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ECONOMIC STUDY OF BLUE SWIMMING CRAB FISHING ACTIVITIES IN JAVA SEA USING ELECTRIC AND SAILING BOAT DESIGN

Kajian Ekonomi Penangkapan Rajungan Menggunakan Desain Kapal Penggerak Listrik dan Layar di Laut Jawa

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ABSTRACT

The United Nations has proclaimed the world's commitment to reducing greenhouse gas emissions in the Paris Agreement, and Indonesia has a net zero emissions target by 2060. One of the efforts to support this commitment is by applying environmentally friendly fishing vessel technology using sail and electric propulsion. However, to convince the application, it is necessary to consider several aspects, especially the economic aspect of business investment. This study aims to calculate the estimated cost of boatbuilding and fishing operations for 10 days in the Java Sea using the development of electric sailboat design. The payback period of a feasible investment is then calculated by comparing the revenue from Blue Swimming Crab (BSC) fishing activities. Based on the result, recognizing that with an investment value of nearly 400 thousand USD to purchase the boat, it is reasonable to set a minimum goal of capturing at least 1,2 Ton of crabs per trip, and a minimum of 20 trips annually, thus the payback period takes 10 years.

Keywords: *Blue swimming crab, Fishing vessel, Java Sea, Net zero emission, Payback period.*

ABSTRAK

Perserikatan Bangsa-Bangsa (PBB) telah mencanangkan komitmen dunia untuk mengurangi emisi gas rumah kaca dalam "*Paris Agreement*" dan Indonesia memiliki target *net zero emissions* pada tahun 2060. Salah satu upaya untuk mendukung komitmen tersebut adalah dengan menerapkan teknologi kapal penangkap ikan ramah lingkungan yaitu kapal yang menggunakan penggerak elektrik dan layar. Namun, untuk meyakinkan aplikasi teknologi tersebut, diperlukan pertimbangan dari beberapa aspek, terutama aspek ekonomi dari sudut pandang investasi kapal. Studi ini bertujuan untuk menghitung estimasi biaya pembuatan kapal dan operasi penangkapan rajungan selama 10 hari di Laut Jawa menggunakan desain kapal layar listrik yang dikembangkan.

Kemudian membandingkan pendapatan dari kegiatan penangkapan rajungan untuk menentukan *payback period* dari investasi yang layak. Berdasarkan hasil studi, disimpulkan bahwa dengan nilai investasi pembuatan kapal hampir 400 ribu US Dolar atau 6 Milyar Rupiah, diperlukan hasil tangkapan minimal 1,2 ton rajungan tiap trip dan 20 trip tiap tahun, sehingga diperlukan waktu 10 tahun untuk mengembalikan modal usaha.

Kata kunci: Kapal perikanan, Laut Jawa, *Net zero emission, Payback period*, Rajungan.

INTRODUCTION

The Paris Agreement is the basis for UN member states to commit to combating global warming due to climate change, which plans on lowering greenhouse gas (GHG) emissions by 43% in 2030 to maintain efforts to keep the rise in the world average temperature to far below 2^{o}C (Parker *et al.* 2018; Rogelj *et al.* 2016; UNFCCC 2023). China, Indonesia, Vietnam, the USA, and Japan are the world's five biggest countries emitting greenhouse gasses, with 49% of total emissions in 2011, creating 81 million tons of CO^2 equivalent collectively (Parker *et al.* 2018).

Indonesia, in the National Determined Contribution (NDC) document, is committed to reducing GHG emissions with targets of 31.89% (conditional) and 43.2% (unconditional) by 2030. Moreover, based on the Ministry of Energy and Mineral Resources press release on October 8th, 2021, Indonesia had determined a roadmap to achieve net zero emissions by 2060, which involves the use of five key principles: expanding the use of new and renewable energy, lowering the use of fossil fuels, using electric vehicles for transportation, increasing the use of electricity in homes and businesses, and using Carbon Capture and Storage (CCS) (esdm.go.id 2023).

In ASEAN, Indonesia's chairmanship in 2023 emphasizes the blue economy as a key sector for sustainable regions in the future, and one of the sub-sectors that has been established is capture fisheries (Widyasanti *et al.* 2021). Indonesia's Long-Term National Development Plan (RPJPN) 2005-2025 incorporates the blue economy's focus on the sustainable use of marine resources into national and municipal policies, although achieving ocean sustainability is difficult due to unsustainable and environmentally harmful fishing activities (Can & Dartanto 2023; Wibawa *et al.* 2015).

Fishing vessels are one of the major sources of dangerous gasses in the supply chain for seafood products. Therefore, although they are not currently required to adhere to IMO requirements, they are projected to do so (Jafarzadeh *et al.* 2017; Koričan *et al.* 2023). In Indonesia, around 89 percent of fishing vessels have a gross registered weight (GT) of less than 10 (Kurniawati *et al.* 2023). Furthermore, in the Java Sea or WPP 712, the optimal number of fishing vessels is 44.243 units based on potential resources (Ardiyani *et al.* 2019).

