5	1/4	1

Social : 5
Cost : 4
Environment : 1

Identification of Eigen Vector

a. Change each value into decimal and add it in columns

Criteria

	Social	Cost	Environment
Social	1.00	2.00	5.00
Cost	0.50	1.00	4.00
Environment	0.20	0.25	1.00
Total	1.70	3.25	10.00

b. Normalize each value by divide each value with total value for its column

Criteria

	Social	Cost	Environment
Social	0.588	0.615	0.500
Cost	0.294	0.308	0.400
Environment	0.118	0.077	0.100
Total	1.000	1.000	1.000

c. Find the average value of each criteria and alternative in row

Criteria

	Social	Cost	Environment	Eigen Vector
Social	0.588	0.615	0.500	0.568
Cost	0.294	0.308	0.400	0.334
Environment	0.118	0.077	0.100	0.098
Total				1

Consistency check

λ = Sum Column Reciprocal matrix X Eigen Vector

$$\begin{vmatrix} 1.70 & 3.25 & 10.00 \end{vmatrix} \times \begin{vmatrix} 0.568 \\ 0.334 \\ 0.098 \end{vmatrix} = 3.033$$

λmax = 3.033
n = 3.000
CI =(λ- *n*)/(*n* -1) = 0.016

RI (n = 3)= 0.580
CR = CI/RI = 0.028 ≤ 0.10

Step 2. Pairwise comparison for alternatives

1. Pairwise comparison for alternative material with respect to Criteria I (Social)

Alternatives	Wood	Wood laminate	GRP	Aluminium	Steel
Wood	1	8	5	9	9
Wood Laminate	1/8	1	1/4	2	2
GRP	1/5	4	1	5	5
Aluminium	1/9	1/2	1/5	1	1
Steel	1/9	1/2	1/5	1	1

2. Pairwise comparison for alternative material with respect to Criteria II (Cost)

	Wood	Wood laminate	GRP	Aluminium	Steel
Wood	1	1	1/3	5	5
Wood Laminate	1	1	1/3	5	5
GRP	3	3	1	7	7
Aluminium	1/5	1/5	1/7	1	1
Steel	1/5	1/5	1/7	1	1

3. Pairwise comparison for alternative material with respect to Criteria III (Environment)

	Wood	Wood laminate	GRP	Aluminium	Steel
Wood	1	1	1	6	9
Wood Laminate	1	1	1	6	9
GRP	1	1	1	6	9
Aluminium	1/6	1/6	1/6	1	4
Steel	1/9	1/9	1/9	1/4	1

Identification of Eigen Vector for Alternatives

A. Converting each value into decimal and add it in columns

A.1 Alternative material with respect to Criteria I (social)

	Wood	Wood laminate	GRP	Aluminium	Steel
Wood	1.00	8.00	5.00	9.00	9.00
Wood Laminate	0.13	1.00	0.25	2.00	2.00
GRP	0.20	4.00	1.00	5.00	5.00
Aluminium	0.11	0.50	0.20	1.00	1.00
Steel	0.11	0.50	0.20	1.00	1.00
Total	1.55	14.00	6.65	18.00	18.00

A.2 Alternative material with respect to Criteria II (Cost)

	Wood	Wood laminate	GRP	Aluminium	Steel
Wood	1.00	1.00	0.33	5.00	5.00
Wood Laminate	1.00	1.00	0.33	5.00	5.00
GRP	3.00	3.00	1.00	7.00	7.00
Aluminium	0.20	0.20	0.14	1.00	1.00
Steel	0.20	0.20	0.14	1.00	1.00
Total	5.40	5.40	1.95	19.00	19.00

A.3 Alternative material with respect to Criteria III (Environment)

	Wood	Wood laminate	GRP	Aluminium	Steel
Wood	1.00	1.00	1.00	6.00	9.00
Wood Laminat	1.00	1.00	1.00	6.00	9.00
GRP	1.00	1.00	1.00	6.00	9.00
Aluminium	0.17	0.17	0.17	1.00	4.00
Steel	0.11	0.11	0.11	0.25	1.00
Total	3.28	3.28	3.28	19.25	32.00

B. Normalising each value by dividing each value with total value of its column

B.1 Alternative material with respect to Criteria I (social)

	Wood	Wood laminate	GRP	Aluminium	Steel
Wood	0.65	0.57	0.75	0.50	0.50
Wood Laminat	0.08	0.07	0.04	0.11	0.11
GRP	0.13	0.29	0.15	0.28	0.28
Aluminium	0.07	0.04	0.03	0.06	0.06
Steel	0.07	0.04	0.03	0.06	0.06
Total	1.00	1.00	1.00	1.00	1.00

