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Programming Evaluation and Review Technique (PERT) Model Development on a Phinisi Ship Building Process

[1,3]Dirgahayu Lantara, [2]Surachman, [1]Sudjito Soeparman, [1]Purnomo Budi Santoso

[1]*Brawijaya University, Mechanical Engineering Department, Engineering Faculty, 65145,Malang, Indonesia*
[2]*Brawijaya University, Economics Department, 65145, Malang, Indonesia,*
[3]*The Muslim University of Indonesia, Industrial Engineering Department, 9023, Makassar, Indonesia.*

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ABSTRACT

Phinisi ship is a traditional sailing ship of Bugis and Makassar tribes of South Sulawesi, Indonesia. In Tanahberru, Bulukumba, South Sulawesi, there are 34 traditional phinisi building companies which built the ship following tradition handed from generation to generation. In building the ship, the builders apply modern technique as well as maintain traditional rituals. The aim of the research was to develop a Programming Evaluation and Review Technique (PERT) model which was applied on building one phinisi ship in 24 companies among 34 phinisi building companies in Tanahberu so that the time and cost on producing the phinisi could be estimated. The production system on building the phinisi was adjusted with the available resources and materials in Tanahberu. Using the PERT model on building the phinisi, it was found that there was a significant change in the number of activities, namely from 47 activities to 176 activities. Applying 176 activities, the completion time and cost in building the same phinisi was calculated for all 24 companies. The results of the research showed that using PERT model, to build one phinisi would require 291 days and 2328 hours, 6 critical paths, probability of 99.71%, 43 components and total cost of IDR 1,538,141,404.

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INTRODUCTION

Phinisi is a traditional two-mastered sailing ship which has been built and used by Bugis and Makassar tribes of South Sulawesi Indonesia. They have sailed many seas and oceans around the world on the phinisi ship. During the manufacturing process, the builders apply traditional and modern techniques. Religious rituals are still practiced to decide each steps of the manufacturing process, e.g. deciding the start day of the process, choosing the best wood, cutting the wood, building the body, finishing etc.

The technique to build a phinisi has been passed down from generation to generation in Bugis and Makassar community, especially in Tanahberu, Bulukumba, South Sulawesi. Figure 1 presents a map of Tanahberu, Bulukumba. The traditional process makes the building process requires a lengthy and unpredictable time. Therefore, the research aims to study how the traditional influenced method in building the phinisi ship in Bugis and Makassar community in Tanahberu, Bulukumba affect the production process. There are 34 phinisi building companies in Tanahberu which built many types and sizes of phinisi ship. The research used a purposive sampling method using 24 companies as research subjects.

The phinisi buiding company in Tanahberu is usually a family business. Phinisi ship has different types and size generally to build a phinisi requires 10-15 workers. The workers are from among their family members. Working in a phinisi building company is the main job of most Tanahberu people. Phinisi building industries in Tanahberu can be categorized as a craftsmanship industrial process in which the production process is mainly based on human ability driven by an artistic aspect and individual ability.

There has been an improvement in the production process of phinisi building, such as the use of electric equipment instead of manual equipment. Figure 2a and 2b show an electric drill and electric scrapper which are used by the phinisi builders.

However, manual methods in building the phinisi are still applied. Figure 3a shows a worker manually measured a part of phinisi, while Fig. 3b shows a manual activity in assembling the phinisi. The challenging

Corresponding Author: Dirgahayu Lantara, The Muslim University of Indonesia, Industrial Engineering Department, 9023, Makassar, Indonesia.
Ph: (+62)411 455667; (+62)411 455696

work in building the phinisi which not only limited by equipment and techniques but also determined by traditional religious believe make the production process is long and unpredictable. Another problem that affects the phinisi production time is the process in choosing raw materials for phinisi. Figure 4 shows a pile of raw materials of phinisi. These situations and problems are of interest to be studied deeply and thoroughly, so that one understands the underlying problems faced by the phinisi builders and how to find a better solution to improve productivity without neglecting traditional values held by the builders. There has been an improvement in the production process of phinisi building, such as the use of electric equipment instead of manual equipment. Figure 2a and 2b show an electric drill and electric scrapper which are used by the phinisi builders.

