International Journal of Civil Engineering and Technology (IJCIET)
Volume 9, Issue 6, June 2018, pp. 861–871, Article ID: IJCIET_09_06_099
Available online at http://iaeme.com/Home/issue/IJCIET?Volume=9&Issue=6
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

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TOTAL COSTS MODEL DEVELOPMENT OF PHINISI SAILBOAT PRODUCTION SYSTEM WITH CRITICAL PATH METHOD (CPM)

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ABSTRACT

Phinisi sailboat is produced by Bugis Ethnic, Makassar, and South Sulawesi. The craftsmen use traditional ways to make Phinisi sailboat. This research purpose is to explore the production system in relation with production design aspects by utilizing and adjusting with craftsmen resources of phinisi shipbuilders. Therefore, process to make a phinisi sailboat provide time of manufacturing, raw materials, and which accumulated in total cost. Subjects were 24 companies from 34 companies located in center of phinisi shipbuilders. They make phinisi sailboat with equal weight, using Critical Path Method (CPM) and activity changes based on components show that 47 activities in traditional method with 176 development activity can change to become 30 activities with CPM method, processing time is 181 days or 2353 hours, components used are 43 components, with 16,486 items material, including the 21 main components with 2004 material item, with total cost of IDR 1,542,362,729.00

Key words: Production systems, Critical Path Method (CPM), Total Cost.

Cite this Article: Dirgahayu Lantara, Takdir Alisyahbana, A. Pawennari, Rahmaniah Malik, Anis Saleh and Hasan Basri, Total Costs Model Development of Phinisi Sailboat Production System with Critical Path Method (CPM), International Journal of Civil Engineering and Technology, 9(6), 2018, pp. 861–871
http://iaeme.com/Home/issue/IJCIET?Volume=9&Issue=6

1. INTRODUCTION

Phinisi is a traditional sailboat from Makassar and Bugis ethnic in South Sulawesi. It uses schooner screen with two poles and seven strands of screen. It has the meaning that Indonesia ancestors able to navigate the seven major oceans in world. In making Phinisi, craftsmen shipbuilders must calculate a good day to start the wood search as a raw material. It usually falls on fifth and seventh day of the month. Number 5 (naparilimai dalle'na) implies the provision is already in hand. Number 7 (natujuangi dalle'na) means always gain sustenance. Furthermore, foreman (punggawa) leads the wood search. For current conditions, wood is b bought from seller. Furthermore, process to lay lunas (wood base) for ship is begun with lunas at Northeast direction. Lunas beam is a symbol of man and lunas at rear is interpreted as a symbol of women. After given mantra, the cut part is marked with a chisel. It is continued to make vessels body, ivory, prop, deck, boat booths, screens and pole screen and finishing. Each stage of process is always preceded by certain rituals. Tanahberu is a center for shipbuilding where craftsmen traditionally make phinisi sailboat. They are coastal communities of Tanahberu, Bulukumba regency, South Sulawesi province. Based on data year 2011, there were 34 phinisi shipbuilders with various types and weights. This study used purposive sampling method by choosing 24 companies as research subjects (Lantara DH, 2013). The production process phinisi shipbuilding has following specifications.

Table 1 Specifications of Phinisi Sailboat as Basic Model.

Weight (Ton)	Size (meter)	Time (month)	Worker (people)	Price (RP)
400	Overall length 46.30 Deck length 37.75 Lunas Length 29.23 Wide 9.50 High 5.65 Sarat 2.36	12	13	2.5 M

The production process is done traditionally same as the ancestors of the predecessor. Phinisi shipbuilding is guided by intuition, but the ship produced can sail oceans same as boat produced with modern production system model today. Craftsmen of phinisi shipbuilding industry in Tanahberu, Bontobahari Subdistrict, Bulukumba district, South Sulawesi province, can be categorized as a craftsmanship production system with natural development. The production process is more emphasis on individual work of art and ability to use the equipment driven by human ability. The production process of this phinisi sailboat consists of 47 activities. It can be decreased to 30 activities and 176 working element activities (Lantara HD 2013) to decrease work time about 6.73%, while the costs can be reduced by 38.47% (Lantara DH et al, 2014).

