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Analysis of Material Supplier Selection in Laminated Bamboo Shipyards Using the Analytical Hierarchy Process Method

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Abstract

An excellent technological breakthrough is the emergence of bamboo as a naturally renewable resource and an alternative material for shipbuilding. This laminated bamboo technology has several advantages since no shipyard builds ships made of laminated bamboo. Hence, this study focuses on the material supply chain to support the production of laminated bamboo ships. The Analytical Hierarchy Process (AHP) method was used to conduct the production of laminated bamboo to ensure an efficient supply of shipyard supplies. The analysis was performed by calculating the weight of the criteria using pairwise comparisons. It was based on a comparison scale of 1-9. The Consistency Ratio (CR) calculation used the size of the matrix. The results showed: PT. A (S5) in Surabaya was a supplier of adhesive materials with a weight of 0.433 and a CR of 0.01, finishing material 1 with a weight of 0.427 and a CR of 0.04; PT. E (S9) in Semarang was a supplier of finishing materials 2 with a weight of 0.491; Kediri (S1) was a supplier of bamboo slats with a weight of 0.361 and a CR of 0.07; UD. G (S11), located in Surabaya, was a supplier of ship mold material components with a weight of 0.456 and a CR of 0.03; UD. J (S14), located in Surabaya, was a supplier of supporting and consumable material components with a weight of 0.351 and a CR of 0.00. It is possible to create laminated bamboo ships using the materials supplied by this chosen material source.

1. Introduction

Recently, materials for building ships, especially wood, have been increasingly difficult to obtain in Indonesia due to illegal logging in the last few decades [1]. Since solid wood is becoming increasingly difficult to find for shipbuilding, researchers have been looking into bamboo slat laminate as a possible replacement material, e.i. tensile strength, bending strength, and compressive strength have been tested in several studies. They have been proven to fulfill the bureau requirements of classification rules [2]. This information has been incorporated into a prototype fishing boat built of laminated bamboo that follows the local wisdom design [3]. It can be seen in Figure 1. This fishing boat has been tested to operate at sea for three months. Based on the results, the fishing boat made of bamboo slats has sufficient strength and durability. Besides, the laminated material for bamboo slats also complies with the Indonesian Classification Bureau (BKI) rules. BKI is a bureau that supervises and certifies the proper construction of a ship in Indonesia.

In addition, The following ship prototype also had a distinctive layout and purpose. The second prototype is a fishing boat for coastal areas, while the third is a river cruise ship. These two prototypes also have been tested in sea, and the constructions have complied with the classification rules. The prototypes of the 2nd and 3rd bamboo slat laminated vessels can be shown in Figure 2 and Figure 3.

The latest technology of bamboo usage for ship construction is very efficient, considering the very positive characteristics of bamboo. Bamboo is a plant that is widely distributed throughout Indonesia and has a large population [2]. In addition, bamboo has a fast growth rate and relatively lower prices. Bamboo has good mechanical properties, which can reduce the size of the construction when compared to solid wood [4].

The previous studies showed different results. Hafiz and team studied the design of laminated bamboo fishing boat with local cultural heritage. The result stated that technical calculations are performed, taking into account the boat's resistance, propulsion, needed power, and stability [5]. This study has the same method with Rahmiati and team. That study tried to implement the Analytical Hierarchy Process (AHP) and the weights of the criteria and sub-criteria to find the best supplier for ceramic [20]. Then, another study showed that the properties improvement of engineered bamboo demonstrates

the potential application of laminated bamboo as a substitution for building and construction material [21]. The effort to reduce wood consumption by using laminated-bamboo based material has not been successful due to the limited socialization on the development of laminated bamboo-based products.

Figure 1. The 1st prototype of fully laminated bamboo slats fishing boat


Figure 2. The 2nd prototype of a coastal fishing boat made of laminated bamboo slats


Figure 3. The 3rd prototype of a fully laminated bamboo river cruise boat

Based on those studies, the potential for shipbuilding with the latest laminated bamboo material can be applied on an industrial scale [5]. A laminated bamboo-based shipyard has high competitiveness compared to other shipyards that produce wooden boats and fibreglass-reinforced plastic (FRP) boats. The advantage of laminated bamboo boats over solid wood or fiberglass ones is that they are more environmentally friendly. Thus, shipyards with the primary material of laminated bamboo slats need to be developed. That is prepared to complete, keep supplying new ships' needs. Bamboo slat shipbuilding requires the establishment of affordable and sufficient material sources [5]. Numerous fundamental materials, auxiliary materials, consumables, and other supporting goods are needed for the shipping sector. Reliable material supply management is required to achieve a bamboo laminated shipyard that is continually expanding.