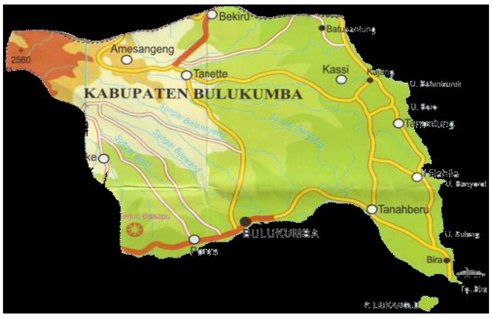

Fig. 1: Presents a map of Tanahberu Bulukumba.

Fig. 2a: Drill.

Fig. 2b: Scraper.

Fig. 3a: Manual components measurement.

Fig. 3b: Assembling the phinisi.

Fig. 4: Materials for building the phinisi.

In order to help phinisi builders to improve productivity a Programming Evaluation and Review Technique (PERT) model is developed. PERT is a network diagram that provides a visual depiction of the major activities and sequence in which they must be completed and widely used to plan and accommodate a project. A basic element of PERT planning is to identify critical activities on which is depend on other activities. Another model which depends on critical activities is Critical Path Method (CPM). The difference between PERT and CPR is that PERT uses a probabilistic approach, whereas CPM uses a deterministic approach (Kong Xiangxing, Zhang Xuan, Hou Zhenting, 2010). Since early 1960, there have been many networking models being developed and studied to plan and coordinate projects by balancing between times, resources and cost in which a series of activities are connected each other (Siamak Baradaran, S.M.T. Fatemi Ghomi, Mahdi Mobini, S.S. Hashemin, 2010).All models include Hypo Critical Path (HCP), Probabilistic Network Evaluation Techique (PNET), Narrow Reliability Bounds (NRB), Critical Chain Scheduling (CCS), Monte Carlo Simulation (MCS) (Jianxun Qi, Xiuhua Zhao). Those models are developed based on CPM model (Liu Jun-Yan, 2012), thus those models are not suitable to be applied in improving productivity of phinisi builders in Tanahberu. Using CPM model, it is not suitable to change times and sequences if the risk factors change. Therefore, PERT model is the best model to estimate times and cost of building the phinisi based on resources and activities involved in the projects.

This paper will discuss about activities of phinisi builders in Tanahberu, Sout Sulawesi, Indonesia. A PERT model is applied to help in estimating times and cost to build a phinisi efficiently and effectively without changing their traditional believes.

Methodology:

The research includes a survey and model development to determine the cost of building a phinisi ship. Based on the early survey, the phinisi building and production techniques were gained by the builder from generation to generation. The production process was leaded by a leader (*ponggawa*) who directed the whole building process using a work diagram provided by a customer. Traditionally, the size, cost and completion time in building the phinisi were discussed and agreed by both the leader and customer. The building process was performed using a fixed layout model in which everything was conducted in a single working station. All raw and supporting materials, preparation, main building and assembling process and finishing job were all performed in the work station. Figure 5a and 5b show the building and assembling process to make a phinisi.

Fig. 5a: Phinisi production process.

Fig. 5b: Phinisi assembling process.

The type, model and size of the phinisi as mentioned earlier were provided by a customer. Figure 6 shows the example of a phinisi design required by the customer, while table 1 presents the required size, time and price.

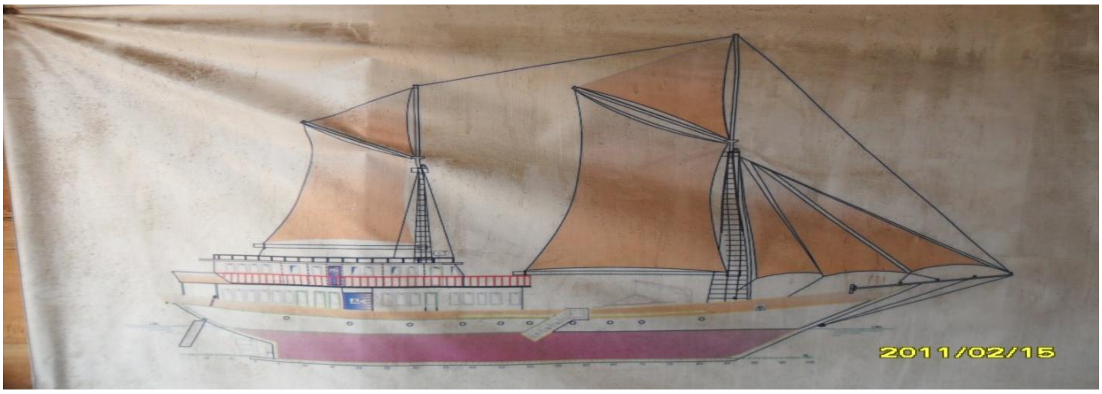

Fig. 6: Phinisi customer’s design.