Work activities to make phinisi sailboat components are shown in Figure 1. It is a process to make inside part of phinisi sailboat. Figure 2 shows the work of outside of phinisi sailboat. Figure 3 shows the process to make the connection between the board material and ship body. Figure 4 is a process to make screen

Figure 1 Process to make inside path of phinisi sailboat

Figure 2 Process to make exterior

Figure 3 Process to connect the board

Figure 4 Process to make screen

Work activities to finish a phinisi sailboat are grouped into assembly operations at specific path from 30 production path. It is adapted from characteristics of job and craftsman ability to perform the work activities to complete one unit phinisi sailboats in order to get shortest time, and lowest cost. Theoretically, purpose to separate path in CPM assembly is to support the operations efficiency.

2. MATERIALS AND METHODS

Optimization examination with PERT can be approximated by Critical Path Method (CPM) (Lantara DH et al, 2014). Conceptually, it combines the use of same equipment and materials and can be done manually (McMullen and Tarasewich, 2003). CPM uses arrow diagrams (activity on arrow) to describe the project activities and a set of products with same main characteristics and generally consists of a platform and various variants (Samson et al, 2001).

CPM recognizes the critical path as a series of components to total number of activities and indicates the longest time period with fastest project completion. Critical path is started from the first until the last activity of project. Critical pathways are important for project implementation. Delayed activity at one track will cause delays in project as a whole.

Concept of *te* and figures earliest activity (the earliest time of occurrence - TE), and last time of activity (the latest time occurrence - TL), then identification of critical activities, critical path and slack can be treated as in CPM:

$$(TE)\text{-}j = (TE)\text{-}i + te(i\text{-}j) \quad (1)$$

$$(TL)\text{-}i = (TL)\text{-}j - te(i\text{-}j) \quad (2)$$

At critical path is:

$$\text{Slack} = 0 \text{ or } (TL) - (TE) = 0 \quad (3)$$

With basic concept of day work method, a model was developed to get wages payment by equation:

$$OKP = \frac{sdg}{jk} \quad (4)$$

okp : worker labor costs (IDR / hour)

sdg : standard salary (IDR)

$\sum$ Jk : Work duration (hour)

Calculation the raw material usage for one unit phinisi sailboat is:

JMP = $\frac{pbk}{jam}$ .. (5)

Where :

jmp: the amount of material usage

pbk: length, width, height of workpiece

h: length, width, height and spacing among material

Materials cost to make phinisi sailboat can be calculated by following equation:

$\sum$ HM $= \sum_{i=1}^{n} SM . HMPS$ (6)

Where :

Σ HM: the total price of material

SM: Material unit

HMPS: Price material per unit

Equation above can be used to make formulations to obtain a total cost with CPM models to make one unit phinisi sailboat with specifications according to Table 1, as adjusted for craftsmen working patterns at center of phinisi shipbuilding with following equation:

$TBCPM = \sum_{i=1}^{30} E\,S_i + D_{i-j}\ (\ N_1 PG_1 + \sum N_2\, PK_2\ ) + \sum$ HM.............................7

Where :

TBCPM = Total Cost of CPM

$\sum_{i=1}^{30} E\,S_i + D_{i-j}$ = Total completion time of phinisi sailboat

N_1 = *Ponggawa* / foreman (shipyard owner)

PG_1 = *Ponggawa* wages in hours (standard of Indonesian experts)

$\sum N_2$ = Total workers to finish phinisi sailboat

PK_2 = wages of workers in hours (UMR- Bulukumba)

ΣHM = Total cost of raw materials.

3. RESULTS AND DISCUSSION

3.1. Calculation of time with Critical Path Method

Schedule controlling in a production system is the most important part in terms of time and costs as a target. In completion a production process, CPM has series activities of components manufacture with longest total amount of time and shows the timeliness of fastest production process. Critical path is started from the beginning to end of production activities, with a constant completion time. PERT is engineered to face the situation with high levels of uncertainty (Jun-Yan Liu, 2012). Critical Path Method (CPM) has a range of activities to make components with a longest total amount of time and show timeliness of fastest production process. Critical path is started s from the beginning to end of production activities, with a constant time completion. It is a method of scheduling techniques is still in use the (Kelly, 1961). Bar chart is very easy to understood and become a communication tool among workers that is widely used as a control tool to implement the activities scheduling (Galloway, 2006).