The shipbuilding industry must be competitive among others to maintain the continuity of its development. One of the most critical aspects of building affordable and high-quality ships is the material supply chain or material supply chain to distribute the materials needed by the shipyard from suppliers [6]. It is essential to determine material suppliers in the company's business processes so that the production process runs smoothly with information on material availability, quality, and prices. Shipyards must consider factors such as quality, quantity, delivery, and costs in supplier decisions that affect company performance [7]. Choosing the right supplier is the key to overcoming this problem. This study aims to determine the right material supplier to support the supply chain of the laminated bamboo shipbuilding industry. The AHP method used in this supplier selection analysis can set criteria and sub-criteria that affect suppliers [8].

2. Methods

This research was conducted using the analytical hierarchy process (AHP) method to assist in deciding on suppliers used in the laminated bamboo shipyard. Literature and field studies were conducted to support the research. The studies collected data on the materials needed to build laminated bamboo boats. The following step was to determine the number of chosen suppliers by categorizing the material components into various regions. Based on the AHP method, a hierarchical structure was created to decide on materials suppliers for the laminated bamboo boat' production. The lower level of the hierarchical structure was arranged into several criteria and sub-criteria. Several criteria and sub-criteria attributes were determined to compile a matrix of comparison results from each element in numbers 1 to 9. The numbers indicated the level of importance of each component. The selection of material suppliers for laminated bamboo shipyards was based on several respondents responding to the questionnaire. The analysis was carried out by calculating the supplier's weighting and ranking criteria and sub-criteria factors using expert choice software [9]. The last stage in this process was to measure the consistency ratio of each element to produce recommendations for selecting the right laminated bamboo shipyard material supplier.

2.1. AHP Procedure

a. Defining the problem and setting goals. AHP is used to select alternatives or develop alternative priorities. At this stage, alternative development is implemented (It explained in Hierarchical Structure Modeling and Supplier Determination)
b. Arranging problems into a hierarchy so that complex problems can be reviewed in a measurable manner. (already explained in Hierarchical Structure Modeling)
c. Setting priorities for each problem element in the hierarchy. This process produces the weight or contribution of elements to the achievement of goals so that elements with the highest weight have priority handling. Priority is generated from a pairwise comparison matrix between all elements at the same hierarchical level. (already explained in the Supplier Assessment Concept)
d. Consistency testing of comparisons between elements obtained at each hierarchical level. (already explained in the Supplier Assessment Concept)

2.2. Material for the Production of Laminated Bamboo Boats

The material requirements were identified through the production process of laminated bamboo boats. The production process of laminated bamboo boats in shipyards used the male mold cold press method. This method involved manufacturing ship molds, lamination of ship shells, lamination of ship construction, and hull finishing [10]. The ship mold was made by cutting plywood based on each frame hull's shape before being assembled into one complete mold.

In contrast to the conventional method, this method prioritized the process of shell lamination using the ship's mold [11]. Lamination was performed longitudinally and transversely based on the carvel method until the hull's thickness was reached. As the ship's sides were reinforced, the mold was taken off the shell's completed form to prevent deformation. The other ship constructions (keel construction, frame, wrang, beam beams, bulkheads, and stiffeners) were laminated using the hull's shell shape as the mold. The bamboo lamination process to form these constructions was performed directly on the ship to fit the ship's planned position and shape. The last stage was finishing the vessel by applying dye and fiber. The material requirements for building a bamboo slat laminated ship consisted of molding materials, ship construction, and finishing materials. The variety of materials needed in this laminated bamboo shipyard was described in detail in Table 1.

Table 1. Shipbuilding material requirement

Manufacturing process	Material requirement
Ship Mold	Plywood, wooden plank, wooden block, and screw
Boat Shell	Bamboo, adhesive glue, thinner, nail, cutting blade, and flap disc
Boat Construction (Keel, frame, floor, beam, bulkhead, and stiffener)	Bamboo, adhesive glue, thinner, nail, nut and bolt, f-clamp, cutting blade, and flap disc
Finishing	Fiberglass cloth, resin, catalyst, polyurethane, dye, thinner, and sandpaper

The production materials at the laminated bamboo shipyard can be classified into primary materials, supporting materials, and consumables [12]; these were shown in Table 2. The primary material was divided into four components. Bamboo slats were the primary material for the construction of bamboo boats. This bamboo slat was obtained by splitting a bamboo stick with a length of 2m, a width of 3.5cm, and a thickness of 5mm. Based on the results of experiments that have been carried out, the type of bamboo that meets its strength to be used in ship construction was a combination of Gigantochloa apus and Bambusa arundinacea [13]. Besides bamboo, an adhesive was a primary material for building this laminated bamboo boat. The lamination method was applied by stacking several layers of bamboo slats. The adhesive bonds each bamboo slat layer as a matrix. Generally, ships were operated in water, so the lamination adhesive must have high strength and be water resistant. The adhesive used must have a minimum adhesion of 1 MPa in accordance with the rules of the Indonesian Classification Bureau.

