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Hazard Identification, Risk Analysis and Risk Assessment on High-Rise Building Construction Project

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Abstract. High-Rise Building (HRB) construction project has complicated the structural design, complexity of work and potential risks in project work. Project risk can obstruct the project activities and achievement. The objectives of this paper are to identify the risks of technical and construction management, allocate the risk to appropriate parties, namely owner, contractor, and shared (owner and contractor), and assign the risk response to dominant risk in the HRB project. Identification of risk was conducted through literature study and validation of the preliminary survey. The risks analysis based on the results of main survey was carried out with severity index method combined with matrix of impact probability. The dominant risks were allocated to the contractor, owner and shared. The results showed that there are eight risks in time impact and seven risks in cost impact from 35 variables of risk. The main impact to time and cost is the low level of productivity.

INTRODUCTION

The construction project (CP) always meets the project risks, along with the complexity of the project [1]. The CP of Tunjungan Plaza 6 (TP 6) and One East Residence Apartment (OERA) are both High-Rise Building (HRB) project. These projects have a complexity of work, structural design, load of work and time schedule. The complexity of project leads to many kinds of risks, particularly the time and cost risk, which potentially influence the realization and achievement of project [2].

Uncertain risks in CP cannot be perished, but it can be minimized through systematic risk analysis (identifying, analyzing and giving response to the project risk). The management of risk is intended to determine, control and minimize the type of risk, and finally to find out the solution and the responsible party of risk [3]. One of the methods in risk management is risk allocation–a strategic management risk–that allocates the identifiable risks to the responsible party.

Under the handling of appropriate party, the identified project risk can be overcome maximally and minimized at the same time. In this research, the risk allocation involved two parties of owner, contractor, as well as shared (contractor and owner). These two parties were selected to demonstrate the cognizance upon risk handling in certain construction project.

, assessment on risk and appropriate construction project risk allocation toward potential risk and determination of appropriate parties for construction project allocation is required.

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METHODS

Research concept

This research is a case study to evaluate and allocate the risk in construction project of Tunjungan Plaza 6 (TP6) and One East Residence Apartment (OERA), Surabaya. The research was conducted to make a risk assessment, analyze the dominant risk, and allocate the risk to the contractor, owner, or shared (contractor and owner).

Variables of Research

Variables of research were management and technical risk. Technical risk comprised of labour, material and equipment risk, construction risk, and financial risk.

Population and Sample

Population of the TP 6 Surabaya and OERA construction project involved in this study were the construction manager and respondents. These participants included those who understand and competent in their purview, e.g., project manager, site manager, engineer, cost control and schedule, site supervisor.

Research procedure

1. Identification was conducted through literature study, observation and interview by distributing the questionnaire to the respondents.
2. Analysis was done through:
   a. Distributing the preliminary questionnaire to test the validity and reliability of identification.
   b. Distributing the main questionnaire and interview.
   c. Appraisal (assessment) upon frequency level upon ensued impact from the risk by using HIRA method.
   d. Appraisal upon the risk allocation based on the dominant ensued.
   e. Depiction of appraisal result into matrix diagram based on frequency and impact.

Analysis which exerts the occurrence impact of risk frequency using the questionnaire distribution at the second stage (frequency questionnaire and impact) to the respondent. The scale used in measuring the potency upon the frequency and impact is Likert scale within interval 1 to 5. Mathematically, risk level could be stated as below:

$$R = P \text{ x } I \tag{1}$$

Furthermore, since the P and I value from every risk variable was obtained merely from small number of respondents, so it needs to compile the assessment result P and I value with Severity Index method.