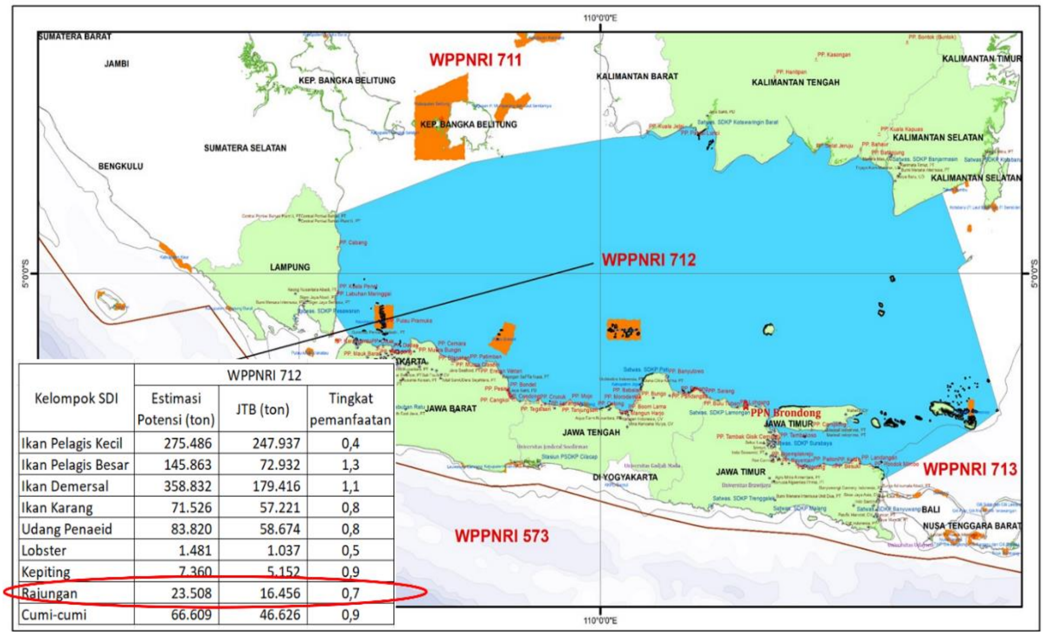
Blue Swimming Crab (BSC) is a valuable export commodity of fishery products and must be maintained sustainably to serve as a source of welfare for Indonesian fishermen (Redjeki *et al*. 2021; Kamelia & Muhsoni 2020; Rahman *et al.* 2019; Muawanah *et al.* 2017). The majority of Indonesian BSCs are distributed in the US market (Laksono *et al.* 2023; Cendrakasih *et al*. 2023). Particularly for BSC fishing activities, nets, and traps are the predominant friendly fishing gear used on BSC fishing vessels than others (Endrawati *et al.* 2023). Further, Wiloso *et al.* (2022) claim that BSC fishing boats using traps have an environmental impact of up to three times greater than nets because trap vessels utilize diesel, making them catch farther and need more fuel. However, trap fishing gear has a high level of selectivity compared to nets due to low by-catch (Hufiadi 2017; Zulkarnain *et al.* 2019; Utami *et al*. 2020), and crabs that are captured under liveable conditions also have the mobility to the wider fishing ground (Susanto *et al*. 2021; Jayanto *et al.* 2018). According to research findings by Ummaiyah *et al.* (2017) in Rembang, by Susanto *et al.* (2023) in Bangkalan, and by Soegiri *et al.* (2014) in Jepara Regencies has an extremely high level of environmental friendliness >90% based on the weight ratio of primary and side catches.

According to Wiloso *et al.* (2022) findings, for one ton of BSC catching use fishing traps is around 386 liters of diesel fuel burning. Hence, achievement or innovation is required in applying BSC fishing traps to reduce fossil fuel as an alternative for business actors having a role in the government program, along with the principles of the blue economy and simultaneously achieving success toward net zero emissions. Addressing this issue necessitates a shift towards sustainable alternatives, such as transitioning to electric propulsion systems or exploring renewable energy sources like wind power. By embracing cleaner technology and practices, BSC fishing boats can mitigate their environmental impact, paving the way for a more sustainable future for marine ecosystems and fishing communities alike. Furthermore, both technical and non-technical perspectives on using ecologically friendly fishing boats for BSC fishing activities in Indonesia with sail and electric propulsion are fascinating to explore, especially regarding economy and investment. This study aims to calculate the estimated cost of boatbuilding and fishing operations for 10 days in the Java Sea using the development of electric sailboat design. The payback period of a feasible investment is then calculated by comparing the revenue from Blue Swimming Crab (BSC) fishing activities.

BSC fishing regulation in the Java Sea or 712 Fisheries Management Area (WPP NRI 712)

The Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 79/KEPMEN-KP/2016 mainly governs the laws pertaining to fishing in WPP NRI 712. The WPP NRI 712 fisheries management plan is contained in this regulation. Decree Number 70/KEPMEN-KP/2016 of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia also concerns the Management Plan of BSC Fisheries in the State Fisheries Management Area. More specifically, the regulation of the Director General of Capture Fisheries Number 6/PER-DJPT/2020 relating to the Harvest Strategy BSC in the WPP NRI 712 since this region produces the most BSC (49% of the country's total production), has the most fish processing units (UPIs) (65% of which are used for processing BSC), has the most mini plants (57%) and BSC fishermen (50%) in Indonesia and has a jointly managed population (www.kkp.go.id 2023).

As can be shown, WPP NRI 712 has a BSC potential of 23.508 tons, a maximum allowable quantity of 16.456 tons, and a utilization rate of 0,7 which are those whereby fishing activity is sustained according to close monitoring and for fleets engaged in BSC fishing in this area that primarily use boats under 10 GT that are subject to provincial permit (Number 6/PER-DJPT/2020). According to APRI (Indonesia BSC Management Association), in 2021, 36.000 BSC fishing boats are expected to use traps to operate in shallow water. 10% of boats are larger than 5 GT, 30% between 2-3 GT, and the remainder are smaller than 2 GT (Wiloso *et al.* 2022). Furthermore, the BSC management authority must develop an effective management strategy using info regarding ecology, availability, sustaining perspective, and capture capabilities (Putra *et al.* 2023).



