

# Mitigation of Delay Risk in Ship Construction Project With Lean Approach

1<sup>st</sup> Fandy Bestario Harlan  
Business Management  
Politeknik Negeri Batam  
Batam, Indonesia  
fandybestario@polibatam.ac.id

2<sup>nd</sup> Dodi Prima Resda  
Information Technology  
Politeknik Negeri Batam  
Batam, Indonesia  
dodi.prima@polibatam.ac.id

**Abstract**— PT. XYZ is a shipyard company that has problem about ship construction delay up to 40% of progress. The objectives of this research is determine the intensity of waste activity that occurred by a questionnaire method to four expert respondent. The result showed the existence of two biggest waste activity that is defect 19.77% and unnecessary motion 16.10%. Based on analysis and testimony by workers, instability of electric current, exhaustion and overwork are main causes of late construction completion.

**Keywords**— Waste, Assessment, Ship, Construction, Lean, Project, Management

## I. INTRODUCTION

Construction projects are generally the most high-risk businesses. According to Small, E.P (2017), 57% of total construction activity is non-added value activity. The ship construction project is a competitive project with major risks such as the delay in delivery of the vessel to the owner, work accidents, and production errors that cause the ship not to match the owner's order so with a large level of risk need good planning and control in the field. PT. XYZ start as a company providing ship repair services but is now able to build new ships that meet international standards and regulations. There is a risk of delays that occurred in the construction of 100 TEUS container ship construction at PT. XYZ so that the necessary evaluation of the process of construction activities in the field. In the construction of 100 TEUS container vessels, construction delays have reached 40 percent of the target. So that the complexity of existing activities in the shipyard and the limited management of the company to carry out monitoring in every aspect of construction activities, so it is necessary to conduct a systematic and strategic research to see the level of productivity in the company.

## II. METHODOLOGY

### A. Hull Block Construction

According to Storch, R.L (1995), Construction of shipbuilding with Hull Block Construction Method consists of three parts of work area activity, namely:

#### a. Fabrication Part

The fabrication part is the earliest level of physical work done by the shipyard when constructing a new ship. This work area consists of preparatory activities,

marking, cutting and assembly of small pieces of construction material.

#### b. Assembly Part

The block assembly stage is the core work on ship construction. Block assembly is the act of combining two or several panels becoming a ship block. This merging process usually requires heavy equipment to support its production activities.

#### c. Hull Erection Part

This process is the last job in constructing a new ship. This process makes the connection between the blocks 1 with the other section of the ship blocks that previously done in the assembly process.

#### d. Risk Management

According to Standards Australia/ Standards New Zealand 4360: 2005, risk is the possibility of an event that is impact to company's objectives. In addition, risk management is a culture, process and structure that is gear towards realizing goals while managing side effects.

$$Y_j \text{ final} = \frac{s_j}{S_j} \times \frac{f_j}{F_j} \times P_j$$

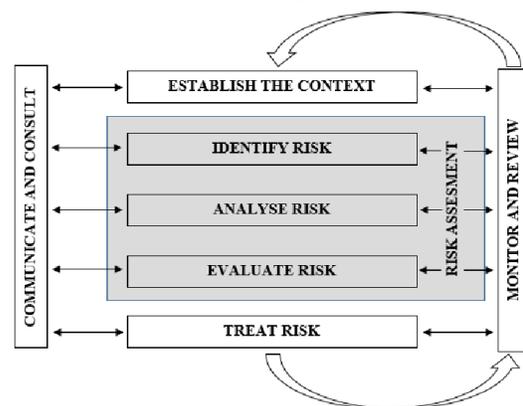


Fig. 1. Stages of risk management

### B. Critical Path Method (CPM)

The Critical Track Method or Project Network is the method used to determine the critical activities in a series of hull construction schedules. CPM used to determine the area to analyze the risk of the overall work.

Early Start	Duration	Early Finish
Task Name		
Late Start	Slack	Late Finish

Fig. 2. Duration of activity

Early Finish = Early Start + Duration

Late Start = Late Finish – Duration

Slack = Late Finish – Early Finish

While the critical flow is an activity that has a value slack = zero.

