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The Significance Risk for Factors of Labour, Material, and Equipment on Construction Project Quality

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Abstract – The construction involves a series of activities that possibly face problems or risks. The risk probability is an uncertain condition that results in a negative impact on the project objectives. Threats can come from the resources factor in a construction project, such as labour, materials, and equipment. The handling of risks in construction work needs to be further reviewed. It is to find risk factors and risk variables contributing to high risk to achieve the quality objectives of construction implementation. The purpose of this study was to analyze the most significant risk towards the quality of construction associated with the condition of the Province of Aceh during 2000-2015. The situation is classified in three periods, namely political conflict (2000-2004 as Period I), rehabilitation and reconstruction (2005-2009 as Period II), and post-rehabilitation and reconstruction (2010-2015 as Period III). Dataset is collected using questionnaires to 15 large qualified contractor companies to capture construction quality information. The risk significance identified based on Risk Importance Index (RII) for frequency and severity of factors and variables. There are 7 variables for labour resources, 10 variables for material resources, and 17 variables for equipment resources. The quality of construction mostly affected by the labour resources factors in Period I and Period III. The risk comes from the variable discipline of workers who are not good (A3). For Period II, the lack of labour capacity (A2) variable become as the most significant risk.

Keywords: risk importance, construction quality, labour, material, equipment

Introduction

Construction work in the different work area will experience various risks. This is caused by events or events that occur in each region will have an influence on the emergence of risk. The Province of Aceh in the last 20 years has experienced a different risk phenomenon which can be divided into 3 (three) periods. Period 1 is the conflict period that occurred (2000-2004), Period 2 is the rehabilitation and reconstruction period after the Aceh earthquake and tsunami disaster (2005-2009), and Period 3 is the post-rehabilitation and reconstruction period (2010-2015). The events that occurred during the last 20 years certainly have the opportunity to provide risks to community activities in Aceh Province, including construction project work. The implementation of construction work that is affected by events in the Province of Aceh over the past 20 years is very vulnerable to the emergence of risks that have an impact on the achievement of construction objectives (cost, time and quality).

Construction work is a series of activities in terms of the construction of facilities and infrastructure with one of the final quality objectives. Construction work carried out by the contractor can be influenced by various factors which, if it occurs, can provide problems or risks to the construction work. The risk is an uncertain condition, which if it happens will have a positive or negative impact on the goals of construction both cost, time, and quality (Abd El-Karim *et al.*, 2015; Kwak & Smith, 2009; PMI, 2008). Furthermore, the definition of risk developed by (Karimiazari *et al.*, 2011; Kerzner, 2009; Lavanya & Malarvizhi, 2008) argues that risk is a measure of probability and the consequences of not achieving the objectives of quality construction projects (Le-Hoai *et al.*, 2008; Kim *and* Huynh, 2008). The positive impact that occurs will undoubtedly be immediately accepted by the executor of construction because it will provide a supportive contribution to achieve the construction goal, but if the risks that arise cause a

negative impact, of course, it will be significantly avoided because it will disrupt the achievement to the failure of the purpose of construction work.

Risk identification is useful for knowing which risks can affect the implementation of construction work and documenting its characteristics (Fortune *et al*., 2011; Gil & Tether, 2011; Zavadskas *et al*., 2010). Risk identification is a continuous process because there may be risks that are only known as long as the construction work is carried out (PMI, 2008). Broadly speaking, there are two risk categories, namely internal and external risks. The internal risk is the risk originating from problems in the implementation of construction work, while the external risk is a risk that arises from issues outside the execution of construction work which, if it occurs, can pose a risk to the project (Low *et al*., 2009; Frame, 2003). Risks were originating from problems in the implementation of construction work, including resources including labour resources, materials, and equipment that can pose risks if not properly managed.

Management of labour resources is a process that needs to be carried out in order to meet the needs of labour resources according to their functions in carrying out construction work, (PMI, 2008). Management of labour resources in the implementation of construction work includes a series of activities needed to increase worker productivity in applying for construction work. Manpower resource management consists of all project stakeholders who support the project. Material resources are one of the critical parts of implementing construction work. Therefore, if control of material resources is not proper, it can result in the material needed not meeting the project objectives (cost, time and quality). Adequate management of material resources can minimize the occurrence of excess material remaining, delay in material arrival, delay in completing the implementation of construction work and adding to the final cost of the project (Bossink & Brouwers, 1994). Equipment resources function as a tool for labour to carry out construction work. (PMI, 2008) states that the project equipment plays a role in completing the work section in carrying out construction work.

