An Integrated Relative Importance Index, Risk Allocation and Bow Tie Analysis for Analyzing Risks of the Amartha View Apartment Development Project

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Abstract. Construction projects have quite a number of risks that can have an impact on the objectives of the project such as cost, time and quality. Good risk management is very important for the success of a project. The Amartha View Apartment development project experienced a variety of problems that affected the smooth running of the project, including late payments from the owner, late material shipments, and delays in achieving project achievement targets. Because of the existence of these various problems, the researcher intends to conduct research with the aim of identifying the risks that have been and may occur in the project, then conducting a risk assessment. Then classify risk allocation, and provide a control strategy (response) to critical risks. Research begins with identification of risks in the project, then evaluates the risks that have been identified. The method used in risk assessment is relative importance index. After conducting a risk assessment, then determining the response strategy that can be carried out on risks with a high category. Determination of response strategies using the bow tie analysis method that will produce a bow tie diagram. There were a total of 3 risks included in the high category including delays in obtaining road access, restrictions on vehicle hours and location delays.

1. Introduction
All business sectors have their own risks, including business related to construction services. Construction projects are considered to have quite a lot of risks because there are many parties involved, including owners, contractors, suppliers, designers, and subcontractors. Risks are losses because unexpected events arise [1]. Construction projects in general are faced with risks that are the main reason for the causes of disputes in the construction industry [2]. Risk management is a system that aims to identify and measure all risks in an open business or project, so that appropriate decisions can be made regarding risk management [3]. Project risk management is a series of processes for risk management planning, identification, analysis, response, supervision, and control of a project. The aim is to increase the likelihood and impact of positive events (opportunities) and minimize the possibility and impact of negative events in a project [4].

PT. PP Urban is currently working on one of the apartment development projects in Ngaliyan, Semarang named Amartha View Apartment. There have been several problems in the project, there are the delay in completion of tower 1, the late payment from the owner, the delay in material delivery, and the changes of initial design. The various problems affect the smooth progress of the project development. So it is important to do a risk analysis of the Amartha View Apartment development project. Analysis of the risk due to failure in handling risk will cause considerable losses. The potential loss from risk will also be greater if the people involved in the project do not have careful behavior, and can be avoided by doing good risk management [5].

Through risk management, it is expected to achieve project objectives in the construction of building infrastructure like precise of time, quality, and cost [6]. The construction industry and the various parties
in it are broadly related to the high level of risk due to the nature of the micro, meso and macro environments to construction [7]. Ref. [8] emphasizes that risk management is critical to the success of a large project. The implementation of a risk management process in a construction project is a key to the success of the project and a successful project is a project that completed on time, within budget, as expected quality and safety [9].

The purpose of the study was to identify the risks that identifying the risks that have been and may occur in the project, then perform the risk assessment. Then classify the allocation of risks, and provide strategies of control to critical risks.

2. Research Methods

2.1. Data Collection and Sample Selection Techniques

Data collection technique used is primary data collection. Primary data obtained from the interview process and record the results of interview that have been done. Then also the primary data obtained from the results of the distribution of questionnaires to the respondents in the field. The sampling technique used is purposive sampling because the questionnaire is filled by experts who understand about the real condition of the project. Respondents in the study are shown in Table 1 below.

| Parties                   | No | Position                              |
|---------------------------|----|---------------------------------------|
| Contractor                | 1  | General Supervisor                    |
|                           | 2  | Surveyor                              |
|                           | 3  | Safety Health Environment Officer     |
|                           | 4  | Project Operations Controller         |
|                           | 5  | Surveyor Assistant                    |
| Construction Management   | 6  | Team Leader                           |
|                           | 7  | Human Safety Engineering              |
|                           | 8  | Quality Control of Architecture       |
|                           | 9  | Construction Management Engineering   |
|                           | 10 | Quality Control of Mechanical Electrical |

2.2. Determination of Research Variables and Questionnaire Model

The research variables used adopted from [10] which presented 42 risks of the construction sector. Then from 42 variable of risks, we conduct validation and got 22 variables consist of 16 internal risks and 5 external risks which will be used in research. Risks based on the source can be divided into two, there are [11]:

1. Internal Risks
   Internal risks are risks that come from within the company, for example damage to project equipment due to operational errors, work accident risk and mismanagement risk.

2. External Risks
   External risks are risks that come from outside the company or organization, for example steal risk, fraud risk, price fluctuations, politics, inflation etc.