B.2 Alternative material with respect to Criteria II (Cost)

	Wood	Wood laminate	GRP	Aluminium	Steel
Wood	0.19	0.19	0.17	0.26	0.26
Wood Laminat	0.19	0.19	0.17	0.26	0.26
GRP	0.56	0.56	0.51	0.37	0.37
Aluminium	0.04	0.04	0.07	0.05	0.05
Steel	0.04	0.04	0.07	0.05	0.05
Total	1.00	1.00	1.00	1.00	1.00

B.3 Alternative material with respect to Criteria III (Environment)

	Wood	Wood laminate	GRP	Aluminium	Steel
Wood	0.31	0.31	0.31	0.31	0.28
Wood Laminat	0.31	0.31	0.31	0.31	0.28
GRP	0.31	0.31	0.31	0.31	0.28
Aluminium	0.05	0.05	0.05	0.05	0.13
Steel	0.03	0.03	0.03	0.01	0.03
Total	1.00	1.00	1.00	1.00	1.00

C. Identifying the Eigen Vector (EV)

C.1 Alternative material with respect to Criteria I (social)

	Wood	Wood laminate	GRP	Aluminium	Steel	EV
Wood	0.65	0.57	0.75	0.50	0.50	0.59
Wood Laminat	0.08	0.07	0.04	0.11	0.11	0.08
GRP	0.13	0.29	0.15	0.28	0.28	0.22
Aluminium	0.07	0.04	0.03	0.06	0.06	0.05
Steel	0.07	0.04	0.03	0.06	0.06	0.05
Total						1.00

C.2 Alternative material with respect to Criteria II (Cost)

	Wood	Wood laminate	GRP	Aluminium	Steel	EV
Wood	0.19	0.19	0.17	0.26	0.26	0.21
Wood Laminat	0.19	0.19	0.17	0.26	0.26	0.21
GRP	0.56	0.56	0.51	0.37	0.37	0.47
Aluminium	0.04	0.04	0.07	0.05	0.05	0.05
Steel	0.04	0.04	0.07	0.05	0.05	0.05
Total						1.00

C.3 Alternative material with respect to Criteria III (Environment)

	Wood	Wood laminate	GRP	Aluminium	Steel	EV
Wood	0.31	0.31	0.31	0.31	0.28	0.30
Wood Laminate	0.31	0.31	0.31	0.31	0.28	0.30
GRP	0.31	0.31	0.31	0.31	0.28	0.30
Aluminium	0.05	0.05	0.05	0.05	0.13	0.07
Steel	0.03	0.03	0.03	0.01	0.03	0.03
Total						1.00

Criteria/ Alternative	Eigen Vector		
	Social	Cost	Environment
Wood	0.59	0.21	0.30
Wood Laminate	0.08	0.21	0.30
GRP	0.22	0.47	0.30
Aluminium	0.05	0.05	0.07
Steel	0.05	0.05	0.03
Total	1.00	1.00	1.00

Final Result:

Wood	0.59	0.21	0.30				0.438	**Wood**
Wood Laminate	0.08	0.21	0.30		0.57		0.148	**Wood Laminate**
GRP	0.22	0.47	0.30	x	0.33	=	0.315	**GRP**
Aluminium	0.05	0.05	0.07		0.10		0.052	**Aluminium**
Steel	0.05	0.05	0.03				0.048	**Steel**

Appendix C

Result from Design Process of Proposed Vessel

C-1 Scantling for proposed fishing vessel

C-2 Designs drawings of proposed fishing vessel

Appendix C. Result from Design Process of Proposed Vessel

C.1 Scantling for Proposed Fishing Vessel

C.1.1 Example of scantling calculation for proposed wooden fishing vessel

Reference: Rules for Wooden Vessel, 1996 edition, Indonesian Classification Bureau

1. Principal dimension for scantling (BKI 1996 Wooden Boat; Section 3.1):
   a) Length L

      L = $\frac{L1 + L2}{2}$ (m)

      L1 = Length between perpendicular = 14.9 m

      L2 = Length of main deck parallel to design water line = 17.2 m

      = (14.9 + 17.2)/2 = 16.0 m

   b) Beam B = 5.5 m

   c) Depth H = 1.7 m

Table C-1 Scantling for Keel, Stem-post and Stern-post (Source: Table 1.A; BKI 1996 Wooden Boat)