Several studies related to the risk of construction projects from labour, material, and equipment factors in Aceh Province have been carried out with an assessment of a number of risk factors towards the objectives of construction projects such as time. The results of these studies are related to the frequency of occurrence of risk factors (Husin *et al*., 2017) and the impact of the emergence of risk factors on the time of construction projects (Husin *et al*., 2018). Based on the background and these problems, this study aims to analyze the risk importance in quality aspects of construction implementation to the contractor as the project executor associated to the project resource factors, namely labour, materials, and equipment. The method used to analyze Risk Importance for quality aspect is Risk importance Index (RII), where RII is multiplication of Frequency Index (FI) and Severity Index (SI). A number of datasets have been collected from contractors with a substantial qualification in Aceh Province. The scope of the study period is in the period 2000-2015 which is divided into three periods, namely the conflict period of 2000-2004, the post-disaster rehabilitation and reconstruction period of 2005-2009, and the post-rehabilitation and reconstruction period of 2010-2015. The risk significance identified by the Risk Importance Index (RII) for frequency and severity of factors and variables. The quality of construction mostly affected by the labour resources factors in Period I and Period III. The risk comes from the variable discipline of workers who are not good (A3). For Period II, the lack of labour capacity (A2) variable become as the most significant risk.

Methods

The data in this study were collected from the results of questionnaires distributed to respondents from construction service providers with substantial qualifications registered with the Construction Service Development Board of Indonesia (LPJK) in Aceh Province. The company is a company that has been established and is experienced in carrying out projects in three periods of review. The number of companies in this study is 15 companies out of a total population of 20 companies, according to company data issued by the LPJK. Most of the respondents who filled out the questionnaire were directors and company managers. The content of the inquiry is a list of questions regarding the characteristics of the respondent/company, the assessment of the opportunities for risk for three resource factors in the three periods of the study, as well as the evaluation of the impact of the risk on construction objectives.

The measurements taken in this study were using a Likert scale. The purpose of the analysis using a Likert's level is to measure the perceptions of respondents regarding the questions on the questionnaire. The answer to each instrument item using a Likert's scale has gradations from very high to very low. The risk assessment category by the respondents used in this study is shown in Table 1. The frequency of

occurrence of a variable is determined by how often the risk variable arises from projects that have been handled by the respondent. The impact on quality is determined by the magnitude of the potential nonconformity in the implementation of the work referring to the planned technical specifications.

Data collection in a study is primarily determined by the quality of the questionnaire used (Del Cano & de la Cruz, 2002). A research questionnaire is said to be of quality and can be accounted for if it has been proven valid and reliable.

Table 1. The scale of the frequency and severity of the risk to quality (Husin, 2019)

Scale	Risk Scale	Scale interpretation
Risk Frequency		
5	Very often	Possible events are above 0.8
4	Often	Possible events >0.6 and ≤ 0.8
3	Often enough	Possible events >0.4 and ≤ 0.6
2	Rarely	Possible events >0.2 and ≤ 0.4
1	Very rarely	Possible events >0.2
Risk Severity to Quality		
5	Very high	Nonconformity of work > 40%
4	High	Nonconformity of work > 20% and ≤ 40%
3	Is being	Nonconformity of work > 10% and ≤ 20%
2	Low	Nonconformity of work > 0% and ≤ 10%
1	Very low	There are nonconformity of work

Characteristics of respondents

In this study, the characteristics of respondents were divided into two, namely the individual components of respondents and company characteristics. The personal characteristics of respondents in this study were used to give an overview of the respondents 'identities related to the results of respondents' answers to the questionnaire. While the characteristics of the respondent companies in this study were used to provide a description of the company related to the object of the review, in this case, the period of political and military conflict, the rehabilitation and reconstruction period, and the post-rehabilitation and reconstruction period (Husin *et al.*, 2017).

Validity and reliability test

Validity test of questionnaires instruments is tested t-student test. If $t_{stat} > t_{sig}$ (0.514) is declared valid and otherwise is declared invalid. Reliability test is a consistency of the questionnaire in measuring what is to be measured, meaning that whenever the measuring instrument is used, it will give the same results (Sugiyono, 2010). Reliability analysis commonly used is analysis using Cronbach Alpha (C-alpha). The testing using the C-alpha coefficient ≥ 0.6 is the value that is considered to be able to test the feasibility of the questionnaire used.

Validity test is used to determine the validity of the questionnaire item. This test was conducted on each questionnaire statement, and the results were compared toward t_{sig} of 0.514. Testing shows that t_{stat} is larger than t_{sig}, as demonstrated in Table 2.