Assessment of the questionnaire using the likert scale of 1 to 5 in successive categories is very rare/very low, rare/low, moderate, frequent/high, and very often/very high. Research variables is shown in Table 2.
Table 2. Variables of research

| Sources | Var | Risk | Description |
|---------|-----|------|-------------|
| Internal | I1  | 1    | Owners’ delayed payment to contractors |
|         | I2  | 2    | Change of design from contractors |
|         | I3  | 3    | Owner sets a tight and unreasonably schedule |
|         | I4  | 4    | Delays gain road access |
|         | I5  | 5    | Improper design |
|         | I6  | 6    | Accidents during construction |
|         | I7  | 7    | Poor quality work |
|         | I8  | 8    | Contractors’ incompetence |
|         | I9  | 9    | Subcontractors’ poor performance |
|         | I10 | 10   | Subcontractors’ breach of contracts (disputes) |
|         | I11 | 11   | Delay of material supply |
|         | I12 | 12   | Restrictions of heavy vehicle operating hours entered the site |
|         | I13 | 13   | Subcontractor replacement |
|         | I14 | 14   | Deficiencies in drawings and specifications |
|         | I15 | 15   | Changes of design required by owners |
|         | I16 | 16   | Reduction of workers by subcontractors |
| External | E1  | 17   | Strikes and labour disputes due to political influence |
|         | E2  | 18   | Inflation and sudden changes in prices |
|         | E3  | 19   | Lack of supply and availability of materials (unstable economic influence) |
|         | E4  | 20   | Unexpected inclement weather |
|         | E5  | 21   | Unforeseen site conditions |

2.3. Risk Assessment and Response Strategy

Risk assessment use relative importance index (RII) method from the result of questionnaire. RII is an analysis that allows a relative quantitative, where the higher rating make the higher influence given by the variables [12]. RII of probability and impact is calculated for each risk. Formulation of RII is shown by eq. (1) [10]:

$$RII = \frac{\sum W_i X_i}{\sum X_i}$$  \hspace{1cm} (1)

Where:

- $RII$ = Relative Importance Index
- $W_i$ = weight assigned to $i^{th}$ response;
- $X_i$ = 1, 2, 3, 4, and 5
- $X_i$ = frequency of the $i^{th}$ response
- $i$ = response category index = 1, 2, 3, 4 and 5 for very low, low, moderate, high and very high, respectively

Than determine the risk rating or Project Risk Rating (PRR) calculated by multiplying the value of RII of probability and RII of impact. Eq. (2) is formulation of the risk rating:

$$Risk\ rating = RII_{\text{probability}} \times RII_{\text{impact}}$$  \hspace{1cm} (2)

Where:

- $RII_{\text{probability}}$ = Relative Importance Index of probability
- $RII_{\text{impact}}$ = Relative Importance Index of impact (Time, Cost, Quality)
The value of the project risk rating is in the range of 1 to 25. The classification of project risk rating values according to [13] there are 1-5 included in the low category, 5-10 included in moderate, 10-15 included in significant category and 15-25 included in high category.

We also do the calculation of risk allocation to know the right parties to handle the risk. Risk allocation is the imposition risks of the projects on the most appropriate parties to handle the risk. The most appropriate party in dealing with the risk is the party that can be the best to control the risk [10].

Calculation of risk allocation using percentages, the recommended allocation is for the party that gets more than 50% of the votes for each risk both owner, contractor, and shared. If a risk did not have a party with more than 50% of the votes, it is labelled “undecided” [10].

Furthermore, determine the responses strategy using bow tie analysis by involving the project parties and construction management expert. Bow tie analysis is an analysis using a diagram that resembles a butterfly bow tie that expresses the relationship between hazard scenarios, threats, controls, and impacts. Bow tie analysis is used to prevent, control and reduce undesirable events by developing a logical connection between cause and effect of an undesirable even [14].

3. Result and Discussion

3.1. RII Probability and Impact

The calculation of RII use equation 2.1. The result of RII calculation for probability and impact is shown in Table 3. In Table 3, the "P" column means probability, "C" means cost, "T" means time, and "Q" means quality. The highest RII of probability is variable I12 or restrictions of heavy vehicle operating hours entered the site.