Table 1: Phinisi specification required by a customer.

Weight (Tons)	Size (metre)		Time (month)	Builder (people)	Price (IDR)
400	Total length Deck length Keel length Width Height Draft	46.30 37.75 29.23 9.50 5.65 2.36	12	13	2,500,000,000

Based on the phinisi design and specification, a PERT model was developed. The PERT model in building the phinisi is presented at Figure 7.

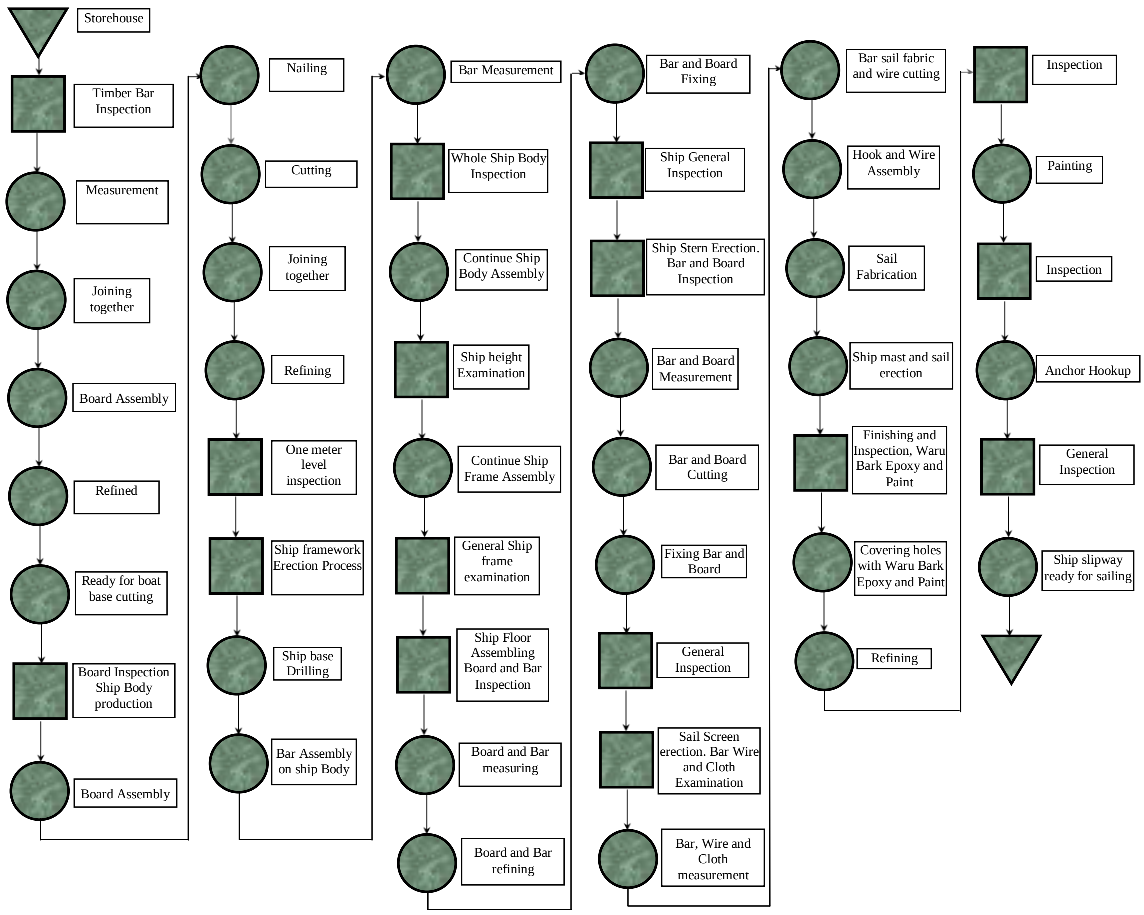

Fig. 7: Production process.