Severity Index concept is one of method to identify P and I value in calculate the risk level. Severity Index (SI) can be calculated with the following formula:

$$SI = \frac{\sum_{i=0}^{4} a_i x_i}{4 \sum_{i=0}^{4} x_i} \times (100\%) \tag{2}$$

Where:

a_i = valuation constants, which have five categories of: $a_0 = 0$, $a_1 = 1$, $a_2 = 2$, $a_3 = 3$, $a_4 = 4$.

x_i = frequency of respondent, which wherein has five categories of: x_0 = very low respondent frequency, so $a_0 = 0$; x_1 = low respondent frequency, so $a_1 = 1$; x_2 = adequate respondent frequency, so $a_2 = 2$; x_3 = high respondent frequency, so $a_3 = 3$; x_4 = very high respondent frequency, so $a_4 = 4$

i = 0, 1, 2, 3, 4,...,n.

Potential risk is the risk that should be noticed because it has the probability of occurrence and negative consequence, in which the potential risk is signed by an error in time estimation, cost estimation or technology design [4]. Risk measurement process predicts the conducted risk frequency and the risk impact. It uses Likert scale to arrange the pontential risk toward frequency and risk impact within interval 1 to 5, which has two risk

measurements. The first, the risk probability measurement has five categories, namely 1 = Rarely (SJ); 2 = Seldom (J); 3 = Fair (C); 4 = Often (S); and 5 = Very Often (SS). The second, the risk impact measurement (impact) that consists of five categories, in which 1 = very small; 2 = small; 3 = fair; 4 = big; and 5 = very big.

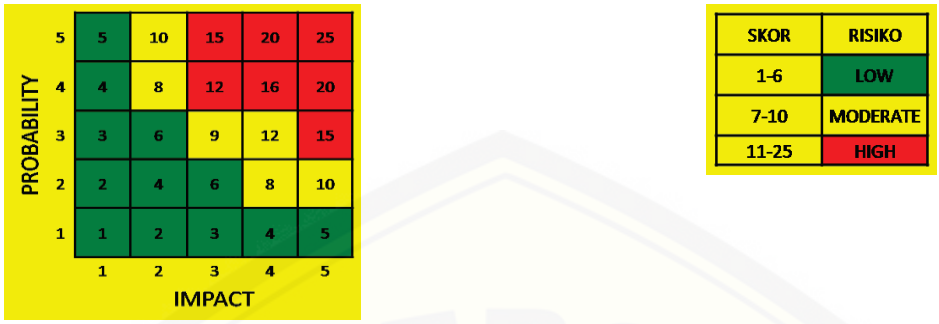

FIGURE 1. Matrix of Probability and Impact.5

After ascertaining the probability level and impact from certain risks, they were plotted into frequency matrix and impact to ascertain the strategy to overcome the existing risks. According to [3], to select the risk response that will be utilized in overcoming the risks by using Risk Map. Figure 2 shows the selected *Risk Map.*

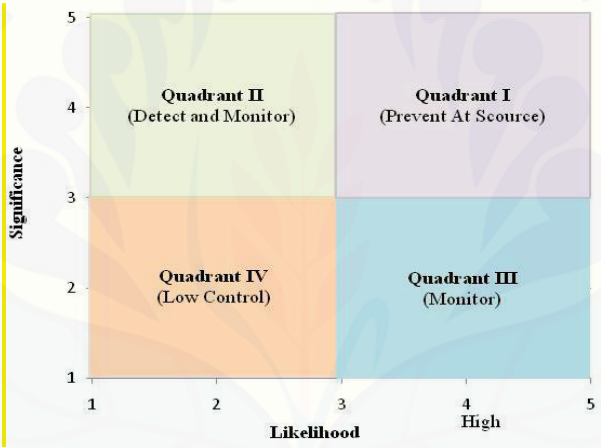

FIGURE 2. Matrix based on Frequency and Impact.[v]

The first quadrant is a place where the risks is located to obtain a fully attention in order to minimize the possibility and the future impact of risk. Meanwhile, the risks at the 2nd quadrant require the tested master plan to address the potential risk situation. The risks at the 3rd quadrant require surveillance and periodic internal restraint to bear their possible levels and impacts. The last, the risks at the 4th quadrant require regular information (low control).