Table 2. Validity test results

No	Risk	Variable		*t-statistic*		
		Total	Code	Period I	Period II	Period III
The validity of risk frequency data						
1	Labour resources	7	A1-A7	0,590-0,934	0,590-0,934	0,792-0,976
2	Material resources	10	B1-B10	0,579-0,870	0,489-0,958	0,582-0,956
3	Equipment resources	17	C1-C17	0,544-0,947	0,544-0,947	0,605-0,939
The validity test of quality risk severity data						
1	Labour resources	7	A1-A7	0,536-0,831	0,566-0,950	0,775-0,951
2	Material resources	10	B1-B10	0,558-0,879	0,529-0,863	0,573-0,980
3	Equipment resources	17	C1-C17	0,517-0,919	0,535-0,880	0,578-0,948

Reliability test is intended to determine the level of reliability of research instruments. Testing is reliable if the value of Cronbach Alpha is ≥ 0.6. the examination shows the research instrument used to collect data is reliable, as shown in Table 3.

Table 3. Reliability test results

No	Risk	Variable		*C-Alpha*		
		Total	Code	Period I	Period II	Period III
The reliability test of risk frequency data						
1	Labour resources	7	A1-A7	0,89	1,14	1,15
2	Material resources	10	B1-B10	0,87	0,86	0,88
3	Equipment resources	17	C1-C17	0,98	0,98	0,87
The reliability test of risk severity data						
1	Labour resources	7	A1-A7	0,74	0,81	0,87
2	Material resources	10	B1-B10	0,88	0,86	0,89
3	Equipment resources	17	C1-C17	0,96	0,96	0,98

Data analysis was used aimed at obtaining the results of the risk frequency and the risk severity (impact of the risk event). Therefore, a review of the Frequency Index (FI) is needed to analyze the possibility of risk events and the Severity Index (SI) to analyze the impact of the risks that occur. The Frequency Index (FI) shows the frequency index of internal risk factors in carrying out construction work while the Severity Index (SI) shows an index of the impact of the occurrence of occurrences of internal risk factors that influence the implementation of construction work (Majid & McCaffer, 1997).

Risk Importance Index (RII) is used to determine rankings to compare relative to the construction risk variables experienced by respondents. Determination of the level of a substantial risk from the parties involved uses RII of each variable originating from each risk factor (Achmadi & Narbuko, 2004). RII is calculated using multiplication between Frequency Index (FI) and Severity Index (SI).

Results

Frequency index

Frequency index (FI) analysis intends to show the frequency index of each risk variable originating from resource risk factors. The FI analysis of the research reviewed in the three periods of the study refers to Husin *et al.* (2017). Based on the results of FI calculations, from the risk factors of labour resources in Period I and II there are 4 (four) variables with a frequency scale "Frequent" that is variable availability of labour that is lacking (A1), lack of labour capacity (A2), discipline poor workers (A3), and low worker productivity (A4). While in Period III, there are no variables from labour resource risk factors and "Frequent" frequency scales. On the risk factors for material resources in Period I there are 1 (one) variable with a frequency scale "Frequent" that is the variable delay in material delivery (B2). While there are no variables from the risk factors for material resources with the "Frequent" frequency scale in Period II and III. In the risk factor of equipment resources in Period I there are two variables with a frequency scale "Frequent", namely the variable delay in equipment mobilization (C3) and the difficulty of access for heavy equipment to be used during implementation to the project location (C10). While there are no variables from equipment resource risk factors with the "Frequent" frequency scale in Period II and III.

Severity index

Severity index (SI) analysis aims to show the index of the severity of the frequency of occurrence of each risk variable derived from resource risk factors. The SI analysis in the study was reviewed in the three study periods, as shown in Table 4.

Risk importance index

Risk important index (RII) analysis aims to show the quality risk of the frequency of occurrence of each variable derived from the risk factors of the resource. RII analysis in this study was reviewed in the three study periods, as shown in Table 4.