Kelompok SDI	WPPNRI 712		
	Estimasi Potensi (ton)	JTB (ton)	Tingkat pemanfaatan
Ikan Pelagis Kecil	275.486	247.937	0,4
Ikan Pelagis Besar	145.863	72.932	1,3
Ikan Demersal	358.832	179.416	1,1
Ikan Karang	71.526	57.221	0,8
Udang Penaeid	83.820	58.674	0,8
Lobster	1.481	1.037	0,5
Kepiting	7.360	5.152	0,9
Rajungan	23.508	16.456	0,7
Cumi-cumi	66.609	46.626	0,9

Figure 1 Shows the WPP NRI 712 with estimated potential, allowable catches, and utilization rate of fish resources (Source: No.19/KEPMEN-KP/2022) (kkp.go.id 2023).

BSC fishing opportunities with sailing and electric propulsion vessels

Globally, nations desire to completely phase out the usage of fossil fuels by 2050 or 2060 in preference for renewable energy sources (Wijaya & Widoatmodjo 2023). The development of hybrid energy systems, a crucial alternative to the goal of zero-carbon transport, will be sped up by new mitigation regulations for harmful emissions (Koričan *et al.* 2023). Sail technology for propelling the fishing boat in the Java Sea has plenty of potential based on the velocity and direction of the wind in this region (Setiyobudi *et al.* 2023). A study by Purwanto & Utama (2015) demonstrated the effectiveness of solar power and sail drive on monohull ships with a displacement of 6 tons and a top speed of 6 knots. With a displacement of 53,69 tons and a sail area of 270,34 square meters, the catamaran sailing ship can travel at a speed of 11,51 knots in winds of 20 knots (Saputro *et al.* 2014). A 281 Gross Tonnage wooden ship with sail drive and electric motors is currently being developed by Sailcargo Inc. in Costa Rica (SAILCARGO INC. 2023). Another study by Octaviani *et al.* (2023) concluded that one way to lower CO2 emissions in the marine industry is to electrify boats, by replacing the traditional diesel with an electric propulsion system.

Based on the study above and application findings, the development of this sail and electric drive system for fishing is quite intriguing because it has the advantages of being environmentally friendly, quiet, and easy to maintain as well as being a potential future mover (Sunardi & Pamungkas 2019). With the average wind speed in the Java Sea being 4-6 m/s or 8-12 Knots during the East Monsoon (Sofiati *et al*. 2020), there is potential to propel sailing fishing boats at speeds of 5-7 Knots (Anderson 2008).

Investment consideration in sailing and electric vessel for BSC fishing

The largest export markets for Indonesia BSC are the United States, Japan, Malaysia, and Singapore. In order to keep being competitive with other exporting nations, tactical steps must be implemented to improve production effectiveness and employ technology to cut production costs (Luhur *et al.* 2020). Electric and sail-powered boats are anticipated to lower production costs while reducing global warming. One of the things to be aware of before investing in BSC fishing boats with electric and sail propulsion is commodity price information, as the price of BSC from fishermen changes significantly depending on the season. The reference price of BSC in 2023, according to the Ministry of Marine Affairs and Fisheries, was about 4,7 USD per kg (www.kkp.go.id 2023). This study focuses on calculating and analyzing boatbuilding cost, operational cost, and revenue to analyze the payback period for the boat's investment.

Investment economics assessment of sail-and-electric-drive BSC fishing vessel

Developing electric and sail-powered BSC fishing boats is a volunteer endeavor to offer fishermen another option to cut operating costs. Additionally, this concept is a work to create an environmentally benign fishing fleet. Moreover, considering the boat's financial investment, a complete assessment should be made before the boat is built.

Even though some of the data presented are secondary, this evaluation aims to go into more detail about the potential benefits of investing in this boat. Nevertheless, it is generally understood that BSC fishing vessels with sail and electric propulsion will undoubtedly require more capital than conventional. Furthermore, according to Fyson (1985), operational costs, maintenance costs, personnel costs, port charges, taxes, and other factors are also very important. Last but not least is the fluctuating market price of BSC items in question.

Investment evaluation is examined under the assumption that capital is partially obtained from the bank loans, and two methods, that is the calculation of Accounting Rate of Return (ARR) and Internal Rate of Return (IRR) and added with the calculation of Payback Period analysis and Net Present Value (NPV), can be used to make decisions. The ARR, a technique for calculating the projected return on a new investment, is the percentage ratio of average net income per year to capital. The IRR calculation, however, is more difficult since it must consider many factors, such as the estimated service life, investment cash flow, present value concept, appropriate rate of interest, and others (Fyson 1985).

MATERIALS AND METHODS

This study aims to calculate the estimated cost of boatbuilding and fishing operations for 10 days in the Java Sea using new electric sailboat design. The payback period of a feasible investment is then calculated by comparing the revenue from Blue Swimming Crab (BSC) fishing activities. With