| Var | RII Impact | Var | RII Impact | Var | RII Impact |
|-----|------------|-----|------------|-----|------------|
| I1  | 3.2 3.2 3.0 2.5 | I8  | 2.2 4.0 4.0 3.9 | I15 | 3.1 2.7 2.8 2.5 |
| I2  | 3.0 2.7 3.6 3.3 | I9  | 2.0 4.1 4.0 4.0 | I16 | 2.7 2.8 4.0 2.8 |
| I3  | 2.8 3.2 4.0 2.4 | I10 | 2.0 3.4 3.9 2.8 | E1  | 1.1 2.5 2.9 2.1 |
| I4  | 4.4 4.5 4.4 2.1 | I11 | 3.5 4.1 4.5 2.6 | E2  | 2.1 3.6 3.4 2.9 |
| I5  | 2.4 2.9 3.1 2.5 | I12 | 4.6 4.0 4.2 2.0 | E3  | 2.6 3.7 3.7 2.7 |
| I6  | 1.4 3.2 3.2 2.3 | I13 | 2.6 3.9 4.1 2.6 | E4  | 3.4 3.3 3.5 2.7 |
| I7  | 2.0 3.7 4.0 3.7 | I14 | 2.5 3.0 3.3 2.6 | E5  | 2.8 3.2 3.3 2.6 |

The highest RII value of the impact on costs is delays gain road access with RII of 4.5 (I4). The highest RII value of the impact on time is delay of material supply with RII of 4.5(I11). The highest RII value of the impact on quality is subcontractors’ poor performance with RII of 4.0 (I9).

3.2. Risk Rating
The result of risk rating is obtained using eq. (2). The risk rating is calculated by multiplying RII of probability value and RII of impact value, which consists of the impact on cost (C), time (T) and quality (Q). The result of calculation of risk rating value can be seen in Table 4. Red color indicates high risk, orange indicates significant risk, blue indicates moderate risk and green indicates low risk. Column B shows the calculation of the value of risk ratings based on their impact on the cost of construction projects. In column B there are 2 risks that including to high risk category there are delays gain road access (I4) and restrictions of heavy vehicle operating hours entered the site (I12).

Then there are 4 risks that including to the significant category of risks. They are delay of material supply (I11), unexpected inclement weather (E4), owners’ delayed payment to contractors (I1), and subcontractor replacement (I13). Also there are 13 risks in moderate category and 2 risks in low category.

Table 4. Risk rating value

| Var | Risk Rating Value | Var | Risk Rating Value | Var | Risk Rating Value |
|-----|-------------------|-----|-------------------|-----|-------------------|
|     | C       | T       | Q       |     | C       | T       | Q       |     | C       | T       | Q       |
| I1  | 10.24   | 9.60    | 8.00    | I8  | 8.80    | 8.80    | 8.58    | I15 | 8.37    | 8.68    | 7.75    |
| I2  | 8.10    | 10.80   | 9.90    | I9  | 8.20    | 8.00    | 8.00    | I16 | 7.56    | 10.80   | 7.56    |
| I3  | 8.96    | 11.20   | 6.72    | I10 | 6.80    | 7.80    | 5.60    | E1  | 2.75    | 3.19    | 2.31    |
| I4  | 19.8    | 19.36   | 9.24    | I11 | 14.35   | 15.75   | 9.10    | E2  | 7.56    | 7.14    | 6.09    |
| I5  | 6.96    | 7.44    | 6.00    | I12 | 18.40   | 19.32   | 9.20    | E3  | 9.62    | 9.62    | 7.02    |
| I6  | 4.48    | 4.48    | 3.22    | I13 | 10.14   | 10.66   | 6.76    | E4  | 11.22   | 11.90   | 9.18    |
| I7  | 7.40    | 8.00    | 7.40    | I14 | 7.50    | 8.25    | 6.50    | E5  | 8.96    | 9.24    | 7.28    |

Column W shows the calculation of risk rating value based on its impact on the time of construction projects. In column W there are 3 risks that including to high risk category there are delays gain road access (I4), restrictions of heavy vehicle operating hours entered the site (I12), and delay of material supply (I11). Then there are 5 risks that including to the significant category such as unexpected inclement weather (E4), owner sets a tight and unreasonably schedule (I3), change of design from contractors (I2), reduction of workers by subcontractors (I16) and subcontractor replacement (I13). Then there are 11 moderate and 2 low category of risks.

Column K shows the calculation of the risk rating value based on their impact on quality of construction projects. In column K there are no risks that including to either significant or high risks category. However there are 19 risks including to the moderate category and 2 risks to the low category. From the calculation of risk rating, the total risks that are included in the significant and high risks category are 6 and 3 risks respectively. Then from the 3 high category risks will analysis using bow tie analysis to determine the responses strategy of each risk.

3.3. Risk Allocation

The recommended allocation of risks is for the party that gets more than 50% of the votes for each risk both owner, contractor, and shared. If a risk did not have a party with more than 50% of the votes. There are 9 risks that are recommended to be handled together are change of design from contractors (I2), owner sets a tight and unreasonably schedule (I3), I5 or improper design, restrictions of heavy vehicle operating hours entered the site (I12), strikes and labour disputes due to political influence (E1), inflation and sudden changes in prices (E2), lack of supply and availability of materials (unstable economic influence) (E3), unexpected inclement weather (E4), and unforeseen site conditions (E5).