L(B/3 + H)	Keel				Stem-post
	Cross section	Keel (Siding x moulded)	Keel and keelson (Siding x moulded)		Siding x moulded
m^2	cm^2	mm	mm	mm	mm
20	320	150 x 215	125 x 140	130 x 115	125 x 180
25	375	160 x 235	130 x 160	135 x 125	135 x 195
30	430	170 x 255	140 x 170	140 x 140	145 x 210
35	485	180 x 275	145 x 185	150 x 145	150 x 225
40	540	190 x 285	150 x 200	155 x 155	160 x 240
50	650	210 x 310	165 x 220	175 x 165	175 x 260
60	750	220 x 340	220 x 340	190 x 175	190 x 280
70	855	235 x 365	190 x 240	205 x 195	200 x 300

2. Scantling calculation for Keel, Keelson, Stem-post and Stern-post (BKI 1996 Wooden Boat; Section 4.1 & 4.2)
   a) Keel:
      - Scantling numeral for keel: L · (B/3 + H) = 56.6
      - Cross section area of keel (based on Table C-1) = 716.2 cm^2
      - Cross section in Table C-1 is for L/H ≤ 8, for L/H > 8 then the cross section should be increased based on Section 3.2.3. Cross section of keel after correction (+16%) = 830.8 cm^2
      - Dimension for keel: 200 mm (siding), 250 mm (moulded)

- Dimension for keelson: 400 mm (siding), 100 mm (moulded)

b) Stem-post:
   - Scantling numeral for stem-post: $L \cdot (B/3 + H) = 56.6$
   - Dimension for stem-post: 200 mm (siding), 300 mm (moulded)

c) Stern-post:
   - Moulded of stern-post is minimum 5% higher than moulded of stem-post, the siding can be similar
   - Dimension for stem-post: 200 mm (siding), 320 mm (moulded)

C.1.2 Example of scantling calculation for proposed FRP fishing vessel

Reference: Rules for small vessel up to 24 m, 2013 edition, Indonesian Classification Bureau

1. Principal dimension for scantling (BKI 2013 Small Vessel; Section 1-A.1.5):

   d) Length L

   $L = \frac{Loa + Lwl}{2}$ (m)

   $= (18.3 + 15.6)/2 = 16.95$ m

   e) Beam B = 5.5 m

   f) Depth (H_1) = Depth (H) + 1/6 Depth keel (H_k) = 0.9 + 0.025 = 0.925

2. Frame spacing (a) (BKI 2013 Small Vessel; Section 1-B.5.8):

   $a = (350 + L)$ (mm) $= (350 + 16.95) = 366.95 \approx 400$ mm

3. Total glass weight for shell laminate [g/m²] (BKI 2013 Small Vessel; Section 1-B.6):

3.1 Keel laminate:

$$G_K = 2.35 \cdot (350 + 5 \cdot L) \sqrt{P_{dBM}}$$

Where:

- P_{dBM} (Bottom hull loadings):

  $\geq 0.4L$ fore $= 2.7L + 3.29 = 49.055$ kN/m^2

  $< 0.4L$ aft $= 2.16L + 2.63 = 39.242$ kN/m^2

Keel laminate weight:

$\geq$ *0.4L fore* $= 2.35 \times (350 + 5 \times 16.95) \times \sqrt{49.055} = 7155.65$ g/m^2

For fishing vessels $= 1.2 \times 7155.65$ g/m^2 $= 8586.78$ g/m^2

$< 0.4L$ *aft* = 2.35 x (350 + 5 x 16.95) x √39.242 = 6400.04 g/m^2

For fishing vessels = 1.2 x 6400.04 g/m^2 = 7680.048 g/m^2

Minimum width of keel laminate:

= (25 · L + 300) [mm]

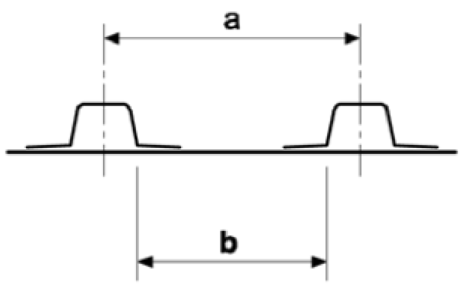
= 25 x 16.95 + 300 = 723.75 mm ≈ 800 mm

3.2 Bottom shell:

$G_{WB} = 1.57 \cdot b \cdot F_P \cdot F_{VB} \cdot \sqrt{P_{dBM}}$

Where:

- b = 350 mm



- F_P (correction factor for aspect ratio of unsupported plate panels) = 1
- F_{VB} (correction factor for speed; v=10 knot) = $0.34 \cdot \sqrt{\frac{v}{\sqrt{Lwl}}} + 0.355 \geq 1.0$