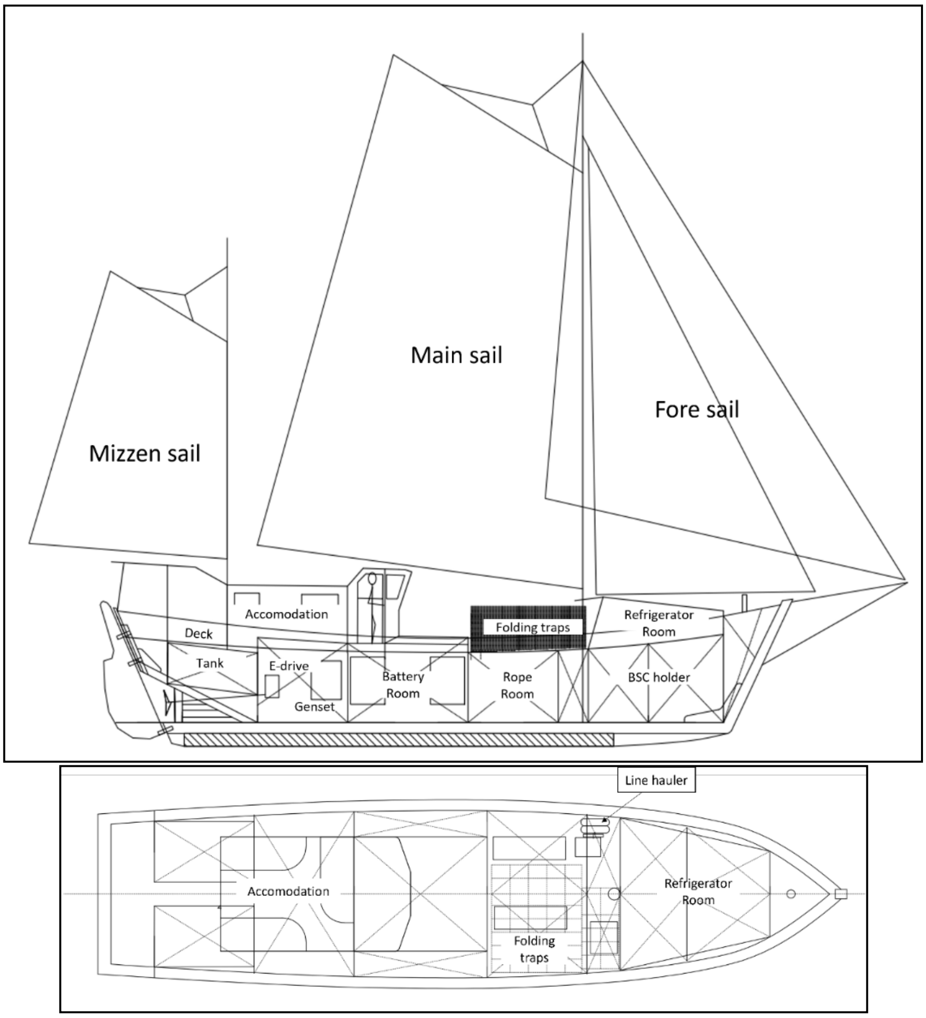


Figure 2 The general arrangement of sail and electric BSC fishing boat developed design.

the support of the Microsoft Excel program, data analysis is performed by applying several kinds of calculation methods, including Accounting Rate of Return (ARR), Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP), after which the results of the analysis and calculation are interpreted.

The dimensions of the vessel employed in this study are based on the size data of the developed design, which pertains to BSC fishing vessels in Rembang Regency, Central Java, that use bugisan-type. The boat dimension according to the development is as follows:

Length over All (LoA) : 15,7 Meter
Breadth (B) : 4 Meter
Depth (D) : 1,64 Meter
Draft (T) : 1,2 Meter
Displacement (Δ) : 32 Ton
BSC Capacity : 2 Ton
Propulsion
- Sail : 189 Meter2 (total) use gaff ketch rigging
- Speed using sail : 5-9 Knot (wind speed between 6-15 Knot)
- Electric drive : 30 kW
- Speed using electric : 6 Knot

Aux. Generator set : 2 x 20 kW.
Battery Capacity : 160 kWh
Traps Capacity : 2000 pcs

More secondary data came from the internet, books, journals, and conversations with Mr. Widodo, crab fishermen in Rembang which investigated from October to November 2022. These data support the estimation of boatbuilding costs, operating costs, income, and others. Additionally, information on the patterns of crab fishing operations and the fishing grounds was gleaned from interviews and backed by GPS data of fishermen in order to calculate the vessel's journey distance and direction of movement.

The following is an illustration depicting the operational area for catching BSC in the Java Sea:

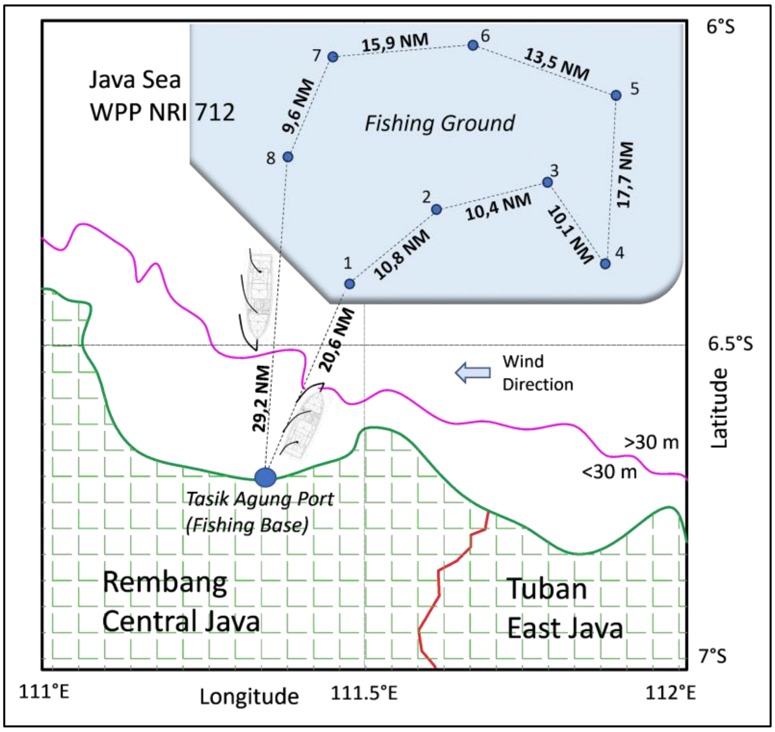


Figure 3. The scenario of the operational journey for catching BSC in the Java Sea-Indonesia (WPP NRI 712) during the East season.