Table 4. Results of analysis of Severity Index (SI) and Risk Importance Index (RII)

Factor	Variable		SI			RII		
	Name	Code	Period I	Period II	Period III	Period I	Period II	Period III
Labour Resources	Low manpower availability	A1	0,570	0,370	0,450	0,222	0,242	0,171
	The ability of the manpower is lacking	A2	0,620	0,620	0,560	0,237	0,201	0,184
	Discipline of unfavorable manpower	A3	0,560	0,610	0,550	0,187	0,187	0,173
	Low manpower productivity	A4	0,370	0,590	0,530	0,216	0,195	0,197
	Less solid team work	A5	0,510	0,470	0,470	0,206	0,161	0,131
	Manpower squabble	A6	0,400	0,400	0,400	0,180	0,181	0,206
	Strike the manpower	A7	0,440	0,420	0,370	0,123	0,099	0,119
Material Resources	Increase in material prices	B1	0,490	0,430	0,390	0,380	0,237	0,246
	Delay in material delivery	B2	0,480	0,410	0,400	0,414	0,414	0,306
	Theft of material	B3	0,400	0,370	0,390	0,366	0,382	0,315
	Material quality is below standard (specification)	B4	0,450	0,480	0,450	0,237	0,378	0,297
	The volume and type of material is not correct	B5	0,490	0,450	0,430	0,251	0,226	0,226
	Damage to material delivery and storage	B6	0,510	0,500	0,470	0,171	0,187	0,181
	Limited material shelter	B7	0,410	0,430	0,370	0,170	0,163	0,133
	Supplier cannot fulfill material order	B8	0,390	0,410	0,370	0,300	0,264	0,239
	Planning & management of good materials	B9	0,490	0,470	0,480	0,313	0,202	0,203
	Material Handling	B10	0,360	0,280	0,350	0,245	0,182	0,192
Equipment Resources	Small equipment capacity	C1	0,440	0,430	0,370	0,167	0,186	0,162
	Placement error equipment	C2	0,370	0,390	0,330	0,248	0,192	0,189
	Late mobilization of equipment	C3	0,370	0,400	0,400	0,238	0,234	0,201
	Equipment is incomplete	C4	0,400	0,400	0,420	0,180	0,160	0,137
	Device damage	C5	0,480	0,450	0,470	0,177	0,169	0,138
	Negligence in inspection of equipment condition	C6	0,450	0,410	0,420	0,242	0,213	0,186
	Productivity and efficiency decreased	C7	0,370	0,440	0,410	0,125	0,090	0,103
	The additional cost of equipment rental	C8	0,450	0,370	0,440	0,163	0,160	0,138
	Fuel scarcity	C9	0,370	0,410	0,450	0,138	0,146	0,115
	Difficult access to entry for heavy equipment	C10	0,530	0,490	0,410	0,237	0,224	0,165
	Bad Planning & management of equipment	C11	0,490	0,490	0,400	0,192	0,176	0,163
	High equipment maintenance costs	C12	0,480	0,430	0,430	0,275	0,264	0,263
	No knowledge for procedures to use equipment	C13	0,400	0,400	0,370	0,216	0,191	0,168
	Unsuitable equipment for work/field conditions	C14	0,450	0,430	0,410	0,182	0,205	0,175
	Ownership of rental equipment	C15	0,430	0,390	0,350	0,216	0,192	0,199
	Ownership of rental-buying tools	C16	0,410	0,400	0,330	0,231	0,213	0,234
	Ownership of own tools	C17	0,330	0,310	0,320	0,360	0,261	0,219

Risk importance index Ranking

Based on the results of the calculation of the average RII in each period, the ranking variables for each factor are ranking, are shown in Table 5. There are 3 conditions of variable patterns between periods, namely some variables have increased, some are fixed and some other have decreased.

Discussion

Based on the results of the calculation of the average RII in each period shows, the risk factor is a decrease from period 1 to the next period, as shown in Figure 1. It is influenced by the poorer discipline variable (A3) is a variable that is a quality risk in Period I and Period III, while the variable labour capacity that is lacking (A2) is a quality risk in Period II. A3 is high in Period I due to the difficulty of getting skilled workers because of the insecure conditions of Aceh; skilled labour can indirectly improve the quality of work, many seek employment outside Aceh. The high risk for A2 in Period II was caused by a reduction in the number of workers caused by the tsunami disaster. Period III of Aceh were normal conditions, and the amount of construction work caused difficulties in obtaining workers with functional capabilities.

From the material resource factor, the delay in the material delivery variable (B2) is a variable which is a quality risk in Period I, while the variable increase in material prices (B1) is a quality risk in Period II and Period III. The high risk for B2 variable in Period I was caused by other triggers, events that occurred during the conflict caused difficulties in access to material, resulting in delays in material shipments. The high risk for B1 variables in Period II and III respectively was caused more by other triggers such as the condition of Aceh Province after natural disasters and uncertain weather conditions.