Based on Fig. 6, Table 1 and Fig. 7, a series of equations were developed to estimate total cost of phinisi building. Fig. 7 was developed using all working elements to build a phinisi specified by Table 1 (Ralph M. Barnes, 1980). The expected completion time, the shortest completion time, the longest completion time, identification critical sequence and a standard deviation were calculated using Eq.1 – Eq.4.

$$te = (a + 4\,m + b)\,(1/6) \quad \text{(Eq.1)}$$

$$TE_{ij} = TE_i + te_{ij} \quad \text{(Eq.2)}$$

$$TLij = TLj - teij \quad \text{(Eq.3)}$$

$$Slack = TL - TE = 0 \quad \text{(Eq.4)}$$

$$Z = \frac{x-\mu}{\sigma} = \frac{T(d) - TE}{St} \quad \text{(Eq.5)}$$

Using a day work method, the salary can be written with Eq.6.

$$OKP = \frac{sdg}{jk} \quad \text{(Eq. 6)}$$

The estimation of raw materials is calculated by Eg.7.

JMP = $\frac{pbk}{jam}$ (Eq. 7)

Arranging Eq.1 to Eq 7, a total cost of building a phinisi ship, then can be calculated as presented by Eq 8.

TBP $= \sum_{i=1}^{176} te_{-i} + te_{i\text{-}j}\,(N_1 PG_1 + \sum N_2 PK_2) + \sum HM$ (Eq.8)

RESULTS AND DISCUSSIONS

Activities and completion time on building a phinisi ship:

Process activities in building a phinisi based on Fig 8 and Table 1 were developed. Table 2 presents activities in building the phinisi, namely 30 component activities and 176 working elements.

Table 2: Activities Component and Working Elements.

No	Activities (Component)	Working elements
1	Keel	Measuring, coding, cutting, scraping, making a cap
2	Stem	Measuring, coding, cutting, scraping, measuring keel holes, making a cap in the keel, measuring a cap, making a cap, drilling, fixing bolts and nuts
3	Stern	Measuring, coding, cutting, scraping, measuring keel holes, making a cap in the keel, measuring a cap, making a cap, drilling, fixing bolts and nuts
4	1st Body	Inspecting wood boards, screwing, fixing, measuring using oiled string and a compass, cutting, scraping, drilling, adjusting and fixing
5	1st Joist	Scrapping, measuring distance between wood beams, coding, drilling, making caps of bolts and nuts, fixing bolts and
6	2nd Body	Fixing, measuring using oiled string and a compass, cutting, scraping, drilling, adjusting and fixing
7	2nd Joist	Scrapping, joining wood beams, drilling, making caps for bolts and nuts, fixing bolts and nuts
8	3rd Body	Fixing, measuring using oiled string and a compass, cutting, scraping, drilling, adjusting and fixing
9	3rd joist	Scrapping, joining wood beams, drilling, making caps for bolts and nuts, fixing bolts and nuts
10	4th Body	Fixing, measuring using oiled string and a compass, cutting, scraping, drilling, adjusting and fixing
11	4th joist	Scrapping, joining wood beams, drilling, making caps for bolts and nuts, fixing bolts and nuts
12	5th Body	Fixing, measuring using oiled string and a compass, cutting, scraping, drilling, adjusting and fixing
13	5th joist	Scrapping, joining wood beams, drilling, making caps for bolts and nuts, fixing bolts and nuts
14	6th Body	Fixing, measuring using oiled string and a compass, cutting, scraping, drilling, adjusting and fixing
15	6th joist	Scrapping, joining wood beams, drilling, making caps for bolts and nuts, fixing bolts and nuts
16	*Pacocorang*	Measuring and coding, cutting, scraping, drilling, fixing bolts and nuts
17	Aft	Measuring and coding, cutting, scraping, drilling, fixing bolts and nuts
18	*Ambing*	Measuring and coding, cutting, scraping, drilling, fixing bolts and nuts
19	*Lepe*	Measuring and coding, cutting, scraping, drilling, fixing bolts and nuts, closing the bolts and nuts
20	Ship ladder	Measuring and coding, cutting, scraping, making caps, fixing the base, finishing
21	Hatch	Measuring wood beams, coding, cutting, scarping, fixing wood beams, measuring wood boards, coding, scraping, fixing wood boards on the wood beams, cutting
22	Hatch *lepe*	Measuring, coding, cutting, scraping, fixing
23	Top side *Lepe*	Measuring, coding, cutting, scraping, fixing
24	Hull	Measuring, coding, cutting, scraping, fixing
25	Bulkhead	Measuring, coding, cutting, scraping, fixing
26	Room roof	Measuring, coding, cutting, scraping, fixing
27	Bridge	Measuring wood beams and boards, coding, cutting, scraping, fixing
28	Bathroom/toilet	Measuring wood beams and boards, coding, cutting, scraping, fixing
29	Finishing	Fixing, sticking, joining, closing imperfect joint, polishing, painting, inspecting, repairing, affixing anchor/machine
30	Sail	Measuring the sail, coding, cutting, measuring the sling, coding, cutting, measuring the mast, coding, cutting, sewing, measuring the ladder, coding, cutting, scraping, foxing the ladder, fixing the sail, adjusting the sail