From the illustration above, the details of the operational activities for BSC catching using sail and electric propulsion are as follows:

Day 1 :
- Exiting the Port area using electric propulsion
- Sail propulsion travels around 20 nautical miles to reach the fishing ground 1
- Setting the BSC traps in the fishing ground area using electric propulsion

Day 2 to 9 :
- Activating the hauling machine to harvest crabs using electric propulsion
- Moving toward the next fishing ground while simultaneously setting traps using sail propulsion

Day 10 :
- The journey back to the Port (fishing base) using sail propulsion
- Entering the Port area using electric propulsion

The next step, based on the above fishing operation trip scenario, is to calculate the revenue from BSC sales, assuming that the boat will operate for 200 days in a year or 20 trips with the remaining time spent on repair and preparing for the unpredictable Western season. Therefore, the following table assumes that fishermen's annual income for the six years is as follows: (Note that the average price of a kilogram of crabs is 4.7 USD according to fish reference price in 2023).

Table 1 is not actual field data; rather, they are based on information gathered from interviews with Rembang fishermen generally, which is how the crab catch projection experiment above was conducted. This is done in order for it to serve as a general account of the crab captured from each trip and in regard to fishermen's reports that the amount of crab caught fluctuates greatly based on the time of year and fishing area. The simulation will be used as a reference in economic calculations with a range of catch results per trip between 800 Kg to 1,700 Kg or approximately USD 3,733 to USD 7,933 gross income per trip.

The evaluation was calculated using these references,

Accounting Rate of Return (ARR)

ARR is frequently used by bankers and businesses to quickly and readily determine whether an investment is feasible, but it has two drawbacks: it does not adequately account for the age of investment and does not include potential future changes in currency values (Fyson 1985).

$$ARR = \frac{Net\ Profit}{Invesment\ cost} x100\% \quad \text{................(1)}$$

Table 1 Estimation/projection of crab catch for 6 years.

Trips	Catch (Kg) in Year to-					
	1	2	3	4	5	6
1.	1,200	1,000	2,200	800	1,500	450
2.	950	900	2,000	1,300	1,300	500
3.	850	1,300	1,000	1,200	1,900	800
4.	1,250	1,700	1,400	1,000	1,800	900
5.	1,500	800	1,800	1,900	1,700	1,300
6.	1,100	1,100	1,300	1,300	1,100	1,600
7.	500	1,400	1,900	1,200	1,000	1,300
8.	350	1,200	2,100	800	1,800	1,000
9.	750	750	1,900	750	1,400	300
10.	1,200	650	1,900	450	1,300	250
11.	1,000	400	1,700	200	2,000	500
12.	950	700	1,900	700	2,100	1,800
13.	1,200	1,000	1,800	800	1,300	1,000
14.	1,600	1,300	1,100	1,100	1,000	1,300
15.	450	2,000	1,300	1,500	850	500
16.	500	1,000	2,100	1,600	750	700
17.	1,500	1,500	1,500	1,900	300	500
18.	1,200	400	1,900	1,000	1,900	600
19.	1,000	250	1,200	950	1,700	200
20.	450	1,000	2,200	1,900	1,300	500
Average/trip	**975**	**1,018**	**1,700**	**1,117**	**1,400**	**800**
In USD	**4,550**	**4,778**	**7,933**	**5,215**	**6,533**	**3,733**

Internal Rate of Return (IRR)

As previously stated, this approach is considerably more thorough than ARR. This approach, also known as the discounted rate of return, is used to reduce net cash flows, resulting in a present value equal to the investment amount (Samuel & Jowis 2013). IRR serves as a depiction of the actual profits made by investors from the project's development and an assessment of an investment's degree of efficacy (Amalia *et al.* 2019).

- Service life estimation

  In this situation, service life is required to determine total revenue and expenses because this economic life depends on the investment product's constituent parts. For wooden boats in Indonesia, the type of wood used significantly impacts their durability and economic life. In addition to wood, a few parts, including machinery, sails, batteries, and more, will be considered when estimating the economic life of a boat. At the very least, the boat will also have a residual value or a salvage price once its economic life is through.

- Investment cash flow

  Describe the state of the investment's financial flows, which are negative when there are outlays of money and positive when there are inflows. Moreover, it should be emphasized that net annual cash flow clearly exceeds net profit (Fyson 1985).

- Present value concept

  This IRR approach considers the future value of money, unlike the ARR. Future dollar values will be lower than current ones. This is because money has a variable earning capability that depends on how it is used (Fyson 1985).

- Appropriate rate of interest (ARI)

  The suitable interest rate for the investment must be determined to assess the present value of money received in the future. The ARI must be more than the interest rate on the loan if a boat investor plans to borrow money from a bank to fund part of the project.

Net present value (NPV) has a comparatively powerful advantage in determining investment suitability due to its consideration of the time value of money (Samuel & Jowis 2013).

$$NPV = \sum_{t=1}^{n} \frac{P_t}{(1+i)^t} - Io \qquad (2)$$

With:

Pt = Net cash flow year to t
i = interest rate (discount rate)
n = Duration of Investment
Io = Value of the initial investment in year 0

The investment is permissible if the NPV is greater than zero, and the investment is rejected if the NPV is less than zero. If the NPV is equal to zero, then the investment is neutral.