C. Waste Assessment Questionnaire

According to Rawabdeh, I.A (2005), Waste Assessment Questionnaire is a method of collecting waste data that occurs in the field by asking some questions to four respondents. Respondents who are asked to answer the question are workers in companies that already expert in their field and overall construction process. Some of the formula used to process data into weights waste is as follows.

$$S_j = \sum_{k=1}^K \frac{W_{j,k}}{N_i} \tag{1}$$

$$s_j = \sum_{k=1}^K X_k \times \frac{W_{j,k}}{N_i} \tag{2}$$

$$Y_j = \frac{s_j}{S_j} \times \frac{f_j}{F_j} \tag{3}$$

$$\tag{4}$$

Description:

S<sub>j</sub> = waste score

W<sub>j</sub> = weight of interconnection of waste

K = question number (1-68)

N<sub>i</sub> = the number of question categorized

s<sub>j</sub> = total of waste weight

X<sub>k</sub> = score of questionnaire answered (1, 0.5, or 0)

Y<sub>j</sub> = initial factor of waste

f<sub>j</sub> = score frequency s<sub>j</sub>

F<sub>j</sub> = score frequency S<sub>j</sub>

Y<sub>j</sub> = final factor of waste

P<sub>j</sub> = probability of waste interconnection

III. ANALYSIS AND RESULTS

Container vessel 100 TEUS be built by PT. XYZ has a length of 74 meters. Hull construction planned to be finish within 205 days but has a progress delay of up to 40 percent. 100 TEUS container ships built by PT. XYZ has a total of 34 blocks and consists of 89 fabrication activities, assembly and erection blocks.

A. Critical Path Analysis

Critical path analysis aims to see activities that have zero-slack time in the whole set of construction activities. Then the analysis of work productivity can be finish on critical activities. Critical activity on the construction of 100 TEUS container ship at PT. XYZ namely:

- a. Fabrication Activities: Block 1, Block 2, Block 3, Block 4, Block 5, Block 6, Block 7, Block 8, Block 9, Block 10, Block 11, Block 12, Block 13, Block 14, Block 15, Block 16, Block 17, Block 18, Block 19, Block 20, Block 21, Block 22, Block 23.
- b. Assembly Activity: Block 23.
- c. Erection Activity: Erection Block 22-23, Erection Block 24-25, Erection Block 27-28-29, Erection Block 30, Erection Block 31, Erection Block 32.

Based on the activities that have a critical duration above, we can analyze the waste that occurred in the field and caused the delay of completion of construction on the activity. Viewing from the result of data processing critical flow above, the dominant activity in the critical line that is on the activity of fabrication and erection block.

B. Identify Waste

At the stage of identification and measurement of waste aims to determine the type of waste that is most dominant in the field. There are two stages in the assessment of waste in this research, which is analyzing interconnection of each waste with Waste Relationship Matrix method and identification of waste with Waste Assessment Questionnaire. Then the final assessment will be the overall weight of each waste that occurs in the field.

1. Waste Relationship Matrix

The following are the steps in the measurement of waste interconnection:

- a. Scoring through the analysis of the interconnection of each waste. Value was gave according to the capacity of the relationship between wastes. Then the total score for interconnection of each waste is categorized into symbols according to the range of values (A, E, I, O, U and X). A = Absolutely Necessary (range 17-20), Value E = Especially Important (range 13-16), Value I = Important (range 9-12), Value O = Ordinary Closeness (range 5-8), Value U = Unimportant (range 1-4), Value X = No relation (range 0). Here is the assessment of the interconnection of each waste.

TABLE I. WASTE INTERCONNECTION SCORE

Waste Symbol	Interconnection	Total	Score Symbol
S_D	SHE_Defect	5	O
S_M	SHE_Motion	10	I
S_T	SHE_Transportation	13	E
S_W	SHE_Waiting	13	E
I_S	Inventory_SHE	12	I
I_D	Inventory_Defect	11	I
I_M	Inventory_Motion	11	I
I_T	Inventory_Transportation	9	I
D_S	Defect_SHE	9	I

D_I	Defect_Inventory	7	O
D_M	Defect_Motion	13	E
D_T	Defect_Transportation	11	I
D_W	Defect_Waiting	13	E
M_I	Motion_Inventory	5	O
M_D	Motion_Defect	15	E
M_W	Motion_Waiting	18	A
M_P	Motion_Process	11	I
T_S	Transportation_SHE	4	U
T_I	Transportation_Inventory	5	O
T_D	Transportation_Defect	10	I
T_M	Transportation_Motion	6	O
T_W	Transportation_Waiting	11	I
P_S	Process_SHE	9	I
P_I	Process_Inventory	3	U
P_D	Process_Defect	11	I
P_M	Process_Motion	10	I
P_W	Process_Waiting	12	I
W_S	Waiting_SHE	4	U
W_I	Waiting_Inventory	20	A
W_D	Waiting_Defect	8	O

b. Arrange the waste relationships matrix based on the total score symbol in the previous table.