Based on above description, data to make one unit phinisi sailboat is stochastic and has been neutralized into deterministic data. In order to calculate CPM, Table 2 shows the activity, activity code and time used to make one unit phinisi sailboat data.

Table 2 Data of activity, activity code and time

No	Activities	Activities code	Duration (Hours)
1	Manufacturing and Installation of *Lunas*	1	24.39
2	Manufacturing/Installation of High Pole	2	3.84
3	Manufacturing/Installation of Bos Pole	3	3.81
4	Puntir/Installation of Dapul 1	4	317.29
5	Manufacturing/Installation of Gading 1	5	32.08
6	Manufacturing/Installation of Dapul 2	6	174.84
7	Manufacturing/Installation of Gading 2	7	30.01
8	Manufacturing/Installation of Dapul 3	8	174.85
9	Manufacturing/Installation of Gading 3	9	30.01
10	Manufacturing/Installation of Dapul 4	10	174.85
11	Manufacturing/Installation of Gading 4	11	30.01
12	Manufacturing/Installation of Dapul 5	12	174.85
13	Manufacturing/Installation of Gading 5	13	30.01
14	Manufacturing/Installation of Dapul 6	14	174.84
15	Manufacturing/Installation of Gading 6	15	30.01
16	Manufacturing/Installation of Pacocorang	16	5.48
17	Manufacturing/Installation of Back Linggi	17	6.79
18	Manufacturing/Installation of Ambing	18	4.35
19	Manufacturing/Installation of Lepe	19	447.95
20	Manufacturing/Installation of Boat Ladder	20	19.79
21	Manufacturing/Installation of Palka	21	42.04
22	Manufacturing/Installation of Lepe in row with palka	22	20.39
23	Manufacturing/Installation of Upper Lepe	23	5
24	Manufacturing/Installation of Room Skeleton	24	4.75
25	Manufacturing/Installation of Room wall	25	9.33
26	Manufacturing/Installation of Room roof	26	6.45
27	Manufacturing/Installation of Steer Ambing	27	4.59
28	Manufacturing/Installation of Water bath and bathroom	28	3.05
29	Finishing	29	268.24
30	Manufacturing/Installation of Screen	30	172.84

Meanwhile, to demonstrate the predecessor activity, it means that earliest time of an activity is derived from such activities could be started. According to basic rules of networking, new activities can be started when the preceding activity has been completed. It can be made in tabular form as follows :

Table 3 Data of activity, predecessor activity and time

No	Activities code	Predecessor activities	Duration (Hours)
1	1	-	24.39
2	2	1	3.84
3	3	1	3.81
4	4	1	317.29
5	5	4	32.08
6	6	5	174.84
7	7	6	30.01
8	8	7	174.85
9	9	8	30.01
10	10	9	174.85
11	11	10	30.01
12	12	11	174.85
13	13	12	30.01
14	14	13	174.84
15	15	14	30.01
16	16	2	5.48
17	17	3	6.79
18	18	15-17	4.35
19	19	15	447.95
20	20	18	19.79
21	21	19 – 20	42.04
22	22	19 – 21	20.39
23	23	22	5
24	24	21	4.75
25	25	24	9.33
26	26	25	6.45
27	27	20	4.59
28	28	27	3.05
29	29	16 – 26 – 28	268.24
30	30	29	172.84

Equation 1 is used to calculate earliest activity (SPA) coupled with next activity. Equation 2 is used to calculate the last moment (SPL) reduced by previous activity. Equation 3 is used to calculate the slack by using SPL - SPA = 0, then it is called the critical path. Calculation results of SPA, SPL, and Slack can be seen in table below.