Furthermore, there were two stages of the finishing process in the construction of ships made of laminated bamboo slats. The finishing stage 1 was the coating of Glass Fiber Cloth on the hull's outer surface. The finishing stage 1 was conducted to increase the tightness of the ship's hull construction. The material used in finishing stage 1 was also classified as the

primary material and consisted of Glass Fiber Cloth components, Resin, and Catalyst. Succeeding was another primary material, namely finishing 2nd, which consisted of Polyurethane, Dye, and Thinner. This stage was the color coating and hull protection. Color coating aimed to improve the aesthetics of the ship's hull to make it looked more beautiful. The protective coating protected the hull from biofouling and UV rays. Naturally, bamboo material will weather fast if exposed to UV rays continuously.

Table 2. Material classification

Classification	Part of component	Material type
Primary material	Construction	Bambusa arundinacea, Dendrocalamus asper, Gigantochloa apus
	Adhesive	Adhesive glue
	Finishing 1st	Glass fiber cloth, Resin, Catalyst
	Finishing 2nd	Polyurethane, Dye, Thinner
Supporting Material	Ship mold	Plywood, Wooden block, Wooden plank
	Clamp	Nail, Screw, Nut and bolt, F-clamp
Consumables	Cutting and sanding	Cutting blade, Flap disc, sandpaper

Supporting materials were materials needed to improve the efficiency of the production process. This method of building a bamboo slats laminated ship used a mold to obtain the shape and size in compliance with the lines plan. The mold used generally consisted of multiplex materials, wooden blocks, and wooden boards. The multiplex was cut to the shape and size conferring to the body plan. This cutting was done using CNC-Milling in order to obtain precise dimensions. Each frame was installed with a multiplex cut to the correct size and position. When building a bamboo slat laminate ship, the mold was strengthened with wooden beams and thick wood boards to ensure that it did not shift during construction. Another essential material in building laminated bamboo boats was the supporting material. This support material consisted of nails, screws, nuts, and F-clamps. These three materials have essential usage functions as well. The function of this supporting material was to assist in the lamination process to obtain a rigid and sturdy composite result. There was a curved shape in some areas of the hull, so in the lamination process, several parts must be held in a curved condition. Hence, a retainer was needed so that the bamboo blades remain in the position and shape of the mold. According to the adhesive's curing time, this holding period was conducted. Based on experience making prototypes of bamboo slat laminated boats, it took about 6 hours until the glue cures perfectly. The last one was consumable material which was also essential material. Three types of consumable materials were needed to construct laminated bamboo vessels: cutting blades, flap discs, and sanding paper. The cutting blades were used to cut bamboo blades or other materials during the ship's production process. In addition, flap discs and sandpaper are used to level and smooth the surface to obtain precise and neat construction.

2.3. Hierarchical Structure Modeling

The supplier selection at the bamboo shipyard was based on the analytical hierarchy process method (AHP). This method can define the category of assessment to determine the supplier. The process hierarchy model (Figure 4) in this supplier selection consisted of objectives, criteria, and alternative supplier choices [14].

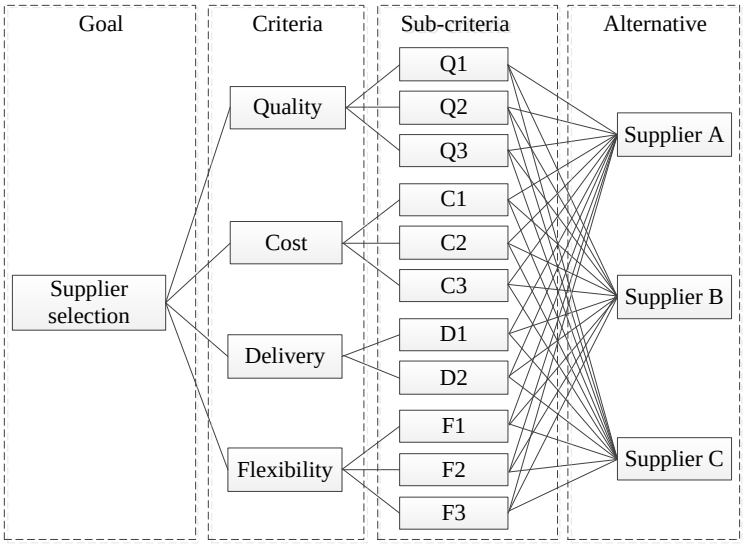

Figure 4. Hierarchy structure of supplier selection

The model showed several levels of the hierarchy. The first level presented the objectives for selecting material suppliers for laminated bamboo shipyards. The following two levels were the criteria and sub-criteria levels. The last level showed the supplier candidate to be chosen. The main criteria for making decisions, shown in Table 3, were divided into four with each of the following sub-criteria:

1. Quality
   The quality level involved physical product conditions that affected production results, such as performance, reliability, and conformity to specifications. Performance of the laminated bamboo boat product was determined by how it looked, and reliability assessed how long it was likely to survive. Lastly, the high-quality laminated bamboo boats must consistently conform to the specifications. The quality criteria consisted of sub-criteria that were shown in Table 3.