TABLE II. WASTE RELATIONSHIP MATRIX (SYMBOL)

T	S	I	D	M	T	P	W
F	S	I	D	M	T	P	W
S	A	X	O	I	E	X	E
I	I	A	I	I	I	X	X
D	I	O	A	E	I	X	E
M	X	O	E	A	X	I	A
T	U	O	I	O	A	X	I
P	I	U	I	I	X	A	I
W	U	A	O	X	X	X	A

c. Replace the symbols in the matrix step b with a predetermined value scale. Scale for each symbol i.e; E = 8, I = 6, O = 4, U = 2.

TABLE III. SCALE AND WEIGHT OF EACH WASTE

T	S	I	D	M	T	P	W	Total	%
F	S	I	D	M	T	P	W	Total	%
S	10	0	4	6	8	0	8	36	14.7%
I	6	10	6	6	6	0	0	34	14.9%
D	6	4	10	8	6	0	8	42	17.2%
M	0	4	8	10	0	6	10	38	15.6%
T	2	4	6	4	10	0	6	32	13.1%
P	6	2	6	6	0	10	6	36	14.8%
W	2	10	4	0	0	0	10	26	10.7%
Total	32	34	44	40	30	16	48	244	
%	13.1%	14.9%	18.0%	16.4%	12.3%	6.5%	19.6%		100%

d. Categorize and count the number of questionnaire questions for each type of waste

TABLE IV. TOTAL QUESTIONS ON EACH TYPE OF WASTE RELATIONSHIP CATEGORY

No.	Type of Question	Total (Ni)
1.	From SHE	3
2.	From Inventory	6
3.	From Defects	8
4.	From Motion	11
5.	From Transportation	4
6.	From Process	7
7.	From Waiting	8
8.	To Defects	4
9.	To Motion	8
10.	To Transportation	4
11.	To Waiting	5
Total Question		68

e. Give weight to each question questionnaire based on Waste Relationship Matrix.

TABLE V. WEIGHTED VALUE BASED ON WRM ON QUESTIONNAIRE

Category	Question Type	Question No.	S	I	D	M	T	P	W
Man	To Motion	1	6	6	8	10	4	6	0
	From Motion	2	0	4	8	10	0	6	10
	-	-	-	-	-	-	-	-	-
Material	To Waiting	8	8	0	8	10	6	6	10
	From Waiting	9	2	10	4	0	0	0	10
	-	-	-	-	-	-	-	-	-
Machine	From Process	32	6	2	6	6	0	10	6
	To Waiting	33	8	0	8	10	6	6	10
	-	-	-	-	-	-	-	-	-
Method	-	-	-	-	-	-	-	-	-
	From Process	67	6	2	6	6	0	10	6
	From Defect	68	6	4	10	8	6	0	8
Total Score			312	346	486	456	268	238	408

f. Eliminate the effects of varying number of questions for each type of question. Eliminating the effect of variation on the number of questions on each waste by divided the weight for each waste in the previous stage with the number of questions (Ni) that exist in each type of waste in the questionnaire.

TABLE VI. THE WEIGHTING OF EACH QUESTION WITH N (I)

Question Type	N(i)	Question (K)	Ws, k	Wi, k	-	Ww, k
To Motion	9	1	0.67	0.67	-	0.00
From Motion	11	2	0.00	0.36	-	0.91
From Defect	9	3	0.67	0.44	-	0.89
From Motion	11	4	0.00	0.36	-	0.91
From Motion	11	5	0.00	0.36	-	0.91
-	-	-	-	-	-	-
From Defect	9	68	0.67	0.44	-	0.89
Score (Sj)			61.07	59.33	-	66.00
Frequency (Fj)			57	61	-	50

2. Waste Assessment Questionnaire

Here are the steps in fetching and processing the Waste Assessment Questionnaire data.

- a. Take the questionnaire to the parties who understand the conditions in the field. Questionnaires was gave to the project manager, PPIC manager and two field surveyor owners who usually always supervise and observe the construction process.
- b. Multiplying the score of the questionnaire results with the weight value in the stages of waste relationship matrix in table 6. Questionnaire given to the company only in the form of unmeasured variables (yes, medium or not). Then the next step is to change the answer on the questionnaire into the form of numbers that is 1, 0.5 or 0. Then the average score of the questionnaire results multiplied by the weight of each question that has calculated in table 6.