RESULTS AND DISCUSSION

Risk Identification

The early step in identifying the risk and technical management was literature study. It was to identify frequent risk managements and technique in construction of high-rise building project, such as TP 6 and OERA project. Identification of risk management was done based on the arranged *route* map classification from the expert's personal opinion at studying the literature. The next step was by preferring the risks based on the prior studies that have high potential risks and gain the cost and time impact. According to the literature study, 35 risk managements and technical risks toward *HRB* project that consist of 12 risk managements (Table. 1) and 23 technical risks (Table. 2) [1-12].

Risk identification process showed the preliminary questionnaire to the four buildings by involving respondents, such as *Project Manager* and *Site Manager* in each project. Respondents would answer by laying down the tick sign (√) inside the column 'risky' or 'not risky'. In this case, 'risky' annotation was the occurred risk variable or probably would happen in the future, meanwhile 'not risky' annotation is risk variable which never happens or unlikely to happen in the future specifically at building project. Subsequently, the preliminary questionnaire survey to the respondents would proceed into the validity test. Researchers utilized the *Guttman* scale for testing the entire answers. 'Risk' as the answer means 1 in score scales, while 'no risk' means 0.

TABLE 1. Identification of Management Risk in the HRB Project

No	Identification of risk	Explanation		Total	Explanation
		Risk	No Risk		
A	Risk of Construction Management	4	1	5	Relevant
A1	Less control and coordination in team	4	1	5	Relevant
A2	Incapable team in planning	4	1	5	Relevant
A3	Submission of construction claim	4	1	5	Relevant
A4	Incorrect in plan of work, cost, schedule (time) and quality	4	1	5	Relevant
A5	Accuracy in determination of the organization structure	4	1	5	Relevant
A6	Low level of employee's discipline	4	1	5	Relevant
A7	Complexity of license and regulation in implementation of project activities	4	1	5	Relevant
A8	Unaccepted work by Owner	4	1	5	Relevant
A9	Level of overheads	5	0	5	Relevant
A10	Management of project resources (material, equipment, employee, financial, and method)	5	0	5	Relevant
A11	Low level of process in observing activity by project parties	5	0	5	Relevant
A12	Incomplete daily report and low level of project document management	2	3	5	Not Relevant

Reference: analysis

Technical risk in this research was divided into 4 (four) categories of risks, e.g., material and equipment, labour, construction, and financial risk. These risks can be seen on Table 2.

Table 2 denotes the variables of validated risk by the respondents from several projects. Respondents decline one risk variable that considers irrelevant with the risk as the systematic inhibition inside the project. Risk variable is "incomplete daily report and terrible documents project management". The risk variable should not be eliminated because it still has the possibility to cause an impact at another project. According to the test results by using Pearson formula, 16 valid risks correlate within the amount of answer score from every respondent and its risk were obtained, meanwhile 19 another risk variables were obtained without any correlation inter-sum of score answer in every respondent's answer and its risk.

Calculation of risk-level score

Under the questionnaire survey regarding with risk frequency and risk impact to the respondents, researchers used the *Likert* scale method to measure *probability* or frequency of risk variable inside the project. Likewise, to measure the *impact* from the risk variable even utilized *Likert* scale method. This method was applied to measure the *probability* or frequency, in which has five scales of probability, namely: Rarely (SJ) equal to 1 (wherein less than three one-life-cycle-time project); Seldom (J) equal to 2 (wherein three to five one-life-cycle-time project); Fair (C) equal to 3 (wherein six to seven one-life-cycle-time project); Often (S) equal to 4 (wherein eight to nine one-life-cycle time project); and Very Often (SS) equal to 5 (wherein more than ten one-life-cycle time project).

Stipulation of scale criteria of *probability* or risk occurrence frequency was obtained from literature study in previous research.6 Meanwhile, *Likert* scale for measuring the impact toward cost and time that consisted of five

scales of impact, namely Very Small (SK); Small (K); Fair (S); Big (B); and Very Big (SB). The complete explanation about the definition of risk impact is shown in Table. 3.