2. Cost
   This sub-criteria was determined by the cost of materials from each supplier. The supplier selection based on materials costs can minimize the cost of laminated bamboo boat production by getting the cheapest and high-quality material. The prices of material procurement must be affordable compared to the predetermined production costs so that no losses happen. The material costs offered must be worth the materials' quality. Suppliers who provided material discounts for a certain purchase can reduce production material costs. Several sub-criteria of cost criteria that needed to be considered in supplier selection can be seen in Table 3.

3. Delivery
   Material delivery was an essential factor in procurement. Material delivery directly affected the time it took to complete a shipbuilding project. The selection of material suppliers must also pay attention to this aspect. In addition, the accuracy of material delivery must comply with the amount of material ordered to ensure the shipbuilding process is on schedule. Some of the sub-criteria in this aspect of delivery were shown in Table 3.

4. Flexibility
   Suppliers' flexibility was vital in meeting unexpected material requests outside regular requests. This aspect was essential because the shipbuilding process has various production risks, including material problems. This problem will cause material needs that the shipyard must meet quickly. Therefore, material suppliers must complete the number of material requests, fulfill material reductions or additions, and meet material demands at any time. Some of the flexibility sub-criteria can be seen in Table 3.

Table 3. Criteria and Sub-criteria

No	Criteria	Sub-criteria
1	Quality	Accuracy of material size and type (Q1) Conformity with material quality standards (Q2) Ability to provide consistent quality (Q3)
2	Cost	Affordability of material prices (C1) Compatibility of material prices with quality (C2) Material price discounts for a certain amount of purchase (C3)
3	Delivery	On-time delivery of materials (D1) Material quantity accuracy (D2)
4	Flexibility	ability to fulfill the number of material requests (F1) Ability to increase the number of materials (F2) Ease of changing material delivery times (F3)

2.4. Supplier Determination

Selection of the right supplier was essential for the laminated bamboo shipyard. Based on the materials needed for laminated bamboo boats, several suppliers have been defined in Table 4. This supplier can fulfill the materials required and was divided into bamboo suppliers, adhesive and finishing 2nd suppliers, finishing 1st suppliers, ship mold suppliers, and consumables suppliers.

Table 4. Supplier list

Material	Supplier
Bamboo	Kediri (S1), Trenggalek (S2), Probolinggo (S3) and Yogyakarta (S4)
Adhesive and Finishing 2	PT. A (S5), PT. B (S6) and PT. C (S7)
Finishing 1	PT. D (S8), PT. E (S9) and PT. F (S10)
Ship mold	UD. G (S11) UD. H (S12) and UD. I (S13)
Clamp, cut and sanding	UD. J (S14) UD. K (S15) and UD. L (S16)

Location was a consideration in supplier selection because the closer the supplier was to the location, the lower the costs incurred by the company for the procurement process [15]. Suppliers' distribution based on location was needed to assess the location aspect. The distribution of suppliers by location can be seen in Figure 5, where there were suppliers in Surabaya, Gresik, Sidoarjo, Probolinggo, Kediri, Trenggalek, Semarang, Yogyakarta, and Jakarta. Each of these suppliers certainly has different product characteristics and criteria.