  = 1.2
- P_{dBM} (Bottom hull loadings):

  ≥ 0.4L fore = 2.7L + 3.29 = 49.055 kN/m^2

  < 0.4L aft = 2.16L + 2.63 = 39.242 kN/m^2

Bottom shell weight:

G_{WB} (≥ 0.4L fore) = 1.57 x 350 x 1 x 1.2 x √49.055 = 4679.31 g/m^2

For fishing vessels = 1.2 x 4679.31 g/m^2 = 5615.17 g/m^2

G_{WB} (< 0.4L aft) = 1.57 x 350 x 1 x 1.2 x √39.242 = 4185.19 g/m^2

For fishing vessels = 1.2 x 4679.31 g/m^2 = 5022.23 g/m^2

C.1.3 Resume of scantling calculation for proposed wooden fishing vessel

Table C-2 Resume scantling for wooden fishing vessel

No	Structural Member	Scantling	Remarks
1	***Keel*** - Total sectional area (cm^2) - Siding (mm) - Moulded (mm) ***Keelson*** - Siding (mm) - Moulded (mm)	 831 200 250 400 100	- Rule: BKI 1996, Sec.4.1 - Minimum density of wood 0.7 tonnes/m^3
2	***Stem-post*** - Siding (mm) - Moulded (mm)	 200 300	- Rule: BKI 1996, Sec.4.2 - Minimum density of wood 0.7 tonnes/m^3
3	***Stern-post*** - Siding (mm) - Moulded (mm)	 200 320	- Rule: BKI 1996, Sec.4.2 - Minimum density of wood 0.7 tonnes/m^3
4	***Transverse frame*** - Spacing (mm) - Siding (mm) - Moulded (mm)	 400 90 135	- Rule: BKI 1996, Sec.4.3 - Minimum density of wood 0.70 tonnes/m^3
5	***Floor*** - Minimum height of floor (mm) - Thickness	 200 90	- Rule: BKI 1996, Sec.4.4 - Minimum density of wood 0.70 tonnes/m^3 - The floor height is measured from the top side of the keel - Min. length of the floor is 0.4 x breadth at related position
6	***Bilge stringers*** - Siding (mm) - Moulded (mm)	 260 70	- Rule: BKI 1996, Sec.4.5 - Minimum density of wood 0.45 tonnes/m^3
7	***Beam stringers*** - Total sectional area (cm^2) Main beam stringer - Siding (mm) - Moulded (mm) Lower beam stringer - Siding (mm) - Moulded (mm)	 295.5 80 250 60 120	- Rule: BKI 1996, Sec.4.6 - Minimum density of wood 0.56 tonnes/m^3
8	***Hull planking*** Side plank and bottom plank - Thickness (mm) - Width (mm) Garboard and sheer strake - Thickness (mm)	 50 200 60	- Rule: BKI 1996, Sec.4.8 - Minimum density of wood 0.56 tonnes/m^3 - Minimum width of the garboard is 521 mm
9	***Deck beam*** - Spacing (mm) - Siding (mm) - Moulded (mm) For engine casing position - Siding (mm) - Moulded (mm)	 400 90 130 180 150	- Rule: BKI 1996, Sec.4.7 - Minimum density of wood 0.56 tonnes/m^3
10	***Deck planking*** Deck plank - Thickness (mm) - Width (mm) Margin plank - Thickness (mm)	 50 100 60	- Rule: BKI 1996, Sec.4.9 - Minimum density of wood 0.45 tonnes/m^3 - Minimum width of the margin plank is 260 mm