The completion time to build one phinisi ship was based on 30 activities and 176 working elements mentioned in Table 2 for 24 phinisi building companies in Tanahberu is presented in Fig 8. It can be seen from the figure that the completion time is varied among the companies. Therefore PERT model was developed to estimate total cost and minimize the completion time in order to build a phinisi vehicle as specified by Table 1.

Based on the Eq. 1-4 presented on the previous section (Section 2), Eq. 1 was used to estimate expected duration time of the 24 companies. Then, the expected duration time was applied into Eq. 2, 3 and 4. Equation 2 was a forward calculation in which an activity can be started if the predecessor activity has been completed. In contrast, Eq. 3 was a backward calculation in which all activities can be started and finished without delaying the production time based on the forward calculation. Eq. 4 was used to calculate critical paths in the production process. It can be calculated using Eq. 4 that activities 171, 172, 173, 174, 175 and 176 were slack activities. Therefore, an improvement to the production process may be gained through activities 1 to 170. Figure 9 shows a network diagram developed after critical paths were evaluated.

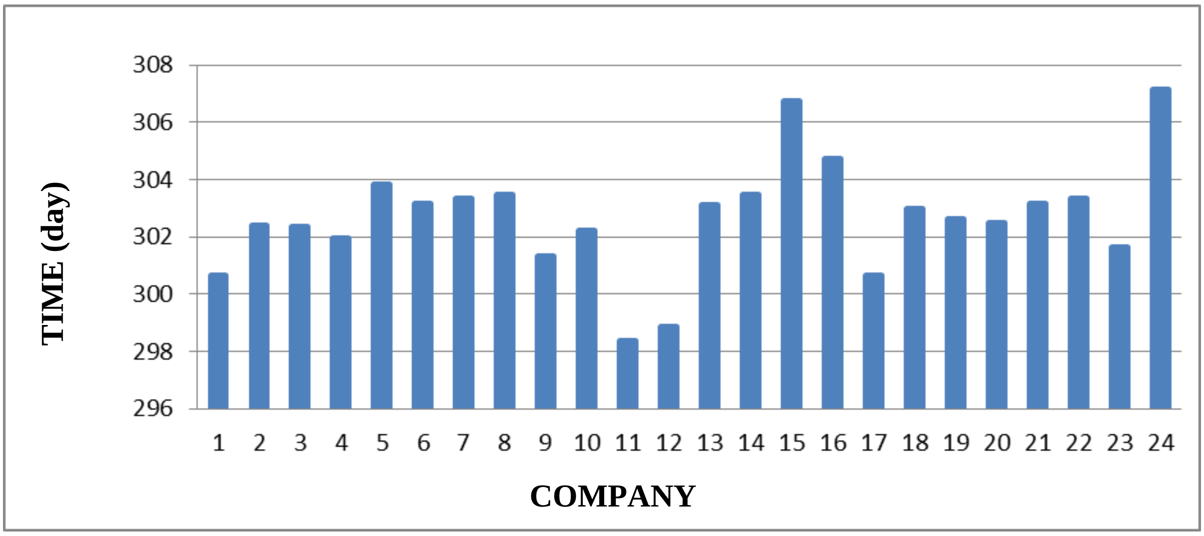

Fig. 8: Completion time of phinisi building of 24 companies in Tanahberu.