Table 4 Calculation Result of SPA, SPL and Slack

Activities code	Earliest time	Latest time	Slack
1	24.39	305.44	281.05
2	28.23	2167.5	2139.27
3	28.2	2134.44	2106.24
4	341.68	329.83	11.85
5	372.76	647.12	274.36
6	403.77	679.2	275.43
7	578.62	753.47	174.85
8	854.05	884.06	30.01
9	783.48	1058.91	275.43
10	958.33	1088.92	130.59
11	988.34	1263.77	275.43
12	1163.19	1293.78	130.59

13	1193.2	1468.62	275.42
14	1368.09	1498.63	130.54
15	1398.06	1673.47	275.41
16	33.71	217.34	183.63
17	34.99	2138.25	2103.54
18	1402.41	2145.04	742.63
19	1846.01	1703.48	142.53
20	1422.2	2149.39	727.19
21	1888.05	2114.25	226.2
22	1908.44	2151.43	242.99
23	1913.44	2171.82	258.38
24	1892.8	2156.29	263.49
25	1902.13	2161.04	258.91
26	1908.58	2170.34	261.76
27	1425.25	2169.18	744.52
28	1428.3	2173.77	745.47
29	2176.82	2176.82	0
30	2349.66	2349.66	0

Calculation result of first activity, last activity occurred and slack in Table 4 can be used to draw critical path network below:

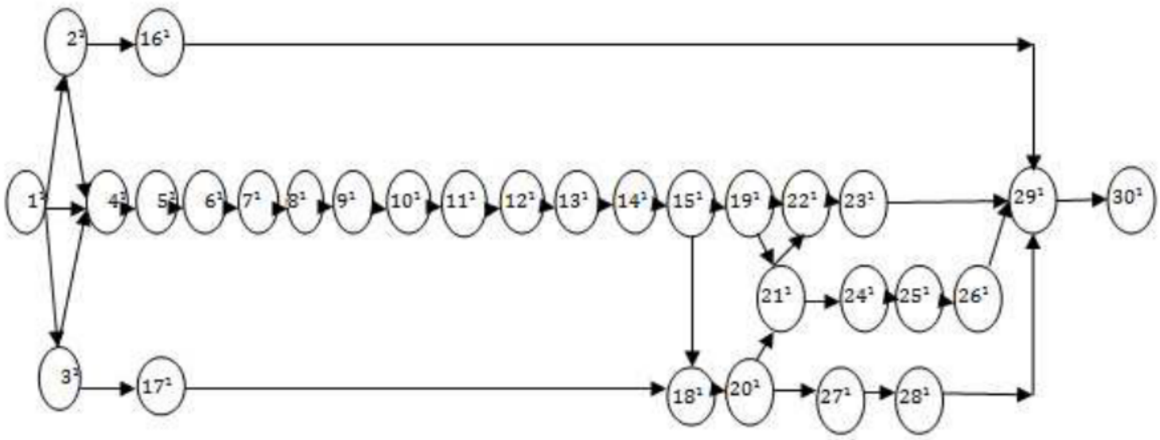

Figure 5 Critical Path Network

Figure 5 shows that critical path activities are occurred at 29 and 30. Using critical path method (CPM), one unit phinisi sailboat can be in 2,349.66 hours. Using 13 hours as a standard working a day, time level to complete one unit phinisi sailboat is 180.74 day, rounded as 181 days.

3.2. Labor costs to Finis One Unit Phinisi Sailboat

Phinisi sailboat manufacturing is leaded by a Ponggawa (foreman) as the owner of shipyard. To calculate wages by Ponggawa (foreman), researchers refer to National Institute of Standards Expert Consultant Indonesia, based on professional experience is IDR 17,850,000 / month (Google, guidelines for minimum standards in 2010). And other labor is IDR 1,440,000 (social services, manpower and transmigration, Bulukumba Subdistrict). Working time in a month equal to 26 days, and one working day equals 8 hours. Using the equation 3, wage of Ponggawa (foreman) per hour = IDR 17.85 million / 26 x 8 = IDR 85,817.

Wage of other labor in hours = IDR 1,440,000 / 26 x 8 = IDR 6923. With number 12 other workers and 1 Ponggawa.

3.3. Material Consumption and Price in Completing One Unit of Phinisi Sailboat

Further discussion family product model analysis is used to calculate material to complete one unit of phinisi sailboat. In according to specifications, equation 4 is used as an example to calculate raw materials of *dapul* (sailboat body) below.

