Risk Mitigation on Infrastructure Port Project Construction (Case Study: Sanur Port Project, Bali, Indonesia)

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Abstract. Port construction projects have complex work stages and high dependence on internal and external conditions so that the emergence of risks that can cause project delays is elevated. Therefore, it is necessary to apply risk management to identify and overcome the risks that will come. This research uses the Analytic Hierarchy Process (AHP) method to rank risks and determine the most dominant risk parameters for risk analysis. This study shows there are 4 dominant delay risks parameter on the Sanur Port project, with the most dominant risk parameter is the high wave parameter. The effect of high wave risk on the Sanur Port construction project is the delay in project work for 98 days. To reduce the impact of risks that may occur, risk mitigation is carried out on aspects of workers, tools, and methods of implementation.

1 Introduction

Port development projects have complex work stages and high dependence on internal and external project conditions, causing the potential for delays to occur in project implementation to be higher [1]. One of the causes of delays in a construction project is the emergence of unexpected risks in one or several stages of construction [2]. The risks contained in the project cannot be eliminated but can be reduced by systematic risk analysis, namely by identifying, analyzing, and responding to project risks [3].

In the risk identification process using a method known as the Lookup Method, this method is in the form of making a risk checklist based on risk data identified on projects that have been done previously. This method is straightforward to apply and can help identify risks in detail [4]. Meanwhile, in the risk ranking analysis based on the impact assessment and risk frequency using the AHP (Analytic Hierarchy Process) method. Analytic Hierarchy Process (AHP) is a structured technique that aims to organize and analyze complex decisions, this method is an accurate approach in measuring the weight of decision criteria [5].

In the Sanur Port construction project, there has been a delay due to being late in dealing with the tidal wave problem at the time of carrying out the survey work. Geographically, the Port of Sanur is in the southern waters of Indonesia and is part of the Indian Ocean with the characteristics of the farthest sea waves [6]. Therefore, it is necessary to do risk analysis in the Sanur Port construction project. The aim is to identify dominant risk parameters, dominant risk impacts and determine risk mitigation methods that may cause delays in the Sanur Port project.

2 Methods

At this stage, the risks that can cause delays in the Sanur Port construction project are carried out. The identified risks are the risks involved in the work on the critical path analysis. This identification is carried out based on a literature study of several journals that discuss the risks in port construction projects using the Lookup method. Critical path analysis using the Critical Path Method (CPM) with the analysis stages include activity grouping based on WBS and assigning a code or numbering to each job to facilitate the preparation of Network diagrams; Network Diagram based on the relationship and duration of each work by the project implementation logic framework; The critical path of the project can be determined based on the total float value of each activity (total float = 0).

In the risk identification process using a method known as the Lookup Method, this method is in the form of making a risk checklist based on risk data identified on projects that have been done previously. This method is straightforward to apply and can help identify risks in detail. Meanwhile, in the risk ranking analysis based on the impact assessment and risk frequency using the AHP (Analytic Hierarchy Process) method. Analytic Hierarchy Process (AHP) is a structured technique that aims to organize and analyze complex decisions, this method is an accurate approach in measuring the weight of decision criteria.

Risk assessment is carried out on the frequency and impact of risk using the likelihood scale according to Table 1 and Table 2. Risk assessment is carried out by distributing questionnaires to service providers and supervisory consultants with a target of 10 respondents with the following criteria:

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a. Have 3 years of working experience in the same position.
b. Have work experience in port construction projects.

Table 1. Rating scale for risk frequency.

Rating Type	Level	Scale	Description
Frequency	Very Low	1	Rarely occurs, only under certain conditions
	Low	2	Sometimes it happens under certain conditions
	Medium	3	Occurs under certain conditions
	High	4	Often occurs in every condition
	Very High	5	Always happens in every condition

Table 2. Rating scale for risk impact.