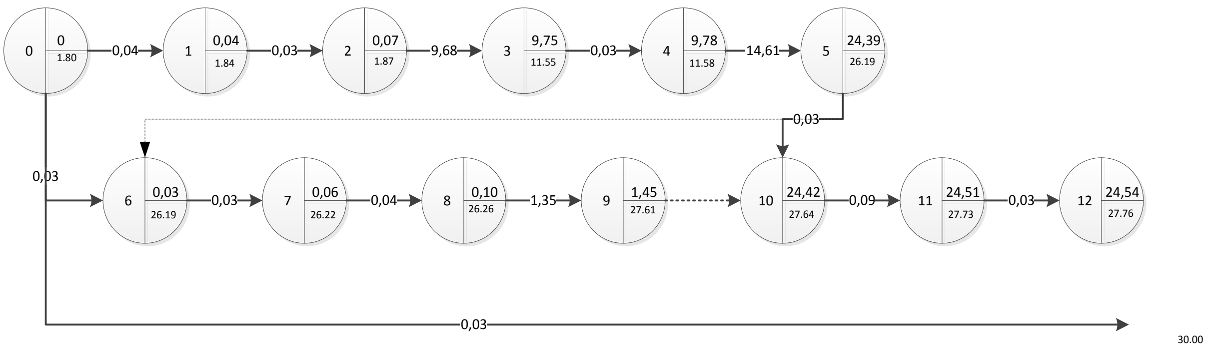

Fig. 9: Example of a network diagram.

The PERT model estimates range of time rather than a single time event. The time range marks the degree of uncertainty in completing each activity. The value of the degree of uncertainty depends on a and b parameters of PERT model which are commonly known as standard deviation and variance. Based on statistics, the value of the standard deviation is 1/6 of the distribution range (b-a).

If the curve of the event time distribution is symmetrical, the curve is called a normal distribution curve. The normal distribution curve has the following characteristics, namely:

1. If the area under the curve is 68% of the total area, the range is 2s
2. If the area under the curve is 68% of the total area, the range is 4s
3. If the area under the curve is 68% of the total area, the range is 6s

The identification of event variance (V (TE)) was calculated based on all events including milestone and the building of one phinisi vehicle. The variance of a successor event equals to V (TE) of the predecessor event and the V (TE) of the current activity, if there is no collaboration events. When there are collaboration events, total V (TE) could be obtained from the longest time range and the biggest variance.

The critical path and completion time on building one phinisi ship are identified using the equations developed which were discussed in the previous section. The relation between expected time (TE) with targeted time T (d) in the PERT model is defined as probability Z in which this method is used when the degree of uncertainty of the event is high. Based on the equation (Eq. 5), the value of the probability Z, was Z = 2.7574 = 0.9971. This value means that the phinisi builders have the probability of 97% to build one phinisi. Thus, 24 phinisi building companies at Tanahberu, Bontobahari, Bulukumba, South Sulawesi, Indonesia could produce a phinisi with the specifications as presented in Table 1 in 291 working days or 2328 working hours.

Salary of phinisi builders:

In building the phinisi, the working activities were leaded by a ponggawa (leader) who also the owner of the phinisi building company. Usually, the salary of the leader and all workers are not calculated. For the sake of the research, the researcher estimated the salary of the leader as well as salaries of all workers. The salary ranges were based on the Indonesian consultant association (Indonesian Consultant Association, 2010). The salary for the leader was IDR 17,850,000 / month, whereas for the worker the salary was IDR 1,440,000 (Depnaker Bulukumba, 20…). The working time for one month is 26 days and 8 hours a day. Therefore, the working hours for one month equal to 208 hours. Thus, the salary for the leader was IDR 85,817/hour and the salary for the worker was IDR 6,923/hour.