TABLE 2. Risk Identification of material and equipment, employer, construction, and financial in HRB project

No	Identification of risk	Explanation		Total	Explanation
		Risk	No Risk		
B1.	Material damage at the time of material delivery	4	1	5	Relevant
B2.	Material and equipment accuracy of procurement	5	0	5	Relevant
B3.	Material loses on the site	5	0	5	Relevant
B4.	Material price	4	1	5	Relevant
B5.	Material and equipment low productivity	5	0	5	Relevant
B6.	Material is low specification	4	1	5	Relevant
B7.	Equipment is broken	5	0	5	Relevant
B8.	Material lack of storage	4	1	5	Relevant
B9.	Low level of employer productivity	5	0	5	Relevant
B10.	Lack of manpower in the site	5	0	5	Relevant
B11.	Poor safety plan in the site	5	0	5	Relevant
B12.	Quality of work is low	5	0	5	Relevant
B13.	Error execution of construction method	3	2	5	Relevant
B14.	Difficulties in the use of new technologies (tools and methods) in the construction and production process	5	0	5	Relevant
B15.	Design error	5	0	5	Relevant
B16.	Change design	5	0	5	Relevant
B.17	Delay project	4	1	5	Relevant
B.18	Bad weather	3	2	5	Relevant
B.19	Difficulty access to reach site location	3	2	5	Relevant
B.20	Differences in implementation and job specifications due to draw read error	4	1	5	Relevant
B.21	Inflation	5	0	5	Relevant
B.22	Lack of capital availability	5	0	5	Relevant
B.23	Lack of payment in contract	5	0	5	Relevant

Reference: analysis.

Note: B1 to B8 are materials and equipment risks; B9 to B12 are employer risks; B13 to B20 are construction risk; B21 to B23 are financial risks.

TABLE 3. Definition of Risk impact

1	Very small	No impact	No impact
2	Small	Impact < 5% to Cost Estimation	delay < 5% for plan
3	Medium	Impact = 5%-10% from cost estimation	Delay= 5%-10%
4	Big	Impact = 10%-15% from cost estimation	Delay = 10%-15%
5	Very big	impact > 15% from cost estimation	Delay >15%

Source: PMBOK (2008).

Score scale of risk impact obtained from PMBOK (2008) [7]is changed into an impact scale in the primary questionnaire. After all *probability* scale score is known (frequency) also *impact* scale score from series of event in

risk variable on time and cost are obtained from TP 6 and OERA project into cultivation by using *Severity index* method, afterwards risk analysis by using *Probability x Impact* (PxI) table. Inputting score scale process *Probability x Impact* is inputting the scale score of *probability* scale on the time and cost from the calculation of *Severity index* (SI) method. Scale score of *probability* and *Impact* that obtains from score of *Severity index* (SI) risk category was converted into the numerical form as below.

1. Probability. It has five scores of scale, namely Very low (SR) = 1; Low (R) = 2; Fair (C) = 3; High (T) = 4; and Very high (ST) = 5.
2. Impact. It has five scores scale, namely Very low (SR) = 1; Low (R) = 2; Fair (C) = 3; High (T) = 4; and Very high (ST) = 5.

It was followed by multiplying the scale in the column of *probability* and scale in *impact* column *probability* and scale *impact* column. The result of *probability* and *impact* multiplication were plotted into the matrix of Probability and Impact. The risks that have a big score in *Probability x Impact* was chosen based on the score larger than 10 or belongs to "*High"* category. The mentioned risks have a major possibility to cause significant impact than other risks on time. Based on the calculation of probability of time impact, it shows on Table 4. This table shows that the TP 6 and the OERA project have five and four dominant risks, respectively.