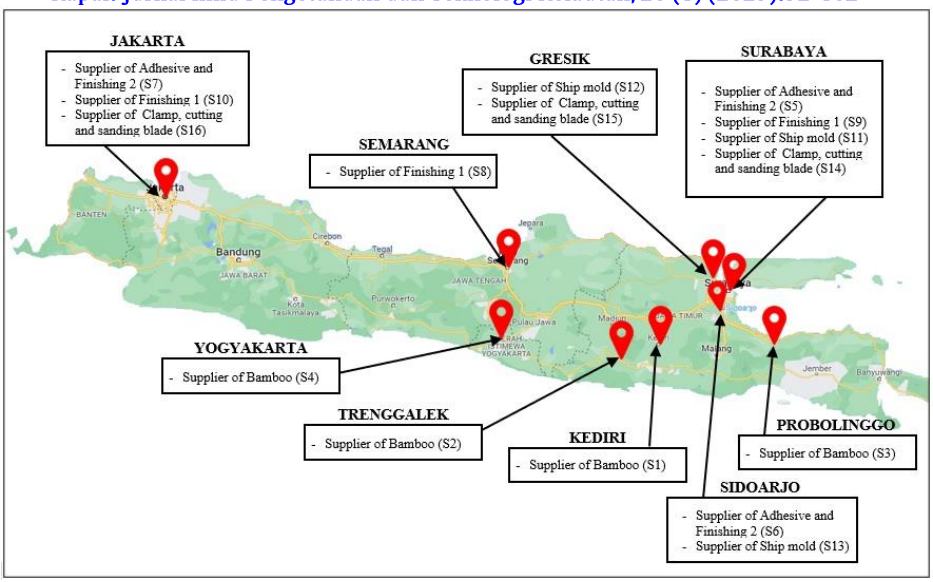

Figure 5. Supplier location in Java region

2.5. Supplier Assessment Concept

The basic concept of the Analytical Hierarchy Process (AHP) assessment was comparison to provide a relative assessment for criteria, sub-criteria, and alternative suppliers. This principle can assess the relative importance of two elements at the same level to determine the weight of the upper-level value [16]. The scoring system used to create the comparison matrix can be seen in Table 5.

Table 5. Criteria assessment based on a comparison scale.

Integrity of interest	Definition
1	Just important as the others
3	Little more important than others
5	Quite important compared to others
7	Very important compared to others
9	Extreme Importance than others
2,4,6,8	The value between two adjacent ratings
Reciprocal	If element 1 has one of the above numbers compared to element j, then j has the opposite value when compared to i

The consistency ratio (CR) value was calculated after the eigenvalues obtained from the results of geometric calculations were multiplied by a matrix on each criterion, sub-criteria, and alternative supplier. If the consistency ratio (CR) value was 10%, then the assessment of the statement data was considered inconsistent [17]. Pairwise comparisons were correct if the consistency ratio (CR) was 10% [18]. To determine the value of CR, first, calculate the value of the consistency index (CI) using Equation 1.

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

CI was the index consistency value, where λ_{max} was the eigenvalue and n indicated the number of variables being compared. The inconsistency limit was measured by dividing the value of CI and RI to determine the random index (RI) value shown in Table 6. A scale of 1 to 15 was used depending on the order of the matrix used [19].

Table 6. Random index value

Matrix scale	Value RI	Matrix scale	Value RI	Matrix Scale	Value RI
1.2	0	6	1.24	11	1.51
3	0.58	7	1.32	12	1.48
4	0.98	8	1.41	13	1.56
5	1.12	9	1.45	14	1.57
6	1.24	10	1.49	15	1.59

3. Results and Discussion

This Analytical Hierarchy Process (AHP) used a questionnaire addressed to 20 professional respondents with significant experience building laminated bamboo boats. Each respondent assessed the criteria and sub-criteria for each supplier. The assessment results were then processed using expert choice software based on the principles of the AHP method. The supplier with the highest score based on the ranking has priority to be chosen.

3.1. Primary Materials Supplier Selection

The selection of the primary material suppliers in this study is divided into the selection of bamboo suppliers, adhesive suppliers, finishing 1st suppliers, and finishing 2nd suppliers. This selection is based on the results of a questionnaire using the AHP method. The analysis results of the primary material supplier choice can be seen in the following description.

A. Bamboo Suppliers Selection

The bamboo types used in the laminated bamboo boat construction are *Bambusa arundinacea*, *Dendrocalamus asper*, and *Gigantochloa apus*. Bamboo suppliers must be able to accommodate the three types of bamboo. However, based on the results of the AHP, the quality criteria became the highest weighted value chosen. The quality criteria reach a value of 0.422, exceeding the cost, delivery, and flexibility criteria which have average values of 0.407, 0.109, and 0.062. The quality criteria have the highest value because they impact the ship's appearance, strength, age, and production process.

Based on the assessment, as shown in Table 7, the results of the matrix calculation showed that Kediri area (S1) was the main priority as a supplier of bamboo material with a total weighting value of 0.363. This value was more excellent when compared to the results of supplier assessments for the Trenggalek (S2), Probolinggo (S3), and Yogyakarta (S4) areas, which have lower values with average weighting results of 0.352, 0.162, 0.123.

Table 7. Global values of bamboo suppliers

Criteria	Weighted Value	CR Value	Sub-criteria	Weighted Value	CR Value	Supplier Weighted Value				CR Value
						S1	S2	S3	S4	
			Q1	0.300		0.408	0.371	0.119	0.102	0.01
Quality	0.422		Q2	0.600	0.02	0.278	0.391	0.196	0.135	0.04
			Q3	0.100		0.241	0.372	0.234	0.153	0.05
			C1	0.547		0.438	0.315	0.155	0.092	0.05
Cost	0.407		C2	0.345	0.05	0.358	0.383	0.136	0.123	0.04
		0.02	C3	0.108		0.342	0.443	0.116	0.099	0.04
			D1	0.750		0.411	0.274	0.162	0.153	0.00
Delivery	0.109		D2	0.250	0.01	0.391	0.305	0.158	0.146	0.04
			F1	0.637		0.409	0.241	0.175	0.175	0.06
Flexibility	0.062		F2	0.258	0.04	0.403	0.364	0.156	0.077	0.01
			F3	0.105		0.281	0.319	0.243	0.157	0.04

The selection of this bamboo supplier was the result of consistent calculations and analysis. The level of consistency in this analysis got a value of 0.02 (smaller than 0.1), so it can be concluded that the results of this supplier selection are also consistent.