C.1.4 Resume of scantling calculation for proposed FRP fishing vessel

Table C-3 Resume scantling for FRP fishing vessel

No	Structure	Scantling	Remarks
1	***Keel laminate*** - Minimum glass content (g/m^2) - Minimum width (mm)	7680 800	- Rule: BKI FRP 2013, Sec.1.B.6 - Layer content: 8CSM 450 g/m^2, 6WR 800 g/m^2, 1CSM 300 g/m^2
2	***Bottom shell laminate*** - ≥ 0.4L fore, minimum glass content (g/m^2) - < 0.4L aft, minimum glass content (g/m^2)	5615 5022	- Rule: BKI FRP 2013, Sec.1.B.6 - Layer content for ≥ 0.4L fore: 5CSM 450 g/m^2, 4WR 800 g/m^2, 1CSM 300 g/m^2 - Layer content for < 0.4L aft: 3CSM 450 g/m^2, 4WR 800 g/m^2, 2CSM 300 g/m^2
3	***Side shell laminate*** - ≥ 0.4L fore, minimum lass content (g/m^2) - < 0.4L aft, minimum glass content (g/m^2)	4280 3828	- Rule: BKI FRP 2013, Sec.1.B.6 - Layer content for ≥ 0.4L fore: 3CSM 450 g/m^2, 3WR 800 g/m^2, 1CSM 300 g/m^2 - Layer content for < 0.4L aft: 3CSM 450 g/m^2, 2WR 800 g/m^2, 1CSM 300 g/m^2
4	***Floors laminate*** - Floors spacing (mm) - Minimum thickness (mm) - Cross section (top-hat type)	400 5 150x60x5	- Rule: BKI FRP 2013, Sec.1.B.6 - Layer content for floors: 4CSM 450 g/m^2, 2WR 600 g/m^2
5	***Transfer frames laminate*** - Frame spacing (mm) - Minimum thickness (mm) - Cross section (top-hat type)	400 4 80x60x4	- Rule: BKI FRP 2013, Sec.1.B.7 - Layer content for frames: 4CSM 450 g/m^2, 1WR 600 g/m^2
6	***Deck laminate*** - Minimum glass content (g/m^2)	2345	- Rule: BKI FRP 2013, Sec.1.B.8 - Layer content for deck: 2CSM 450 g/m^2, 2WR 800 g/m^2, 1CSM 300 g/m^2

No	Structure	Scantling	Remarks
7	***Deck beam laminate*** - Deck beams spacing (mm) - Minimum thickness (mm) - Cross section (top-hat type)	400 3 60x60x3	- Rule: BKI FRP 2013, Sec.1.B.8 - Layer content for deck beams: 4CSM 450 g/m², 2WR 600 g/m²
8	***Bulkhead laminate*** - Minimum glass content (g/m²)	4806	- Rule: BKI FRP 2013, Sec.1.B.7 - Layer content for bulkhead: 3CSM 450 g/m², 3WR 800 g/m², 1CSM 300 g/m²
9	***Bulkhead stiffener laminate*** - Bulkhead stiffener spacing (mm) - Minimum thickness (mm) - Cross section (top-hat type)	1000 5 100x100x5	- Rule: BKI FRP 2013, Sec.1.B.7 - Layer content for bulkhead stiffener: 4CSM 450 g/m², 2WR 600 g/m²
10	***Deckhouse wall laminate*** - Minimum glass content (g/m²)	2123	- Rule: BKI FRP 2013, Sec.1.B.8 - Layer content for deckhouse wall: 2CSM 450 g/m², 2WR 600 g/m², 1CSM 300 g/m²
11	***Bulkhead stiffener laminate*** - Deckhouse stiffener spacing (mm) - Minimum thickness (mm) - Cross section (top-hat type)	500 3 40x40x3	- Rule: BKI FRP 2013, Sec.1.B.8 - Layer content for bulkhead stiffener: 4CSM 450 g/m², 2WR 600 g/m²