Rating Type	Level	Scale	Description
Impact	Very Low	1	No impact on the project schedule
	Low	2	There was a delay of < 5%
	Medium	3	There is a delay of 5% - 7%
	High	4	There is a delay of 7% - 10%
	Very High	5	There was a delay of 10% / the project stopped

The risk rating analysis determines the most dominant risk parameters based on risk ranking using the Analytic Hierarchy Process (AHP) method. The risk ranking is carried out based on the risk categories in table 3 and table 4. The stages of risk rating analysis using AHP consist of making hierarchies, matrix normalization, matrix consistency testing, calculating local values, calculating global and final values (Table 3).

Table 3. Risk level.

Symbol	Description	Definition
H	High Risk	Risks in certain activities with the impact of stopping the project and large losses in the cost aspect, these risks need special handling by the project leader.
S	Significant Risk	Risks in certain activities with a significant impact on productivity decline need to be handled by the project manager.
M	Medium Risk	The routine risk with a significant impact this risk can be handled directly in the field.
L	Low Risk	Routine risks that occur with insignificant impact are recorded in the project implementation budget.

3 Data collection

The data collected in this study consisted of several types of data, such as primary data as the S curve of the Sanur Port project obtained from competition documents; secondary data as research variables; and qualitative data as statements or values obtained from the results of distributing questionnaires and are subjective. Secondary data are sourced from documents on procurement of construction work, design, and construction of the port facilities in Sanur, Denpasar, Bali Province that have been signed by the Directorate General of Sea Transportation. Primary data in this study were obtained from a questionnaire of expert who were involved in the Sanur Port Project in Denpasar, Bali.

The location study is in Sanur Port, Bali Province, Indonesia. The location of the port is at 08°04'40" South Latitude to 08°50'48" South Latitude and 114°25'53" East Longitude to 115°42'20" East longitude. The port will be developed into tourism port that connects Bali to Nusa Penida Island (Fig. 1).

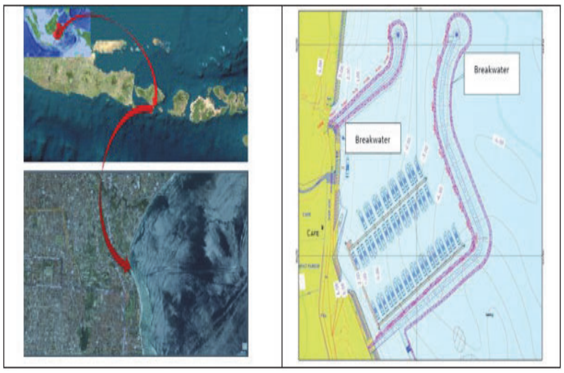

Fig. 1. Study area.

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4 Results and discussion

4.1 Risk assessment

The high category risks resulting from the risk rating are grouped according to the risk type parameters listed in Table 4. Thus, the most dominant risk parameters can be determined (Table 4).

Table 4. Risk parameter.

Risk Variable	Risk Parameter
Natural Risk	Weather
	Force Majeure
	Tidal Wave
Economic Risk	Inflation
Environmental Risk	Project field
	Local communities
Human Resources (HR) Risk and Management	HR Competence
	Communication between stakeholders
Financial Risk	Tool
	Material
Technical Risk	Design
	Administration and Permission
Project Risk	Work safety
	Execution method

Based on the most dominant risk parameters obtained from the results of the risk rating analysis, then an analysis of the impact of the most dominant risk parameters on the project duration is carried out [7]. This analysis is carried out to analyze how much additional duration can be caused by the most dominant risk parameter on the project duration. After obtaining the most dominant risk causing delays in project implementation, it can be continued by determining the risk mitigation efforts. The determination of this mitigation method is based on a literature study related to these risk variables. The results based on literature studies - journals with similar topics show that there are 50 risks on the critical path that can cause delays in the Sanur Port development project.

Preparation of project scheduling using the Critical Path Method (CPM) with Network Diagram type Activity on Arrow (AOA) based on the S curve data of the Sanur Port project.

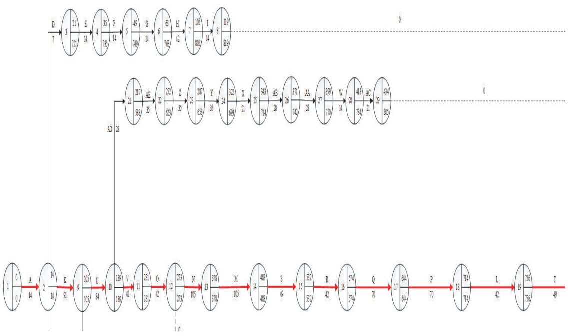

Fig. 2. Sanur port project network diagram.