B. Adhesive Material Suppliers Selection

The adhesive is one of the crucial materials for constructing a laminated bamboo boat. This adhesive is used to glue the bamboo slats into a single laminate. The adhesive used in this construction has an epoxy polyamide type. The cost criteria have the highest value of 0.536, surpassing quality, delivery, and flexibility with an average value of 0.318, 0.092, and 0.054. The cost criteria are the most important because the adhesive is needed in large quantities. A large number of needs for this adhesive requires the selection of suppliers to prioritize the affordable adhesive despite good quality standards. The analysis results in Table 8 showed that PT. A (S5) located in Surabaya was a top priority as a supplier of adhesive material with a total value of 0.434. This value outperforms the assessment results of the supplier PT. B (S6) in Sidoarjo and PT. C (S7) in Jakarta with an average weighted value of 0.422 and 0.144. The inconsistency value in this analysis has a value below 0.1. This value indicated that the adhesive material supplier selection analysis was consistent, resulting in consistent supplier selection results.

Table 8. Global values of adhesive material suppliers

Criteria	Weighted Value	CR Value	Sub-criteria	Weighted Value	CR Value	Supplier Weighted Value			CR Value
						S5	S6	S7	
			Q1	0.683		0.558	0.320	0.122	0.020
Quality	0.318		Q2	0.200	0.02	0.547	0.345	0.108	0.050
			Q3	0.117		0.625	0.136	0.239	0.020
			C1	0.600		0.286	0.571	0.143	0.000
Cost	0.536		C2	0.300	0.05	0.387	0.443	0.170	0.020
		0.01	C3	0.100		0.547	0.345	0.108	0.050
			D1	0.667		0.500	0.333	0.167	0.000
Delivery	0.092		D2	0.333	0.01	0.400	0.400	0.200	0.000
			F1	0.584		0.558	0.320	0.122	0.020
Flexibility	0.054		F2	0.184	0.04	0.345	0.547	0.108	0.050
			F3	0.232		0.547	0.345	0.108	0.050

C. Finishing 1st Material Suppliers Selection

Finishing 1st material is a finishing component that provides additional watertight ness to the ship's hull. These materials include fiberglass cloth, resin, and catalyst. The cost criteria are the essential criteria with a value of 0.452, higher than the quality, delivery, and flexibility criteria: 0.341, 0.099, and 0.108. The cost criteria are the most important because the quality of the material provided by each supplier is almost the same, so the price of the goods is more important. In addition, this material is not needed in large quantities and in a fast time, so the delivery and flexibility factors are optional criteria. The results of the supplier selection analysis for finishing 1st have an inconsistent value below 0.1. Thus, the results and analysis process are consistent. The AHP results in Table 9 showed PT. E (S9), located in Surabaya, was a top priority as a supplier of finishing 1st material components with a total weighting value of 0.490. PT. E has a higher value compared to the supplier assessment result of PT. D (S8) at Semarang and PT. F (S10) in Jakarta (0.310 and 0.200).

Table 9. Global values of Finishing 1st material supplier

Criteria	Weighted Value	CR Value	Sub-criteria	Weighted Value	CR Value	Weighted Value Supplier			CR Value
						S8	S9	S10	
			Q1	0.446		0.250	0.500	0.250	0.000
Quality	0.341		Q2	0.433	0.005	0.260	0.413	0.327	0.050
			Q3	0.121		0.297	0.540	0.163	0.009
			C1	0.648		0.286	0.571	0.143	0.000
Cost	0.452		C2	0.230	0.004	0.323	0.588	0.089	0.009
		0.04	C3	0.122		0.550	0.240	0.210	0.020
Delivery	0.099		D1	0.667	0	0.311	0.493	0.196	0.050
			D2	0.333		0.333	0.333	0.333	0.000
			F1	0.413		0.333	0.527	0.140	0.050
Flexibility	0.108		F2	0.327	0.05	0.387	0.444	0.169	0.020
			F3	0.260		0.500	0.250	0.250	0.000

D. Finishing 2nd Material Suppliers Selection

Finishing 2nd material is a material that is intended to provide an aesthetic value and anti-fouling on the ship. This material consists of color stain, clear polyurethane, and dye. The cost criteria have the highest weighting value of 0.564, higher than quality, delivery, and flexibility, with an average value of 0.289, 0.098, and 0.049. The cost criteria become the most important because the costs required for finishing 2nd materials are pretty expensive. In addition, this material is not needed in large quantities and in a fast time, so the delivery and flexibility factors are the lowest choices.