Then there are 8 risks that appropriate handled by contractor such as accidents during construction (I6), poor quality work (I7), contractors’ incompetence (I8), subcontractors’ poor performance (I9), subcontractors’ breach of contracts (disputes) (I10), delay of material supply (I11), subcontractor...
replacement (I13), and reduction of workers by subcontractors (I16). There are only 4 proper risks if handled by the owner include owners’ delayed payment to contractors (I1), delays gain road access (I4), deficiencies in drawings and specifications (I14) and changes of design required by owners (I15).

3.4. Bow Tie Analysis

We divides the scenario in the bow tie diagram in five colours there are white circle in the middle is the risk, orange for causes of the risk, green for precautions, blue for the recovery action, and the grey for the impact or effect of risk. Here is a bow tie diagram for 3 risks with high category.

a. Delays gain roads access

The causes of this risk are occurrence because of communication errors between the contractor and the owner, the restriction of the neighbourhood residents because they do not agree if the road is passed by heavy vehicles, and the owner takes very long to make a decision. The consequences of delays gain road access are delays in starting construction projects, cessation of temporary construction processes when roads are closed by residents, material transport vehicles can not reach the project site, and the contractor's cost losses.

Precautions that can be done are provide compensation funds to residents in the project environment which through by heavy vehicle (risk reduction), discussing the access of the road between the contractor and the owner before to the project is start (risk transfer and risk avoidance), approaching, socializing and conducting discussions with citizens so that owners know the demands of citizens (risk reduction), making alternative roads to the project site without passing the streets or residential citizens (risk avoidance).

Recovery actions that can be done are if access of the road is open then the construction process should begin to be done in accordance with the schedule that has been planned. Then transfers material from large heavy vehicles to small vehicles in order to enter the project site and the owner or contractor shows good intention to the residents by improve the residents' roads (risk retention and risk reduction). The bow tie diagram for the first risk is shown in Figure 1.

![Delays gain roads access](image)

Figure 1. Delays gain roads access

b. Restrictions of heavy vehicle operating hours entered the site

The restriction is due to the decision of the owner to limit the operating hours of heavy vehicles to the project site due to an agreement between the owner and the residents in the project area. Then because the heavy vehicle disrupt the activities of residents. The consequences are material vehicle
stuck outside the site, delayed work of project, increased vehicle costs and casting cannot be done at night. Precautions that can be done are make an alternative road to the project (risk avoidance). Then socialize the project schedule to residents for particular day (risk reduction). Providing compensation to the residents because of roads damaged by heavy vehicles (risk reduction).

Recovery actions that can be done are coordinate with material suppliers related to delivery time, build a batching plant within the project area. Then prepare the cast land at night, transfer material from large vehicle to small vehicle and build material storage warehouse (risk retention and risk reduction). The bow tie diagram for the second risk is shown in Figure 2.

c. Delay of material supply

The causes are poor material supplier performance, heavy vehicle’s operating time is limited to entering the project, and late payment from contractor to supplier caused by late/delay payment from owner to contractor. Then the supplier is not willing to send material to the project and unexpected road conditions. The resulting consequences are out of material stock, cessation of work, hampered progress, repatriation of workers by foreman, swelling of labor costs and inefficient of using construction equipment.

Preventive responses action are penalty to supplier if the material has been ordered not sent or arrive on time (risk transfer), on time payment (risk avoidance). In addition, all licensing matters must be completed as soon as possible. Then establish good communication and cooperation with the supplier (risk avoidance). Recovery actions that can be done there are contractors can switch to purchases at next level suppliers, establish work shifts when materials arrive, and look for alternatives to other suppliers or keep purchasing small amounts of material that can be bought around the site (risk retention and risk reduction). The bow tie diagram for the third risk is shown in Figure 3.
4. Conclusion
There are several conclusions in this study. First, risk identification is the process of listing risks that may occur in an activity. In this study, we identify risk based on the source of risk consisting of internal and external. There are 16 risks that include the internal risk and five risks that include external risk. Second, from the result of risk assessment, the total risks that are included in the significant and high category are 9 risks. Third, the allocation of risk is the imposition of the risks that exist in a project to the appropriate party in handling the risk. There are 8 risks that recommended to be handled by the contractor, 9 risks that are recommended to be shared, and 4 risks that are recommended to handle by owner. Fourth, the risk response strategies are obtained using bow tie analysis. There are 3 risks with high category such as delays gain roads access, restrictions of heavy vehicle operating hours entered the site and delay of material supply. Delays gain roads access is the highest risk.

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