Payback Period is calculated to determine how quickly an investment will yield a return and can be measured using the following formula:

$$PP = \frac{F}{G} x\ (1\ Year) \quad \text{.............................(3)}$$

With:
PP = Payback Period
F = Total investment
G = Total revenue per year

RESULT

This boat was designed to be able to run with sail and electric propulsion, having each system of propulsion being operated alternately not simultaneously. The vessel is operated mostly by sail drive, meaning that electric power is only required when conditions arise, such as when leaving and entering a port or while adjusting the boat's position when hoisting the traps. The operation of sails on fishing boats involves several key mechanisms that allow the sails to harness wind power efficiently for propulsion. When the wind blows from east to west in the Java Sea, for instance, during the eastern season, sailing boats can use it to cruise from south to north or vice versa, which is advantageous for fishermen in Rembang or along Java's north coast. Sail power can supplement or even replace traditional engine propulsion.

However, it stands to reason that sophisticated technologies and sustainability concepts will affect the cost of investment. These BSC fishing boats may have high start-up costs due to their substantial technological and environmental investment, but the long-term advantages will exceed that cost. The vessel's primary draw are its favorable reputation for international fishing and operational sustainability.

Before determining if an investment in sails and electric propulsion fishing vessels is appropriate, several estimations and assumptions must be made.

- Estimated boat building cost and technical lifespan.

A vessel's cost is greatly influenced by how it was built, the caliber of the materials, and the construction standards utilized. The norms of the Indonesian Classification Agency and the Ministry of Transportation of the Republic of Indonesia are referenced in this study. Moreover, for the estimated price of each component in this boat, references are made to online data sources and seller interviews. To determine the vessel's estimated price, complete the following Table 2.

From the estimated construction cost of the boat above, the required cost for a new building with the sail and electric propulsion design is USD 396,336 or around USD 400,000. It is a significant investment for fishermen to acquire a boat with such environmentally friendly technology.

Next, establish the boat's expected technical life and its percentage of residual value to calculate the depreciation value every year. The vessel we developed has a technical life expectancy of 20 years, and at the end of the economic year, it is worth 39,634 USD, or 10% of the boat's purchase price. According to the evaluation above, the annual depreciation value is USD 18,773.

- The estimated the expenses

The next estimate is to figure out how much each year is spent on expenses in each BSC-catching operation. The breakdown of the cost for running an electric and sail-powered BSC boat is as follows in Table 3.

The expenditure estimate is based on the boat owner's expenses on each journey, totaled over the course of a year. The estimate is calculated using information directly obtained from fishermen as well as data from scientific journals used as a reference. Maintenance cost for instance, the references used are data from several journals: Samuel & Jowis (2013) indicates 3% of the boat's price, Saputra *et al.* (2011) indicate 6%, and Amalia *et al.* (2019) indicates 18%. Then, the average of these reference data is taken for the maintenance cost over one year, which is 8.87% of the boat's price estimated.

Table 2 The vessel's estimated price.

No.	Part	Material	Unit	Volume	Unit Price	Price (USD)
1.	**Hull Construction**					**58,532**
	- Keel & stem/stern post	Ironwood	m^3	1.78	2,000	3,556
	- Planking, deck, beam, mast, and others	Teak wood	m^3	13.36	1,067	14,249
	- Frame & knee	Nyamplung	m^3	2.51	667	1,676
	- Beam shelves, seating	Bangkirai	m^3	2.31	733	1,695
	- Ballast keel	Steel	Kg	6,217	1.3	8,290
	- Fastening	Marine use	Kg	700	5.3	3,733
	- Manpower, tool, coating, finishing & consumable	-	lot	1	25,333	25,333
2.	**Machinery and Electrical**					**205,436**
	- Generator set. 20 kVA	Marine	Unit	2	7,022	14,043
	- Electric-drive 30 kW	Marine	Unit	1	76,678	76,678
	- Mechanical system of propulsion	Marine	Set	1	1,333	1,333
	- Electric line hauler	Marine	Set	1	2,333	2,333
	- Refrigerator system	Marine	Set	1	1,533	1,533
	- Fresh water generator	Marine	Set	1	1,533	1,533
	- Machinery installation	Marine	Lot	1	667	667
	- Battery LiFePo4 80 kWh	Marine	Set	2	47,361	94,722
	- Solar panel 545 WP	Marine	Unit	6	210	1,260
	- Control system	Marine	Set	1	6,667	6,667
	- Installation and cabling	Marine	Set	1	4,667	4,667
3.	**Outfitting**					**27,824**
	- Tank, pump, and pipeline	Marine	Lot	1	5,109	5,109
	- Safety equipment	Marine	Lot	1	1,180	1,180
	- Sail & rigging	Marine	Lot	1	14,758	14,758
	- Navigation equipment	Marine	Lot	1	1,923	1,923
	- Accommodation Equipment	General	Lot	1	620	620
	- BSC holder					
	- Fishing gear (traps & roping)	Marine	Lot	1	400	400
		Marine	Lot	1	3,833	3,833
4.	Detail design	-	Lot	1	8,754	8,754
5.	Launching	-	Lot	1	13,333	13,333
6.	Certification	-	Lot	1	14,000	14,000
7.	Overhead	-	Lot	1	29,179	29,179
Total						**357,059**
Tax						**39,276**
Grand total						**396,336**

Table 3 Annual expenditures estimation

No.	Item	Unit	Volume	Unit price (USD)	Total/ Trip (USD)	Total/ Year (USD)
1.	Fuel oil (diesel)	Litre	300	0.53	160	3,200
2.	Bait	Kg	200	0.8	160	3,200
3.	Food supplies	Man-day	40	5	200	4,000
4.	Freshwater	Liter	1000	0.01	6.67	133
5.	Charging from the grid (PLN)	Kwh	160	0.11	17.8	356
6.	Crew salaries 4 men (Skipper can be 2 part)	Man-day	50	13.33	666.67	13,333
				Regular expenses	1,211	24,223
	Maintenance (8,87% from boat unit price) (ref.)				1,652	33,052
				Total operating expenses	**2,863**	**57,275**

The anticipated 300 liters of fuel required for the generator set is to charge batteries for ten days at sea. This amount of diesel fuel required is according to technical requirements (290 grams/kWh), and the calculation assumes that the boat predominantly moves using sail propulsion from the Port (fishing base) to the fishing ground and vice versa, as well as between fishing grounds. For bait needs, food supplies, freshwater, grid electricity, and crew salaries are also routine expenditure estimates that must be paid for each trip.