The length of deck = 37.75 meters and height = 5.65 meters. Material used to make dapul (sailboat body) is board with a length of 5 meters, and a width of 0:20 meters. Material needs for Dapul = 37.75 / 5 = 7.55, rounded as 8 pieces, and 5.65 / 0.20 = 28.25 = 29 pieces, (rounded) to obtain = 8 x 29 x 2 = 464 pieces of board with 7 x 20 x 500. Therefore, dapul need = 464 x 0.07 = 32.48 M^3.

Material is obtained from various stores to sell phinisi sailboat equipment, and wood sellers come from region of South Sulawesi province. Overall calculation results of material needs and material prices, as well as the total cost of material needed to make one unit of phinisi sailboat is shown in Table 5 below.

Table 5 Raw material needs price and total price for manufacture of one unit phinisi sailboat.

No	Components	Material	Size	Unit	Total Unit	Unit Price (IDR)	Total Price (IDR)
1	*Lunas*	Beam	40 X 40 X 3000	1	4.8 M^3	6.500.000	31.200.000
2	High Pole	Beam	25 X 25 X 1000	1	0.625 M^3	6.500.000	4.062.500
3	Bos Pole	Beam	25 X 25 X 1000	1	0.625 M^3	6.500.000	4.062.500
4	Dapul (Sailboat Body)	Board	7 X 20 X 500	464	32.48 M^3	6.500.000	211.120.000
5	Gading (Sailboat Skeleton)	Beam	10 X 10 X 500	285	14.25 M^3	6.500.000	92.625.000
6	Pacocorang	Beam	20 X 20 X 1000	1	0.4 M^3	6.500.000	2.600.000
7	Linggi (Rear Part)	Beam	20 X 20 X 800	1	0.32 M^3	6.500.000	2.080.000
8	Ambing	Beam	25 X 25 X 400	2	0.5 M^3	6.500.000	3.250.000
9	Lepe (Lower Part)	Board	4 X 20 X 500	326	13.04 M^3	6.500.000	84.760.000
10	Sailboat Ladder	Board	5 X 20 X 800	2	0.16 M^3	6.500.000	1.040.000
11	Sailboat Palka	Beam	10 X 10 X 500	167	8.35 M^3	6.500.000	54.275.000
12	Sailboat Palka	Board	3 X 20 X 500	359	10.77 M^3	6.500.000	70.005.000
13	Screen Pole	Beam	20 X 20 X 1000	2	0.8 M^3	6.500.000	5.200.000
14	Lepe (Parallel With Palka)	Board	4 X 20 X 500	59	2.36 M^3	6.500.000	15.340.000
15	Lepe (Above Part)	Board	8 X 18 X 500	12	0.864 M^3	6.500.000	5.616.000
16	Room Skeleton	Beam	10 X 10 X 500	68	3.4 M^3	6.500.000	22.100.000
17	Room Wall	Board	3 X 20 X 500	68	2.04 M^3	6.500.000	13.260.000
18	Room Roof	Board	4 X 20 X 500	70	2.8 M^3	6.500.000	18.200.000
19	Bathroom	Board	10x 10 X 500	36	1.8 M^3	6.500.000	11.700.000
20	Bathroom	Board	3 X 20 X 500	72	2.16 M^3	6.500.000	14.040.000
21	Bolt And Mur	Steel	D ½ - P 35 Cm	1652	Piece	10.000	16.520.000
22	Bolt And Mur	Steel	D 5/8- P 35 Cm	4819	Piece	17.500	84.332.500
23	Peg	Steel	-	7110	Piece	-	-
24	Gelam (Wood Skin)	-	Kg	104	Kg	25.000	26.000.000
25	Glue	-	5 Kg	22	5 Kg	130.000	2.860.000
26	Putty/ Putty Knife	-	5 Kg	22	5 Kg	130.000	2.860.000
27	Sandpaper (Rough)	-	Rol - Aa 100	20	Rol (50m)	400.000	8.000.000
28	Sandpaper (Smooth)	-	Rol - P.240	20	Rol (50m)	400.000	8.000.000
29	Basic Paint/ Paint Tools	-	5 Kg	22	5 Kg	80.000	1.760.000
30	Color Paint/ Paint Tools	-	5 Kg	22	5 Kg	85.000	1.870.000
31	Steel Plate	-	240 X 120 X 0.3	13	Piece	600.000	7.800.000
32	Sailboat Machine	-	400 Ton	1	Piece	275.000.000	275.000.000
33	Generator Machine	-	20 Pk	1	Piece	14.000.000	14.000.000