The critical path in the Sanur Port Project consists of 14 work items which are a series of work on the southern breakwater with a total duration of 819 days (Fig.2).

Respondents for this risk assessment consist of service providers and consultants who oversee the Sanur Port project, with a target number of 12 respondents (Fig.3).

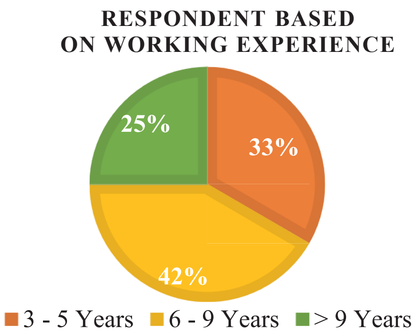

Fig. 3. Percentage of respondents based on work experience.

Based on the respondent's profile in Figure 3, a work experience dependence test on the respondents' answers using the Kruskal-Wallis method. The results of the Kruskal-Wallis test show the probability value of all variables > 0.05. So, it can be concluded that there is no difference in the perception of respondents' answers based on work experience background.

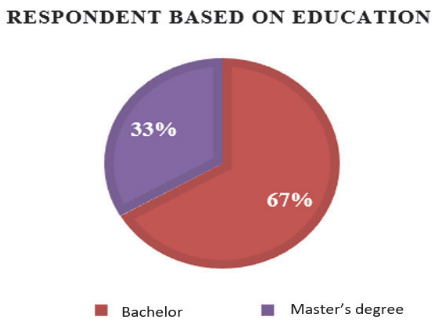

Fig. 4. Percentage of respondents based on education.

Based on the respondent's profile in Figure 3, an education dependency test was conducted on the respondent's answers using the Mann-Whitney method (Fig.4). The Mann-Whitney test results show the probability value of all variables > 0.05. So, it can be concluded that there is no difference in the perception of respondents' answers based on educational background.

Next, the validity test was carried out using the Moment Pearson Correlation method and the reliability test using the Cronbach-Alpha method using the SPSS version 25 program. Based on the test results, the results are presented in Table 5 for the validity test and Table 6 for the reliability test.

Table 5. Validity test result.

		N	%
Cases	*Valid*	12	100,0
	Excluded	0	0,0
	Total	12	100,0

Table 6. Reliability test result parameter.

Cronbach's Alpha	N of Items
0,822	50

4.2 Risk rating analysis using AHP method

The first stage in ranking analysis using the AHP method is to create a hierarchical structure. The hierarchical structure in this study is shown in Figure 5.

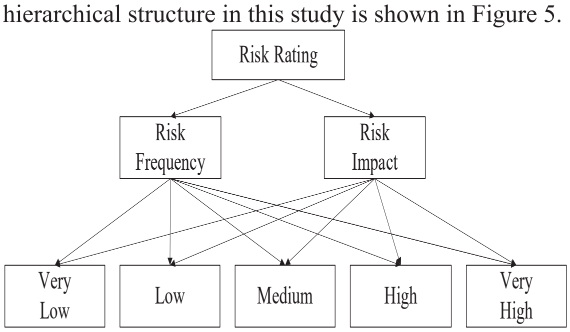

Fig. 5. Hierarchical structure.

The next step is to consider the elements of frequency and impact according to Tables 7 and 8.

Table 7. Paired matrix for risk frequency.

Risk	Very high	High	Medium	Low	Very low
Very high	1,00	3,00	5,00	7,00	9,00
High	0,33	1,00	3,00	5,00	7,00
Medium	0,20	0,33	1,00	3,00	5,00
Low	0,14	0,20	0,33	1,00	3,00
Very low	0,11	0,14	0,20	0,33	1,00
Total	1,79	4,68	9,53	16,33	25,00

Table 8. Paired matrix for risk impact.