The materials amount:

Using the PERT model, it is paramount to calculate the amount of materials needed to build a phinisi. Based on Table 1 (the ship specifications) and Eq. 7, the required materials can be calculated. An example of the calculation of required materials for ship's body is as follows. The body of the phinisi ship is presented in Fig 11 and 12. Based on Figure 11 and 12, the phinisi deck has a length of 37.75 m and height of 5.65 m. The size of the wood board used for the phinisi body was 5 m (length) x 0.20 m (width) x 0.07m (depth). The boards required for the phinisi body based on its length was 7.55 boards and it was rounded to 8 boards. While the boards required based on the phinisi width was 29 boards. Therefore total boards to build a phinisi were 464 boards. The total volume of the boards was 32.48 m^3. The required materials for other parts of the phinisi were calculated using a similar method and used to estimate the price of the materials.

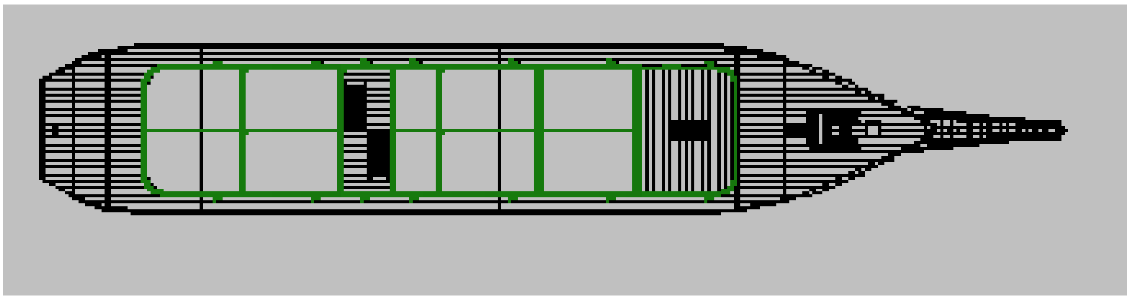

Fig. 11: Top view of the phinisi body model.

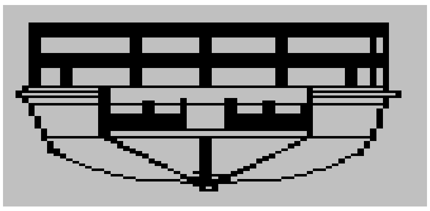

Fig. 12: Front view of the phinisi body model.

Table 3 presents the price list of the materials. The price of the materials was gathered from local stores of phinisi equipment stores and wood stores in South Sulawesi.

Total cost on building the phinisi:

Using Eq. 8, the total cost on building the phinisi could be obtained as follows:
= 2328 hr (1 x IDR 85,817 / hr + 12 x IDR 6,923 / hr) + IDR 1,144,958,500
= IDR 199,781,976 + IDR 193,400,928 + IDR 1,144,958,500 = IDR 1,538,141,404

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A Comparison between time and cost of the base model and PERT model:

The total cost on building the phinisi based on the base model and PERT model was calculated. The results of the calculation were presented in Table 4. It can be seen from Table 4 that the completion time in building phinisi reduced from 312 day 2496 when using base model to 291 day 2328 hours when using PERT model. The time reduction when applying PERT model on building the ship was 6.73%. Furthermore, there was also cost reduction of 38.47 % when using PERT model compared to when using base model on building the phinisi. In short, PERT model can be applied to help builders of phinisi to save time and money and hopefully help the phinisi company more competitive.

Tabel 3: Phinisi Materials Price lists.