TABLE 4. *Probability x Impact* upon time and preferred risk in TP 6 and OERA project

Name of project	No.	Type of Risk	P	I	Note	P x I
TP 6 project	B3.	Material loses on the site	4	4	H	12
	B9.	Low level of employer productivity	4	4	H	16
	B10.	Lack of manpower in the site	4	4	H	16
	A3	Submission of construction claim	3	4	H	12
	A11	Low level of process in observing activity by project parties	3	4	H	12
OERA project	B10.	Lack of manpower in the site	4	4	H	16
	B15.	Design error	3	4	H	12
	B16.	Change design	4	4	H	16
	B.17	Delay project	3	4	H	12

Reference: analysis

Based on the results of *Probability x Impact* on the time as shown on Table. 4, several different risks despite the construction project has the similarity of HRB specification.

TABLE 5. *Probability x Impact* upon the cost with preferred risk in TP 6 and OERA project

Name of project	No.	Type of Risk	P	I	Note	P x I
TP 6 project	B9.	Low level of employer productivity	4	4	H	16
	B10.	Lack of manpower in the site	4	4	H	16
	A9	Level of overheads	3	5	H	15
OERA project	B10.	Lack of manpower in the site	4	4	H	16
	B15.	Design error	3	4	H	12
	B16.	Change design	4	4	H	16
	B.17	Delay project	3	4	H	12
	B.23	Lack of payment in contract	3	4	H	12

Risk taking has a relative high score that equals with the determination of big impact on time. The risks occur based on the score that is more than 10 or include in "*high"* category. The risks have high possibility to be the highest and cause the massive and significant impact than other risks on the cost. Based on the results of *Probability x Impact* on cost and time in TP 6 and OERA project (Table. 5), the relative different risks between two projects were obtained. This case demonstrated that construction project has a unique trait because every project has its own risk although they have the similar characteristics of HRB.

Risk allocation

Based on Table. 6, it obtained the different opinions between construction practitioner and construction site expertise. Those differences are risk allocation of construction proposal design in error and over budget (Overheads). Those differences emerge once construction practitioner sustains the progress in the site.

TABLE 6. List of risk allocation performed by an expertise and construction practitioner

No	Type of Risk	Risk Management	
		Expertise	Practitioner
1	Low level of employer productivity	contractor	contractor
2	Lack of manpower in the site	contractor	contractor
3	Material loses on the site	contractor	contractor
4	Construction Claim	shared	owner
5	Low supervision on site	shared	shared
6	Change design	owner	owner
7	Design error	shared	owner
8	Delay project	shared	shared
9	Overheads	contractor	shared
10	Delay payment in contract	owner	owner

Dominant Risk Response on Time

The applied risk analysis yielded 8 (eight) dominant risks that is possible to be major and give the significant upon the time in TP 6 Surabaya and OERA project. The risks could be mentioned in the risk matrix as below.

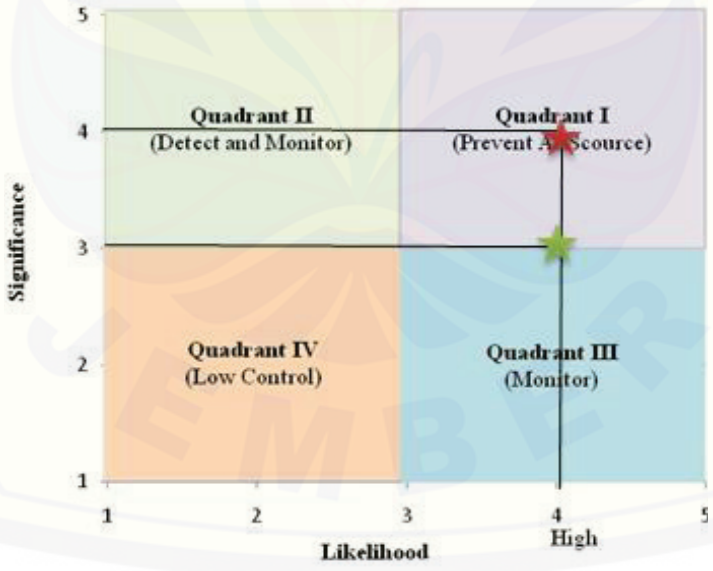

FIGURE 3. *Risk Map* that is dominant on time.