The analysis of supplier selection for finishing 2nd has an inconsistency value below 0.1, indicating that the results of this analysis are consistent. The results of the study shown in Table 10 showed that PT. A (S5) located in Surabaya was a top priority as a supplier of finishing 2nd materials with a total weighting value of 0.427. This result was lower than the assessment result of the supplier PT. B (S6) in Sidoarjo and PT. C (S7) in Jakarta has an average value of 0.411 and 0.162.

Table 10. Global values of Finishing 2nd material suppliers

Criteria	Weighted Value	CR Value	Sub-criteria	Weighted Value	CR Value	Supplier Weighted Value			CR Value
						S5	S6	S7	
			Q1	0.333		0.413	0.327	0.260	0.050
Quality	0.289		Q2	0.527	0.05	0.458	0.416	0.126	0.009
			Q3	0.140		0.584	0.232	0.184	0.050
			C1	0.428		0.230	0.648	0.122	0.004
Cost	0.564		C2	0.428	0.00	0.558	0.320	0.122	0.020
		0.07	C3	0.144		0.493	0.311	0.196	0.050
Delivery	0.098		D1	0.500	0.00	0.400	0.400	0.200	0.000
			D2	0.500		0.327	0.413	0.260	0.000
			F1	0.550		0.528	0.332	0.140	0.020
Flexibility	0.049		F2	0.210	0.02	0.416	0.458	0.126	0.050
			F3	0.240		0.376	0.475	0.149	0.050

3.2. Supporting Material Suppliers Selection

This study's selection of supporting material suppliers is divided into the choice of material suppliers for making ship molds and clamping. This selection was based on the questionnaire results using the AHP method. The analysis results of the selection of supporting materials suppliers can be seen in the following description.

A. Selection of Ship Mold Material Suppliers

The materials needed to manufacture ship molds consist of plywood, wooden planks, and wooden blocks. Generally, the quality provided by suppliers is similar, but suppliers compete to give the lowest possible price. The same thing goes for the AHP results. The cost criteria are the most crucial, with a value of 0.419, exceeding the quality, delivery, and flexibility criteria with an average value of 0.295, 0.158, and 0.128.

Table 11. Global values of ship mold material suppliers

Criteria	Weighted Value	CR Value	Sub-criteria	Weighted Value	CR Value	Weighted Value Supplier			CR Value
						S5	S6	S7	
Quality	0.295	0.03	Q1	0.416	0.01	0.594	0.249	0.157	0.050
			Q2	0.458		0.413	0.260	0.327	0.050
			Q3	0.126		0.493	0.196	0.311	0.050
Cost	0.419		C1	0.540	0.01	0.573	0.256	0.171	0.080
			C2	0.297		0.342	0.524	0.134	0.000
			C3	0.163		0.370	0.406	0.224	0.009
Delivery	0.158		D1	0.667	0.00	0.493	0.311	0.196	0.050
			D2	0.333		0.333	0.333	0.333	0.000
Flexibility	0.128		F1	0.527	0.05	0.493	0.311	0.196	0.050
			F2	0.333		0.491	0.233	0.276	0.030
			F3	0.14		0.413	0.327	0.260	0.050

Based on the results of AHP calculations, PT. G (S11), located in Surabaya, was a top priority as a supplier of ship mold material with a total value of 0.456, as shown in Table 11. This value exceeded the results of the supplier assessment of PT. H (S12) in Gresik and PT. I (S13) in Sidoarjo with an average score of 0.330 and 0.214. The analysis process for this ship mold material supplier was considered consistent with the highest inconsistency value of 0.08.

B. Selection of Clamp Material Suppliers

One of the essential components in the lamination process is the clamp material. This material holds and applies pressure during the lamination process until the glue reaches the curing point. This clamp material consists of nails, nuts and bolts, screws, and F-clamps. Table 12 showed the results of the AHP calculation, showing that the cost criteria were the most important, with a value of 0.409. In addition, quality was the following criteria with a value of 0.313, exceeding delivery and flexibility with a value of 0.167 and 0.111.

Table 12. Global values of clamp material suppliers.

Criteria	Weighted Value	CR Value	Sub-criteria	Weighted Value	CR Value	Weighted Value Supplier			CR Value
						S14	S15	S16	
Quality	0.313	0.03	Q1	0.258	0.04	0.480	0.180	0.340	0.004
			Q2	0.637		0.617	0.212	0.171	0.030
			Q3	0.105		0.578	0.218	0.204	0.004
Cost	0.409		C1	0.594	0.05	0.379	0.289	0.332	0.020
			C2	0.249		0.587	0.264	0.149	0.010
			C3	0.157		0.596	0.276	0.128	0.020
Delivery	0.167		D1	0.600	0.00	0.464	0.281	0.255	0.009
			D2	0.400		0.507	0.307	0.186	0.009
Flexibility	0.111		F1	0.644	0.03	0.556	0.222	0.222	0.000
			F2	0.222		0.556	0.312	0.132	0.030
			F3	0.134		0.592	0.258	0.150	0.020

The analysis of the selection of clamp material suppliers was considered consistent with the highest inconsistency value of 0.05. The results of the AHP that UD. J (S14), located in Surabaya, was a top priority as a clamp material supplier with a total value of 0.496. This value exceeded the assessment results of UD. K (15) in Gresik and UD. L (S16) in Jakarta with an average assessment result of 0.259 and 0.245.