Risk	Very high	High	Medium	Low	Very low
Very high	1,00	3,00	5,00	7,00	9,00
High	0,33	1,00	3,00	5,00	7,00
Medium	0,20	0,33	1,00	3,00	5,00
Low	0,14	0,20	0,33	1,00	3,00
Very low	0,11	0,14	0,20	0,33	1,00

The weighting of elements for each alternative in the risk frequency and risk impact matrix can be seen in Table 9 and Table 10.

Table 9. Element weight for risk frequency.

	Very high	High	Medium	Low	Very low
Weight	1,000	0,518	0,267	0,135	0,069

Table 10. Element weight for risk impact.

	Very high	High	Medium	Low	Very low
Weight	1,000	0,518	0,267	0,135	0,069

The value of the weight matrix can be said to be consistent if the maximum eigenvalue (λmax) must approach the value of the number of elements (n) and the remaining eigenvalues are close to zero. Calculate the maximum eigenvalue by dividing the total value of the previous vector by the number of values (n).

n = 5
λmax = 5,24

From the calculation of the maximum eigenvalue above, the value is close to the value of n with the remaining 0.24, which is close to zero. Thus, it can be concluded that this matrix has been consistent. The next step is to calculate the CRH value to determine the level of accuracy.

$$CCI = \frac{\lambda maks\text{-}n}{n\text{-}1} \quad (1)$$

$$= 0{,}061$$

The CRI value based on the value of n = 5 is 1.12.

$$CRH = \frac{CCI}{CRI} \quad (2)$$

$$= 0{,}05$$

Based on the results of the calculation of CRH, which is less than 10%, the hierarchy is consistent and has a high level of accuracy. The following are the results of risk ranking based on the final value according to the risk level category in table 3, which are presented in Table 11 below.

Table 11. Risk rating.

Variable	Final Value	Rating	Risk Level	Variable	Final Value	Rating	Risk Level
B2	2,742	1	H	E3	1,455	26	M
C4	2,742	2	H	C3	1,389	27	L
F3	2,736	3	H	E1	1,323	28	L
D6	2,610	4	H	E7	1,323	29	L
E6	2,610	5	H	D4	1,290	30	L
G6	2,610	6	H	A3	1,257	31	L
G8	2,584	7	H	H2	1,257	32	L
A4	2,544	8	H	H4	1,257	33	L
H6	2,492	9	H	G3	1,224	34	L
F5	2,459	10	H	G7	1,224	35	L
G5	2,346	11	H	D1	1,191	36	L
B6	2,313	12	H	F4	1,191	37	L
F2	2,280	13	S	G2	1,191	38	L
E5	2,214	14	S	B7	1,158	39	L
B1	2,181	15	S	H1	1,125	40	L
E4	2,142	16	S	B5	1,125	41	L
E8	2,129	17	S	D2	1,125	42	L
B8	2,115	18	S	I1	1,125	43	L
B4	2,082	19	S	D5	1,092	44	L
A1	1,884	20	S	G4	1,092	45	L
C1	1,719	21	M	D3	1,059	46	L
A2	1,719	22	M	E2	1,059	47	L
B3	1,686	23	M	G1	1,059	48	L
C2	1,620	24	M	H5	1,059	49	L
F1	1,620	25	M	H3	0,993	50	L

Risks with a high category from the previous ranking results are then grouped based on the risk parameters in Table 4. The results of the analysis of the dominant risk parameters in Table 12 show four dominant risk parameters: tidal waves, force majeure, weather, and design, with tidal waves being the most important risk parameter. Dominant in the implementation of the Sanur Port project.

Table 12. Risk rating.