Table 5. Results of analysis of Risk Importance Index (RII) Ranking

Risk Factor	Variable Code	Period I		Period II		Period III	
		RII	Rank	RII	Rank	RII	Rank
Mateial Resources	B1	0,380	2	0,237	5	0,246	4
	B2	0,414	1	0,414	1	0,306	2
	B3	0,366	3	0,382	2	0,315	1
	B4	0,237	8	0,378	3	0,297	3
	B5	0,251	6	0,226	6	0,226	6
	B6	0,171	9	0,187	8	0,181	9
	B7	0,170	10	0,163	10	0,133	10
	B8	0,300	5	0,264	4	0,239	5
	B9	0,313	4	0,202	7	0,203	7
	B10	0,245	7	0,182	9	0,192	8
Equipment Resources	C1	0,167	14	0,186	11	0,162	12
	C2	0,248	3	0,192	8	0,189	6
	C3	0,238	5	0,234	3	0,201	4
	C4	0,180	12	0,160	14	0,137	15
	C5	0,177	13	0,169	13	0,138	13
	C6	0,242	4	0,213	5	0,186	7
	C7	0,125	17	0,090	17	0,103	17
	C8	0,163	15	0,160	15	0,138	14
	C9	0,138	16	0,146	16	0,115	16
	C10	0,237	6	0,224	4	0,165	10
	C11	0,192	10	0,176	12	0,163	11
	C12	0,275	2	0,264	1	0,263	1
	C13	0,216	9	0,191	10	0,168	9
	C14	0,182	11	0,205	7	0,175	8
	C15	0,216	8	0,192	9	0,199	5
	C16	0,231	7	0,213	6	0,234	2
	C17	0,360	1	0,261	2	0,219	3
Labour Resources	A1	0,222	2	0,242	1	0,171	5
	A2	0,237	1	0,201	2	0,184	3
	A3	0,187	5	0,187	4	0,173	4
	A4	0,216	3	0,195	3	0,197	2
	A5	0,206	4	0,161	6	0,131	6
	A6	0,180	6	0,181	5	0,206	1
	A7	0,123	7	0,099	7	0,119	7

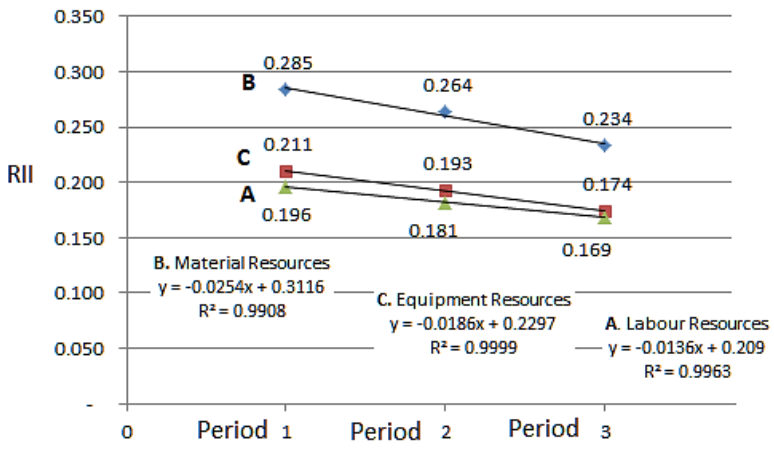

Figure 1. Factor risk pattern over the three periods in Aceh

From the equipment resources factor, the variable difficulty in accessing heavy equipment to be used during implementation to the project location (C10) is the variable which is the quality risk in Period I, while the tool damage variable (C5) is the quality risk in Period II and Period III. The high risk for variable C10 in Period I was caused by internal or external triggers such as riots, sabotage of facilities/materials, warfare. While the high risk for C5 variables in Period II and III was caused more by other triggers such as

equipment placement errors, negligence in checking equipment conditions, and not understanding the procedures for using the equipment.

Conclusions

This study shows the results of studies related to risk assessment using indicators of frequency, severity, and risk importance. Project risk is a superposition of RII on all risk variables. Each variable is a function of frequency and severity. High and low risks are influenced by both frequency and severity. The RII analysis is used as input to assess the most dominant risk for the quality of each resource risk factor in the three periods of the study.

From the results of the analysis, it is known that the risk factors for labour risk variables that cause a decrease in construction quality are more influenced by the variable discipline of workers who are not good (A3) and lack of labour capacity (A2). In the material risk factors, the risk variable, which causes a decrease in construction quality is more influenced by the variable delay in material delivery (B2) and the increase in material prices (B1). In equipment risk factors the risk variable that causes a decrease in construction quality is more influenced by the variable difficulty of access for heavy equipment to be used during implementation to the project location (C10) and equipment damage (C5).

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