34	Electric Cable	-	Rol (100 M)	2	Rol	650.000	1.300.000
35	Stop Contact /Fitting	-	Piece	22	Piece	35.000	770.000
36	Complete Lampiran	-	Piece	20	Piece	160.000	3.200.000
37	Reservoir	-	4 M3	2	Piece	550.000	1.100.000
38	Screen Cloth	-	Meter	162	Meter	50.000	8.100.000
39	Nylon Rope	-	N0. 18 (88 M)	44	Kg	30.000	1.320.000
40	Sling Rope	-	N0. 10	117	Meter	18.000	2.106.000
41	Ladder Rope	-	Meter	130	Meter	20.000	2.340.000
42	Anchor Rope	-	No. 20 (44 M)	160	Kg	34.000	5.440.000
43	Rope	-	2 Part	2	Part	1.850.000	3.700.000
						T O T A L	1.144.958.500

Source: Data processed from various shops seller of sailboat building equipment in South Sulawesi.

4. TOTAL COST CALCULATION OF PHINISI SAILBOAT MANUFACTURING

Equation 7 is used to calculate total cost to make one unit of phinisi sailboat.

2353 hour (1x IDR 85.817/hour + 12 x IDR 6.923/hour) + IDR 1.144.958.500

= IDR. 201.927.401 + IDR 195.477.828 + IDR 1.144.958.500 = IDR 1.542.362.729,-

5. COMPARISON OF TIME AND COST BETWEEN BASE MODEL AND CPM MODEL

Compariton between model is used to know the best model (Sivaraos et. al., 2014). Actual total cost model in accordance with craftsmen ability to make phinisi sailboat in Bulukumba is below.

Working time = 4056 hours, with total cost of To 2,500,000,000 to complete one unit of phinisi sailboat. CPM Analysis show that total time of 2353 hours with total cost of IDR 1,542,362,729. It needs a numerical modeling (Ilham et. al., 2010)

This result show that CPM model can d be paired with base model and actual models as reference in this research. Time and costs used are below.

Table 6 Time and Cost Comparison of Phinisi Sailboat Building Between Actual Model and CPM model.

Model	**Time**		**Cost (IDR)**	**%**	
	Days	**Hours**		**Time**	**Cost**
Actual Model	312	4056	2.500.000.000	41.99	38.31
CPM Model	181	2353	1.542.362.729		

Table 6 shows that critical path model (CPM) that paired with actual model based on weight and size as in Table 1 will decrease time and cost to manufacture one unit of phinisi sailboat. Time decreased 131 days or a total 1703 hours (41.99%), while cost decreases IDR 957,637,271 (38.31%).

Computation is needed to know the model condition (Saleh et. al., 2010) Hypothesis testing is done by standard normal distribution probability Z, to calculate or determine the total time probability to complete one unit phinisi sailboat based on CPM models and basic model. Result show CPM model is better than basic model based on equation of Z distribution.

$$Z = \frac{2496 - 2352}{60.9264} = 2.3635$$

Based on calculation, Z value = 2.3635. From normal distribution table, the Z value = 0.9909. It means that CPM models are better than basic model to complete one unit phinisi sailboat.

6. CONCLUSIONS

- Workers ability from 24 phinisi sailboat builder to make one unit phinisi sailboat in accordance with specifications, CPM models can reduce completion time by 46.47%. The cost can be reduced by 39.53%.
- Ponggawa wage is IDR 85 817 per hour, whereas the workers wage is IDR 6923 per hour. Total wages of Ponggawa is IDR 199,781,976, while total workers wages are IDR 193,400,928.
- The materials used are 43 components with a material of 16,486 items, including 21 main components with 2004 material item, with a total material cost of IDR 1,144,958,500.
- Normal distribution table shows Z value = 0.9909. It means CPM model is better than traditional model.

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