Appendix C-2

Design drawings of proposed fishing vessel

Figure C-1 Final General Arrangement Proposed Vessel

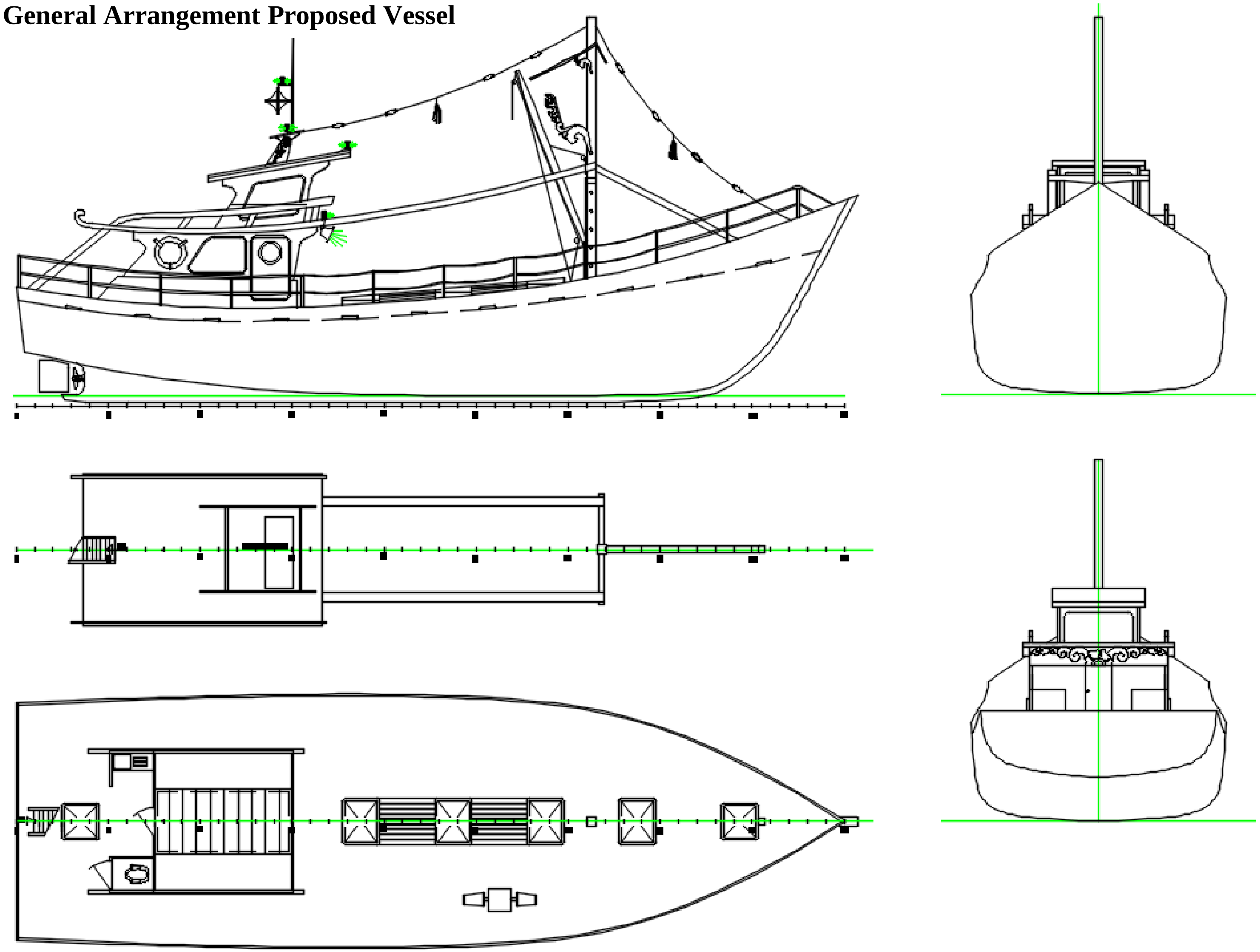