Code	Risk	Risk Rating	Risk Level	Risk Parameter
B2	Delayed hydro-oceanographic survey due to high sea waves	1	H	Tidal Wave
C4	Delayed compaction process due to tidal waves	2	H	Tidal Wave
F3	Disruption of the tetrapod installation process due to high sea waves	3	H	Tidal Wave
D6	Late implementation of Geotextile works due to tidal waves	4	H	Tidal Wave
E6	Disruption of the stone installation process due to high sea waves	5	H	Tidal Wave
G6	Disruption of the process of installing concrete blocks due to high sea waves	6	H	Tidal Wave
G8	Potential for destructive natural disasters during the implementation of concrete block installation work (Fire, Tidal Flood and Earthquake)	7	H	Force Majeure
H6	Potential destructive natural disasters during concrete floor work (Fire, Tidal Flood and Earthquake)	9	H	Force Majeure
F5	Potential destructive natural disasters during the implementation of tetrapod installation work (Fire, Tidal Flood and Earthquake)	10	H	Force Majeure
A4	Extreme climate disrupts the mobilization of pontoon boats to the project	8	H	Weather
G5	Disruption of loading of concrete blocks to barges due to bad weather	11	H	Weather
B6	Changes to design/work details	12	H	Design

4.3 Risk impact analysis

Analysis of the impact of tidal wave risk on project duration is carried out by plotting the time of the occurrence of tidal waves on the bar chart of the Sanur Port project plan bar chart.

Based on shipping safety, everything published by Meteorology, Climatology and Geophysical Agency that barges or pontoons can sail safely at a wave height of less than or equal to 1.5 meters, so sea work is carried out during high tide weeks (> 2.5 m occurs) cannot be implemented based on these safety factors. Based on the bar chart with the time of occurrence of waves, there has been an increase in the duration of some work and causing an increase in the duration of the project. The following is an additional duration that occurs in the work of marine facilities at the Sanur Port project due to the tidal wave risk parameter (Fig. 6).

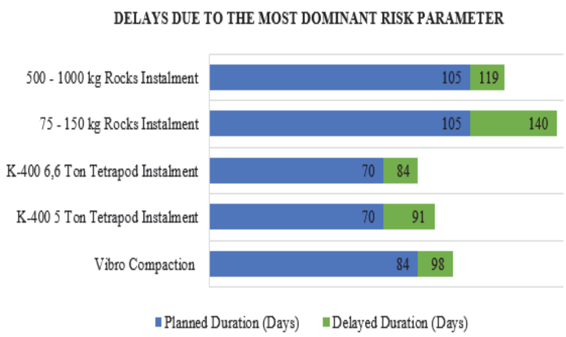

Fig. 6. Addition of duration due to the most dominant risk parameter.

4.4 Risk mitigation

There are several steps to handling the most dominant risk parameters so that project objectives can be achieved, especially the timeliness of project completion in accordance with the plan. The following is the risk mitigation that has been identified in terms of workers, tools, and methods of carrying out a literature study on journals and Construction Safety Plan documents (Table 13).

Table 13. Risk mitigation [8, 9].

Worker	Equipment	Instalment Method
1. Workers must have technical competence in the field of Port Project construction [8]. 2. Equipment operators have special competencies as evidenced by Construction Safety Standard [9]. 3. Every worker must use safety tools according to standards (helmets, safety shoes, vests, and life jackets) [9].	1. Determine the appropriate heavy equipment according to wave conditions [8]. 2. Inspect and test the equipment using Construction Safety Standard [9]. 3. Equip the work area with signs and lifeboats	1. Determine the appropriate implementation method according to tidal wave conditions [8]. 2. Optimizing work when wave conditions are normal or low tide according to wave forecast data obtained from the local Meteorology, Climatology and Geophysical Agency [8].

5 Conclusion

Based on the results of research and discussion, several conclusions can be drawn, such as, There are 50 risks on the critical path that can cause delays in the Sanur Port development project. The most dominant risk parameter is the Tidal Wave. The analysis results of the influence of tidal wave risk parameters on the Sanur Port construction project showed a delay in the project duration of 98 days. And several mitigation steps are needed to minimize the impact of risks on aspects of workers, tools, and methods of implementation such as:

a. Workers: must have technical competence in the field of Port Project construction.
b. Equipment: Determine the appropriate heavy equipment according to wave conditions, inspect and test the equipment based on Construction Safety Standard.
c. Construction method: determine the construction method according to tidal wave conditions, optimizing work when wave conditions are normal or low tide according to wave forecast data obtained from the local Meteorology, Climatology and Geophysical Agency.

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