3.3. Consumables Material Suppliers Selection

Consumables are used only once in the ship's production process as cutting and sanding materials. The supplier must be able to fulfill the material consisting of the wood cutting blade, flap disc, and sandpaper. The need for this consumable material is quite a lot, so the cost of the required material components must be cheap enough. The same goes for the AHP result, where the cost criterion is the most essential (value of 0.438). The results of the AHP calculation in Table 13 showed that UD. J (S14), located in Surabaya, was a top priority as a supplier of consumables with a total value of 0.531. This value exceeded UD. K (15) in Gresik and UD. L (S16) in Jakarta with a value of 0.320 and 0.149.

Table 13. Global values of Consumable Suppliers

Criteria	Weighted Value	CR Value	Sub-criteria	Weighted Value	CR Value	Weighted Value Supplier			CR Value
						S14	S15	S16	
Quality	0.348	0.05	Q1	0.302	0.02	0.545	0.273	0.182	0.000
			Q2	0.525		0.454	0.347	0.199	0.020
			Q3	0.173		0.444	0.387	0.169	0.020
Cost	0.438		C1	0.525	0.02	0.590	0.290	0.120	0.040
			C2	0.302		0.611	0.244	0.145	0.030

		C3	0.173		0.598	0.290	0.112	0.001
Delivery	0.131	D1	0.714	0.00	0.511	0.373	0.116	0.008
		D2	0.286		0.469	0.353	0.178	0.080
		F1	0.510		0.472	0.444	0.084	0.004
Flexibility	0.083	F2	0.348	0.00	0.694	0.210	0.096	0.009
		F3	0.142		0.460	0.382	0.158	0.030

3.4. Result Summary

Supplier selection followed predetermined criteria or conditions to simplify the decision-making process. This supplier selection was based on the AHP method by analyzing each supplier for each component: primary materials, supporting materials, and consumables. The primary materials consisted of: bamboo material, adhesive, finishing 1st, and finishing 2nd. Based on the analysis results, Kediri area (S1), with a value of 0.363, became the foremost priority in providing suppliers of bamboo material. In the assessment of bamboo suppliers, quality criteria were the most important criteria because the quality of the material affects the quality of the laminated bamboo boat product. PT. A (S5), located in Surabaya, became the next top priority in providing adhesive and finishing 1st material component with global values of 0.434 and 0.427, respectively. The selected finishing 2nd material supplier was PT. E (S9) in Semarang area with a value of 0.490. The cost criteria in selecting an adhesive, finishing 1st and 2nd materials were priority criteria due to intense price competition even though the quality tended to be the same.

Supporting materials consisted of ship mold and clamp materials. The supplier chosen to provide ship mold materials was UD. G (S11) in Surabaya area with a value of 0.456. The supplier was selected because the location of the supplier was closer to the shipyard. Also, the material cost provided by this supplier was cheaper than other suppliers. In addition, the supplier of selected clamp components was UD. J (S14) in Surabaya area with a value of 0.496. UD. J (S14) was the priority supplier selected to provide consumables with a value of 0.531. Overall, the suppliers needed by the laminated bamboo shipyard to supply ship production materials were in Surabaya. Most suppliers in Surabaya can provide high-quality materials at affordable prices. In addition, the supplier can also provide materials quickly and has a reasonably fast lead time due to the closer transportation distance to the shipyard.

4. Conclusion

According to the result and discussion above, material suppliers at the shipyard are selected based on the Analytical Hierarchy Process (AHP) results. The Analytical Hierarchy Process (AHP) process was carried out by assessing suppliers based on their criteria and sub-criteria. The results of this assessment are as follows Kediri area (S1) is a top priority as a supplier of construction materials with a global weighting value of 0.363. PT. A (S5) in Surabaya area is a top priority as a supplier of adhesive glue material components with a global weighting value of 0.434. PT. E (S8) in Semarang area is a top priority as a supplier of finishing material components 1 with a global weighting value of 0.490. PT. A (S5) in Surabaya area is a top priority as a supplier of finishing material components 2 with a global weighting value of 0.427. UD. G (S11) in Surabaya area is a top priority as a supplier of ship mold materials with a global weighting value of 0.456. UD. J (S14) in Surabaya area is a top priority as a supplier of clamp material components with a global weighting value of 0.496. UD. J (S14) in Surabaya area is a top priority as a supplier of consumable material components with a global weighting value of 0.531.

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