Figure C-2 Transverse Sections Wooden Proposed Vessel

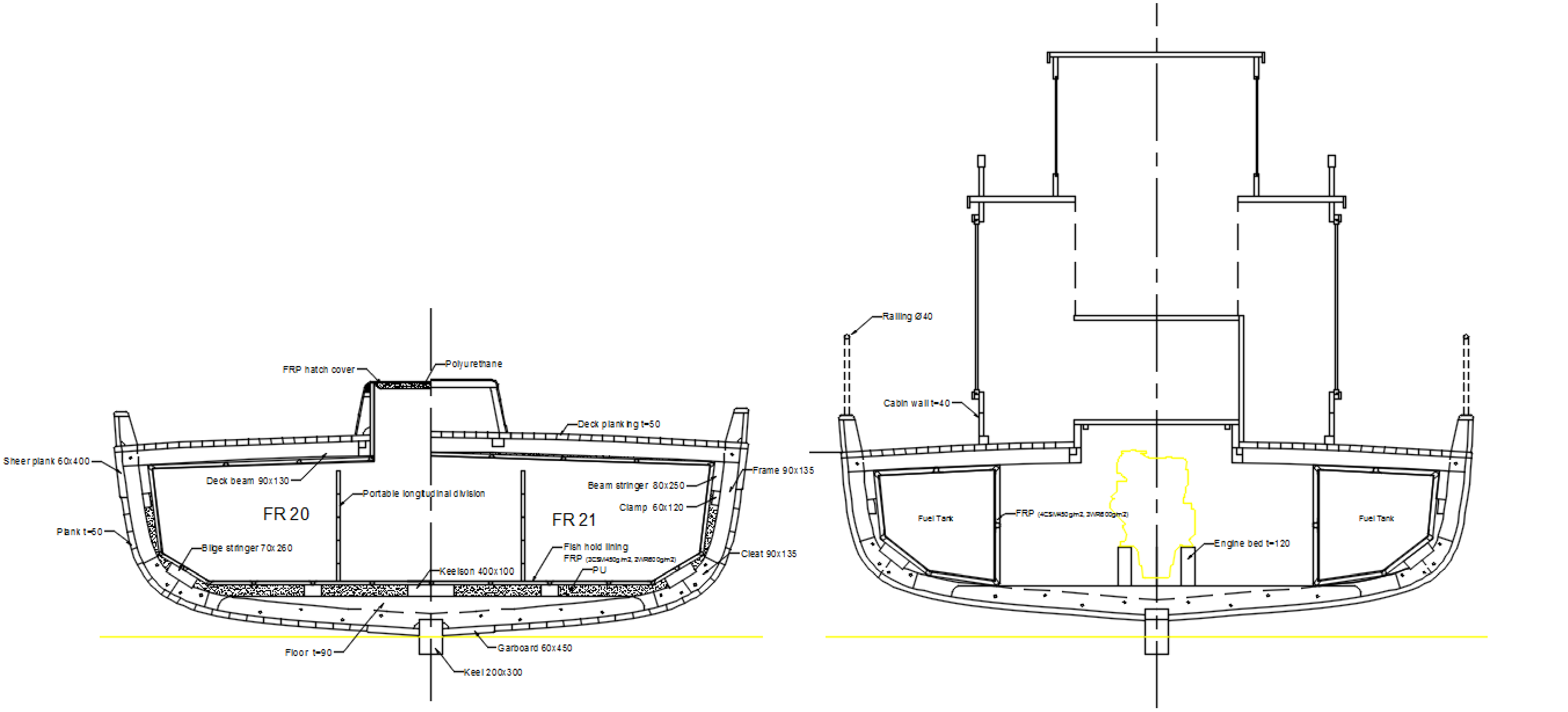


Figure C-3 Longitudinal Structure Wooden Proposed Vessel

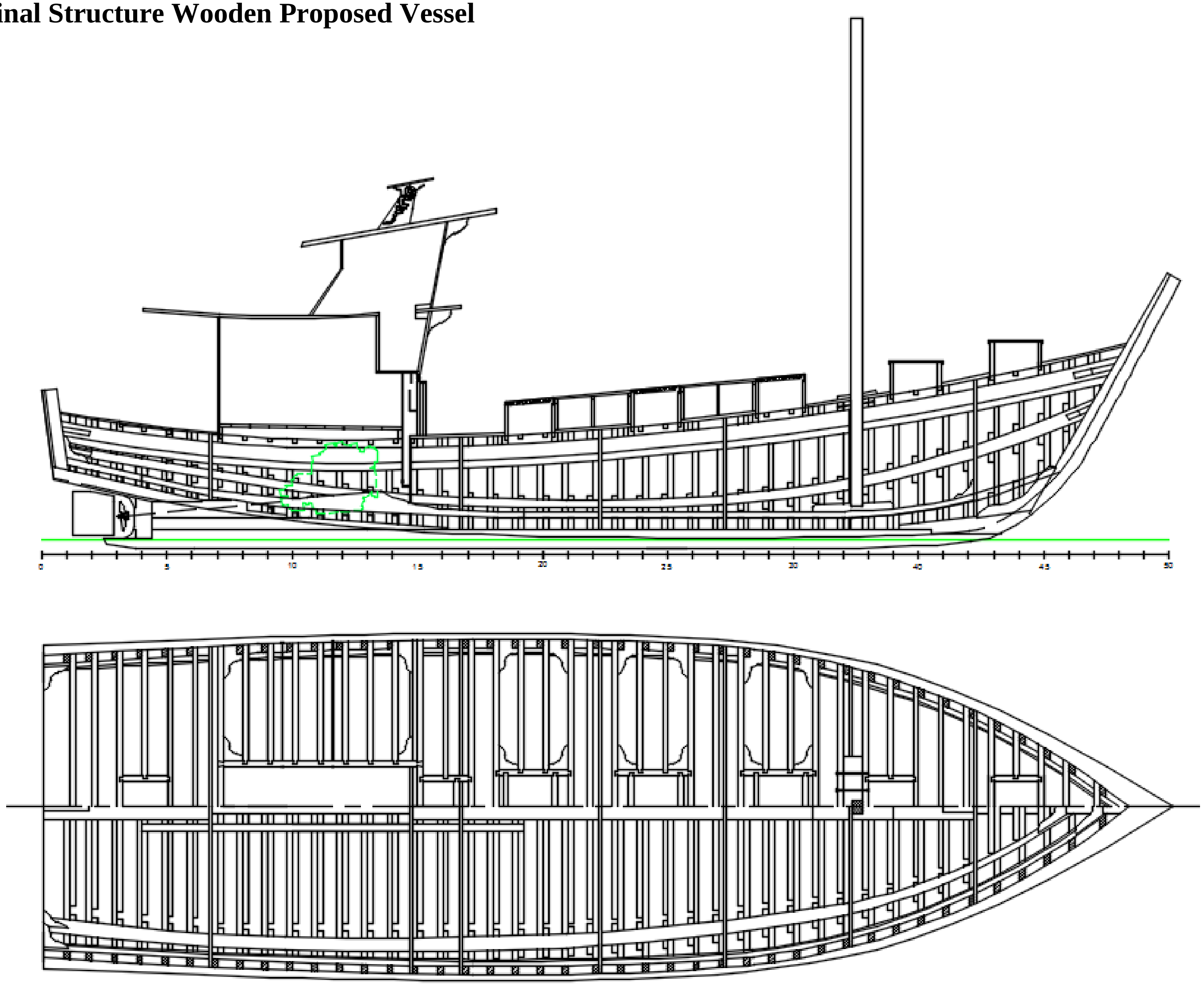