TABLE VII. CALCULATION OF QUESTIONNAIRE DATA

Question (K)	Question Type	N of Question	Quesioner Answer				Average	Ws, k	-	Ww, k
			1	2	3	4				
1	To Motion	9	1	1	1	1	1.00	0.67	-	0.00
2	From Motion	11	1	0.5	0.5	1	0.75	0.00	-	0.68
3	From Defect	9	1	1	1	1	1	0.67	-	0.89
-	-	-	-	-	-	-	-	-	-	-
68	From Defect	9	0.5	0.5	0.5	0.5	0.5	0.33	-	0.44
		Score (sj)						34.61	-	32.43
		Frequency (fj)						57	-	50

- c. Calculate total score and frequency for each type of waste. This stage calculates the total score (sj) on each column type of waste and frequency in each column (fj) by ignoring the zero values contained in the results of the questionnaire scores.
- d. Calculates the initial indicators for each type of waste (Yj). After the weighted value of each question is calculated, then calculate the initial indicator of the interconnection of the type of waste with the results of the questionnaire scores.
- e. Calculate the final value of waste factor (Yj final). To calculate the value of Yj (final) by multiplying the value (Pj) and Yj. While in the final stage, calculate the weight of the previous multiplication (Pj and Yj). For the result as in the table below.

TABLE VIII. RESULT OF DOMINANT WASTE (FINAL)

	S	I	D	M	T	P	W
Yj	0.57	0.57	0.54	0.53	0.53	0.54	0.49
Pj	192.57	222.01	309.60	255.84	161.13	96.20	209.72
Yj(final)	109.14	126.55	166.30	135.46	85.20	52.29	103.06
Weight	12.97%	15.04%	19.77%	16.10%	10.13%	6.22%	12.25%
Rating	4	3	1	2	6	7	5

IV. DISCUSSION

One of the qualitative methods to assess the existence of waste in the company is by questionnaire method. Doing waste continuously without any prevention or repair by the company will cause losses on the company's business activities. In the ship construction business, the delay in order fulfillment of vessels to the owner is one of the major risks that should be avoid by company. Then with the waste that has been identified above, Together the company looking for alternative improvements to reduce the waste that occurred in the field. There are two dominant wastes of defect and unnecessary motion. Analyses of the causes of these two wastes in the field are:

1. Defect occurs due to errors in the process or working methods. Errors often found in the fabrication process so that material repair worked during the process of sub assembly and assembly. Then the working time on the assembly process becomes long. In addition, the work area of assembly and erection often occur unstable electrical voltage that often occurs overheating in welding or lack of electricity. Then, some materials stored in open space so that the quality and condition of the material becomes worse. Improper material transfer processes also caused deformation of the material. Then some evaluation and improvement that can be applied in PT. XYZ are like:
  - a. Evaluate the condition of the facility and overall welding equipment. Repair or replace broken equipment.
  - b. Hire welders with skill certificates or minimum experience in two shipbuilding projects.
  - c. Evaluate workload of workers and add field workers
2. While unnecessary motion waste is caused by frequent rotation of workers in the field to complete work in other work areas that lack of manpower. This condition causes operator fatigue and reduced concentration on job responsibilities. Manpower rotation often occurs in the work area of assembly and erection. While in the erection area, construction did on a closed area inside the ship deck that lack of air and light. In addition, the large number of new ship building projects resulted in the accumulation of raw materials and in-process materials in the production area. Structuring raw materials and in-process materials are not ergonomic. This is because the production materials are large so there is no special storage. On this situation, will reduce the productivity of workers in the field. Then some evaluation and improvement that can be applied in PT. XYZ are like:
  - a. Arrange raw material (plate) in one place.
  - b. Put in-process material close to the work area of the next process.
  - c. Evaluate workload of workers and add field workers.

## V. CONCLUSIONS

Based on waste assessment using waste assessment questionnaire method to four respondents, the dominant waste activity occurred in PT. XYZ is defect material and unnecessary motion. While the weight of each waste activity that occurs that; defect material 19.77%, unnecessary motion 16.10%, inventory management 15.04%, SHE 12.97%, waiting activities 12.25%, transportation 10.13% and unproprioate process 6.22%. Alternative improvement to defect material process is by increasing regulator maintenance or replaces the broken part, using capacitor bank to make electricity more stable. In addition, the solution caused by the uncapable welder is by increasing the selection of sub-con welder that does not have a certificate of expertise or experience. Increase the number of field workers to avoid job rotation and excessive fatigue. Besides it's arranging the in-process material adjacent to the work area.

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