Figure 3 denotes the position of various dominant risks on the distinct time in each quadrant over *Risk Map*. The ratio with red star represents low level of labour productivity, site labour deficiency, design conversion, while green star represents the risk damage and/or site material forfeit, claim construction proposal, the terrible surveillance with the stakeholders, site labour deficiency, and error design and project.

Dominant risk on cost

The result of analysis obtained 7 (seven) dominants risks that affect the required time of TP 6 Surabaya and OERA project. Furthermore, the *risk map* of dominant risk on the cost is as follows.

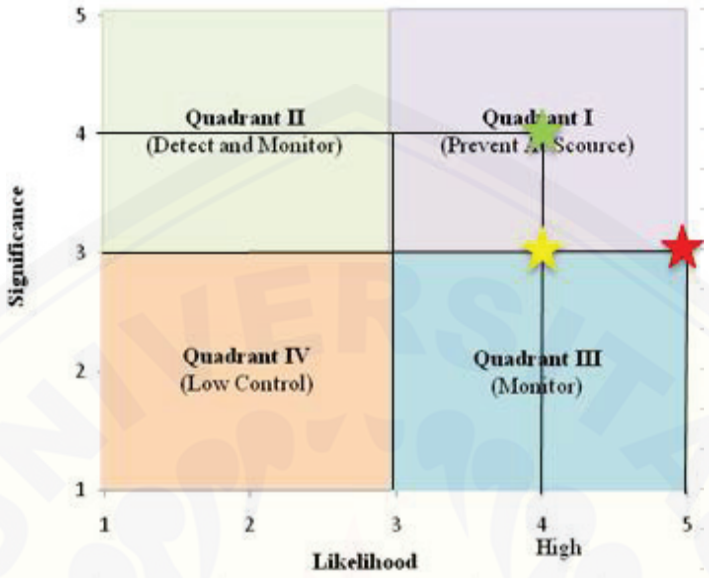

FIGURE 4. *Risk Map* which is dominant on cost.

From Figure 4, the location of dominant risk on cost was inside the quadrants in *Risk Map.* Marked green-risk indicates the low level of labour productivity, site labour deficiency and design alteration. The yellow star indicates the error-design risk, project tardiness and also payment retardation in contract. Meanwhile, red-star indicates the risk related to the amount of the extra outlays (overheads).

CONCLUSIONS

1. The study revealed 35 technical risk variables and risk management on TP 6 Surabaya project and *One East Residence Apartment* project. Those variables of risk are divided into 12 risk managements and 23 technical risks, while the technical risk consists of material risk and equipment, labour risk, construction risk and financial risk.
2. Dominant risk allocation of TP 6 Surabaya and *One East Residence Apartment* project is obtained from construction practitioner and experts in risk management. According to the risk practitioner, the dominant risk should be allocated to the *Owner,* whereas according to risk expert, it should be allocated to the contractor and *Shared* (*Owner* and contractor).
3. The most significant impact in dominant risk for time and cost is the humility level of labour productivity, risk response which can be conducted by recruiting the new skilled labour and proper assignation. The overtime procurement evaluates the labour daily productivity. The provision of incentive to labours who have an average productivity and penalty to the labours who have a menial productivity.

SUGGESTIONS

1. The research could be proceeded to the more thoroughly level study with detailing parts over the project phase from the pre-construction into the post-construction by expanding the risk factors within the study.
2. The research can be expanded by enclosing the cost analysis and the working time hindrance in every existing risk.

3. Further researcher may enhance the location objects that will automatically particularize construction risk upon several ongoing projects.

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