Figure C-4 Transverse Sections FRP Proposed Vessel

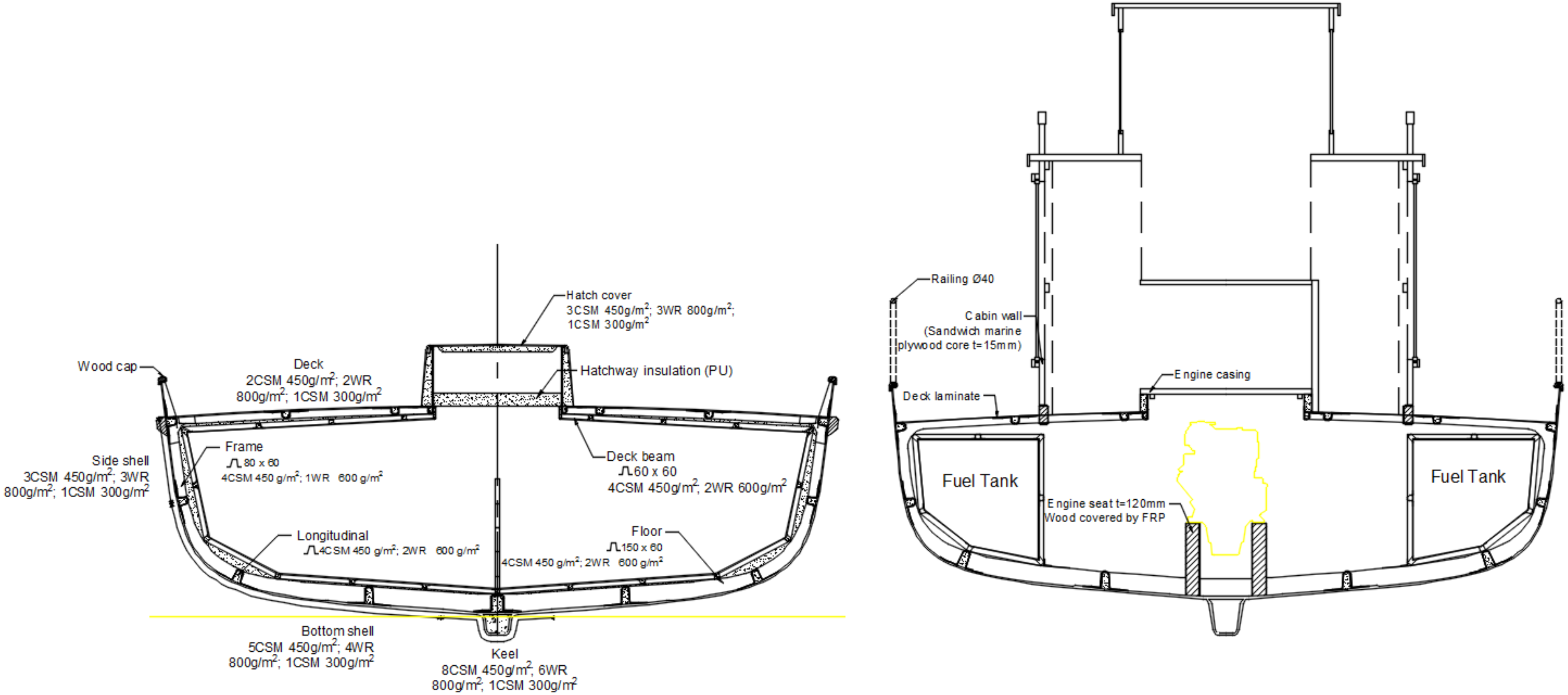


Figure C-5 Longitudinal Structure FRP Proposed Vessel