Therefore, for each voyage, the routine expenditure amounts to USD 1,211, and when maintenance costs of USD 1,652 are added, it becomes USD 2,863. And over one year, the total estimated operational expenditure of the vessel is approximately USD 57,275.

The analysis was conducted using Microsoft Excel with an anticipated boat life of 20 years and the ARR, PP, IRR, NPV, and BEP evaluation criteria, based on the scenario and projected expenses above. The expected income from the crab capture, which ranges from 800 kilograms each trip to 1,700 kilograms per trip, is used to vary the computations. The calculations' outcomes are as follows (Table 4).

A detail of the 20-year cumulative cash flow for each condition from 1 to 10 can be seen in the graph below (Figure 4).

According to the evaluation's results, for the simple criteria of ARR and PP, a percentage of ARR more than 10% can be attained if BSC fishing earnings average 1,100 Kg per trip and the Payback Period (PP) is set at nine years and ten months. And PP will be faster if accompanied by an increase in income. Subsequently, there are more intricate computations for the IRR, NPV, and BEP requirements. These calculations entail evaluating changes in currency value as well as total cash flows, including the depreciation value of boat assets. According to the table above, an average revenue of 1,200 Kg per trip for fishermen can result in an IRR above 10%, which is correlated with a positive NPV value and breakeven (BEP) in year 10. In accordance with the above analysis, in order for capital to be recovered within ten years, a BSC fishing vessel with electric propulsion and sails that have an investment value of nearly USD 400,000 must aim to catch at least 1,200 Kg of crabs per trip and at a minimum 20 trips in a year.

These BSC fishing boats may have a high initial cost due to their substantial technology and environmental investments, but the long-term advantages will outweigh that cost. The following is a simulation of the difference in fuel consumption of each propulsion (Table 5).

Only the fuel needed for boat propulsion is shown in the above table. Diesel fuel usage is utilized in the development of sail and electric propulsion boats to meet battery charging requirements, additionally, diesel fuel usage is utilized on Rembang boats presently in service to meet the demands of their 120 HP propulsion conventional engine. The three drive variants have the same mileage and speed, but they differ significantly. For example, the sail drive uses just 94 liters of fuel for an electric drive while entering and exiting ports and when hauling pots. In the meanwhile, the generator set needs 215 liters of diesel fuel if using a full electric drive. For conventional drivers that exist in fishermen, fuel needs in one trip are 387 liters.

Table 4 Evaluation criteria calculation

Condi-tion No.	BSC Catch /trip (Kg/USD)	Criteria									
		ARR (%)		PP (Year)		IRR (%)		NPV		BEP in year	
		Min. 10		Min. 1		Min. 10		Min. 0		Min. 1	
1.	800/3,733	3.45	×	29.02	×	1.07	×	-	×	20	×
2.	900/4,200	5.68	×	17.59	×	3.71	×	-	×	16	×
3.	1,000/4,667	7.92	×	12.63	×	6.05	×	-	×	14	×
4.	1,100/5,133	10.16	√	9.84	√	8.17	×	-	×	12	×
5.	1,200/5,600	12.39	√	8.07	√	10.15	√	+	√	10	√
6.	1,300/6,067	14.63	√	6.83	√	12.02	√	+	√	9	√
7.	1,400/6,533	16.87	√	5.93	√	13.81	√	+	√	8	√
8.	1,500/7,000	19.11	√	5.23	√	15.54	√	+	√	7	√
9.	1,600/7,467	21.34	√	4.69	√	17.22	√	+	√	7	√
10.	1,700/7,933	23.58	√	4.24	√	18.86	√	+	√	6	√

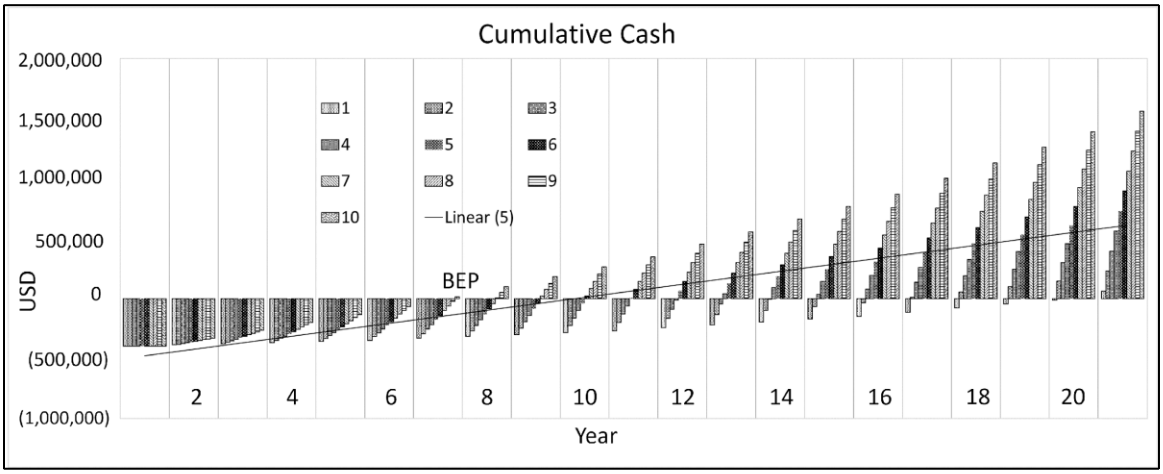


Figure 4 Cumulative cash flow graph

Table 5 Fuel (diesel) consumption for propulsion only per trip (10 days)