NO	Component	material	Size (mm)	amount	Total unit	Unit price (Rp)	TOT AL price (Rp)
1	Keel	wood board	40 X 40 X 3000	1	4.8 M3	6.500.000	31.200.000
2	Stem	wood board	25 X 25 X 1000	1	0.625 M3	6.500.000	4.062.500
3	Stern	wood board	25 X 25 X 1000	1	0.625 M3	6.500.000	4.062.500
4	Body	wood board	7 X 20 X 500	464	32.48 M3	6.500.000	211.120.000
5	Joist	wood beam	10 X 10 X 500	285	14.25 M3	6.500.000	92.625.000
6	*PACOCORANG*	wood beam	20 X 20 X 1000	1	0.4 M3	6.500.000	2.600.000
7	Aft	wood beam	20 X 20 X 800	1	0.32 M3	6.500.000	2.080.000
8	*AMBING*	wood beam	25 X 25 X 400	2	0.5 M3	6.500.000	3.250.000
9	*LEPE*	wood board	4 X 20 X 500	326	13.04 M3	6.500.000	84.760.000
10	Ladder	wood board	5 X 20 X 800	2	0.16 M3	6.500.000	1.040.000
11	Hatch	wood beam	10 X 10 X 500	167	8.35 M3	6.500.000	54.275.000
12	Hatch	wood board	3 X 20 X 500	359	10.77 M3	6.500.000	70.005.000
13	Sail	wood beam	20 X 20 X 1000	2	0.8 M3	6.500.000	5.200.000
14	*LEPE (concurrent to the aft)*	wood board	4 X 20 X 500	59	2.36 M3	6.500.000	15.340.000
15	*LEPE top)*	wood board	8 X 18 X 500	12	0.864 M3	6.500.000	5.616.000
16	Hull	wood beam	10 X 10 X 500	68	3.4 M3	6.500.000	22.100.000
17	Bulkhead	wood board	3 X 20 X 500	68	2.04 M3	6.500.000	13.260.000
18	Room roof	wood board	4 X 20 X 500	70	2.8 M3	6.500.000	18.200.000
19	Bathroom	wood beam	10X 10 X 500	36	1.8 M3	6.500.000	11.700.000
20	Bath room	wood board	3 X 20 X 500	72	2.16 M3	6.500.000	14.040.000
21	Bolts and nuts	Steel	D ½ - P 35 CM	1652	pcs	10.000	16.520.000
22	Bolts and nuts	Steel	D 5/8- P 35 CM	4819	pcs	17.500	84.332.500
23	Peg	wood board	-	7110	pcs	-	-
24	Wood skin	-	KG	104	KG	25.000	26.000.000
25	Wood glue	-	5 KG	22	5 KG	130.000	2.860.000
26	Wood putty	-	5 KG	22	5 KG	130.000	2.860.000
27	Harsh grinding paper	-	ROL - AA 100	20	ROL (50M)	400.000	8.000.000
28	Fine grinding paper	-	ROL - P.240	20	ROL (50M)	400.000	8.000.000
29	base painting/painting tools	-	5 KG	22	5 KG	80.000	1.760.000
30	Color painting/painting tool	-	5 KG	22	5 KG	85.000	1.870.000
31	Steel plate	-	240 X 120 X 0.3	13	pcs	600.000	7.800.000
32	Ship engine	-	400 TON	1	pcs	275 .000.000	275.000.000
33	Generator set	-	20 PK	1	pcs	14.000.000	14.000.000
34	Electric wire	-	ROL (100 M)	2	ROLL	650.000	1.300.000
35	Electric fitting	-	piece	22	pcs	35.000	770.000
36	Light bulb	-	Piece	20	pcs	160.000	3.200.000
37	Reservoir	-	4 M3	2	pcs	550.000	1.100.000
38	mast	-	METER	162	METER	50.000	8.100.000
39	nylon string	-	N0. 18 (88 M)	44	KG	30.000	1.320.000
40	Sling string	-	N0. 10	117	METER	18.000	2.106.000
41	ladder string	-	METER	130	METER	20.000	2.340.000
42	anchor string	-	NO. 20 (44 M)	160	KG	34.000	5.440.000
43	Anchor	-	2 Pieces	2	pcs	1.850.000	3.700.000
						T o t a l	1.144.958.500

Table 4: A Phinisi building cost comparison.

Model	Time		Cost (IDR)	Difference, %	
	Day	Hour		Time	Cost
Base Model	312	2496	2,500,000,000	6.73	38.47
PERT Model	291	2328	1,538,141,404		

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Conclusion:

PERT model has been applied to estimate time and cost on building the phinisi ship of 24 phinisi building companies in Tanahberu, Bulukumba, South Sulawesi, Indonesia. It was found that there were 6 critical paths of 176 paths, namely path 171,172,173,174,175 and 176, respectively, during building the phinisi. The expected completion time using PERT model was 291 day and 2328 hours with the probability of 99.71%. The salary of the leader was IDR 85,817/hour and the salary of the worker was IDR 6,923/hr. Total salary on building one phinisi ship for the leader was IDR 199,781,976 whereas for the workers was IDR 193,400,928. There were 43 types of materials used to build the phinisi with the total cost to purchase the materials was IDR 1,144,958,500. The time reduction in building the phinisi using PERT model was 6.73%, while the cost reduction was 38.47%.

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