Fishing vessel type	Mileage (NM)	Diesel fuel consumption (liter)		
		Sail	Electric	Conventional
- Sail and electric BSC fishing vessel design	138	0	94	-
- Sail and electric BSC fishing vessel design	138	-	215	-
- Rembang BSC fishing vessel existing	138	-	-	387

DISCUSSION

In Indonesia, wooden boats outnumber those constructed with other materials and are mostly employed for small-scale fishing and transport operations. Moreover, throughout production, it typically still adheres to tradition and respects local culture (Kusuma *et al.* 2020; Irvana *et al.* 2022). The capture fisheries industry has access to several alternatives made possible by recent technical advancements. Numerous studies spanning all facets of vessel design, such as hydrodynamics, structure, manufacturing, and construction, are also conducted to optimize studies to enhance the performance and safety of fishing vessels (Liu *et al.* 2019). There is still a need to develop fishing vessel regulation (Suwardjo *et al.* 2010; Nugraha *et al*. 2021)

Sails have long been used as a form of boat propulsion, and their popularity has continued to rise. One of the most recent advancements in sailing technology is using sails in tandem to drive boats and solar panels that can turn solar energy into electricity (Santosa 2019). However, using sails as the primary propulsion on fishing vessels in Indonesia is still in its early stages and only serves as a secondary propulsion. Sail drives were once more explored in the 1980s during a skyrocketing global oil price but dropped as oil prices steadied (Yoshimura, 2002). Now, the use of sail and electric drives presents an opportunity for fishing communities to participate in the decarbonization program.

As one of the environmentally friendly technology alternatives in the capture fisheries sector, BSC fishing vessels with electric propulsion and sails are fantastic to discuss and implement. Since Indonesian fishing vessel technology is still based on tradition, implementing this technology is quite challenging because, in addition to the technical aspects of boat technology, there are also non-technical considerations such as the cost of the investment.

These BSC fishing boats may have a high initial cost due to their substantial technology and environmental investments, but the long-term advantages will outweigh that cost. Operational sustainability, marine resources, and a good reputation for international fishing are the vessel's main features. It can be considered that the boat moves using sail drive from the port to the fishing ground and vice versa, as well as between fishing grounds, as an example of how to calculate the differences in fuel oil expenses in Table 5 above. When compared to without a sail or conventional drive, the amount of diesel fuel used is more than two times greater. Therefore, using sails as the boat's primary propulsion system will significantly assist fishermen in lowering operating expenses and will indirectly cut carbon emissions.

Based on the result of the study above, it is known that building a 15-meter BSC fishing wooden boat with electric and sail propulsion will cost around 400,000 USD or 6 billion IDR (1 USD = 15,000 IDR). With this investment value, the routine of BSC fishing operations to ten days each trip by prioritizing sail drive over electric drive. Additionally, the business must be able to do at least 20 trips in a year at a productivity of 1.2 tons of crab at a market price of 4.7 USD per kilogram. The payback period of this investment falls on the 10 years. According to research by Simamora *et al.* (2017), common fishing vessels between 30 and 50 GT only need an investment of 120,000 USD, which means that the investment value is currently considerably less attractive to fishermen. So further innovation is still required in relation to boat components like batteries, electric motors, sail, DC generator, and other supporting equipment that are not yet produced domestically.

In principle, according to that scenario, the use of sail drive technology on BSC fishing vessels must be prioritized because wind energy in the Java Sea is sufficient to be used as an energy source, especially during the East monsoon (Setyobudi *et al.* 2023). An electric drive is only used when exiting/entering the Port and during trap hauling only. Thus, it can reduce expenditure on energy (fossil fuel). Another consideration of this technology application is based on findings from several studies, it has been shown that BSC records in “deep water” areas are more and relatively larger than catches in shallow waters (Zairion *et al.* 2014). So, it can indirectly help reduce catch density in shallow waters.

Furthermore, Indonesian waters with all their characteristics make it possible to conduct more extensive economic studies related to BSC fishing using wind energy and electric vessels. It is also possible to conduct additional research on the idea of using this vessel for different commodities.

CONCLUSION

The analysis and consideration of investing in BSC fishing vessels with electric drive and sails has resulted in the need for an initial investment value of USD 400.000. If the IRR is higher than 10% and the fishermen’s income from BSC fishing is projected to be 1.2 tons per trip and 20 trips annually, the investment will be attractive to use as a business investment, allowing the Payback Period to be met for ten years.

The present study marks the initiation of a sequence of steps aimed at developing a product appropriate for implementation in fishing communities. Furthermore, additional research with competence in the domains of naval, and marine engineering, capture fisheries, boat construction, and materials is still needed to improve this preliminary study.

SUGGESTIONS

For further research, experimental tests should be carried out from the ship model designed so that a more comprehensive design is obtained as a basis for calculation and economic analysis. Another suggestion is to use more domestic elements to build this boat, particularly for the machinery, electrical, battery, control system, and other components, to save capital expenditures.

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