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| **Authors** | Anastasia Erlita, Mawardi Amin and Bambang Bintoro |
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# Multiphase Project Risk Management on Food Factory Building Construction : Consultant Perspective

*Anastasia Erlita[1], Mawardi Amin[2] and Bambang Purwoko Kusumo Bintoro[3]

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**Abstract:** This article reports research on a flour mill factory building construction in Indonesia by investigating the root cause of time overrun in consultant perspective. While numerous risks are identified during the phases of construction project, it is unknown which risk is the primary cause of project delays. To better understand the optimization of risk management and risk mitigation, a multiphase risk management is proposed, which is divided into 4 phases: pre-design, design, project bidding, and construction phase. As a result, employing the bow-tie analysis enables a more in-depth examination to identify the risk. From each bow-tie diagram, a detailed risk mitigation table can be formulated and easier to plan the response for each risk. Probability Impact Matrix also used to identify the risk score and evaluate the risk. This research begins by giving questionnaire to 45 qualified respondents. It was found that 45 factors that caused the delay in all phases were divided into 7 factors from the pre-design phase, 14 factors from the design phase, 6 factors from the tender phase and 16 factors from the construction phase. As the final step of risk management process, there are various responses in this research depends on their final assessment based on the score and questionnaire result. Factory building construction is quite different from other type of building construction because machine design also being an important part that affects the structural, architectural, mechanical and also electrical aspects.

**Keywords:** Time overrun, Industrial buildings, Flour mills, Bow-tie analysis, Probability Impact Matrix, Risk Management

[1] Master of Civil Engineering Department, Universitas Mercu Buana, Jakarta 11650 Indonesia
[2] Master of Civil Engineering Department, Universitas Mercu Buana, Jakarta 11650 Indonesia
[3] Master of Management Program Study, Universitas Bakrie, Jakarta 12920, Indonesia
*Corresponding author: tasia.arch@gmail.com

## INTRODUCTION

Susetyo, B. and Utami, T. (2017) stated that projects are considered successful if they meet quality targets, cost and time; but cost & time overrun is a common risk in projects around the world (Le-Hoai et al., 2008; Murray and Seif, 2013; Sweis, 2013), Unfortunately, project delay is a common risk and happens to almost all projects in Indonesia (Le Hoai et al., 2008) even though the supervision function has been carried out properly.

According to previous study by Ullah (2017), an appropriate in-depth study of time and cost issues in the construction industry is needed, which can identify alternative solutions and measure the level of possible solutions to ensure the successful completion of construction projects. Based on PMBOK 6th Edition, the project management process consists of 5 stages of the process: initiating, planning, executing, monitoring & controlling, and closing, but in this study will focus on initiating, planning, and executing phases, and elaborate various risks that can arise by identifying, measuring, mapping, developing alternative risk treatments, monitoring risks, and controlling risk management or prevention with risk management system.

In current issue, time overrun cases in Indonesia increase during the pandemic because of the status of Large-Scale Social Restrictions in many areas in Indonesia affects the mobilization process, availability of materials and workers (PUPR, 2020). During the pandemic or every situation, food production must continue for human survival, so that time overrun on flour mills factory building construction and other food factory buildings needs to be reduced. To minimize the risk, a project manager should monitor the project carefully and find the way to minimize the delay so that a project runs on time and the project costs can be well controlled. Delays will affect to job interruptions, low productivity, project delays, cost increases, third party claims and contract terminations. It also refers to a long construction period due to problems that occurred during project implementation (Kikwasi, 2012). Sudirman, W. B. and Hardjomuljadi, S. (2011) stated that project management can be defined as the application of knowledge, skills, tools, and techniques to complete the project in order to meet its requirements.

The object of research chosen was an 8-storey flour factory building that located in an industrial area in Indonesia. This building was taken to be the object of research because of its high complexity, and risk management can be applied in all phases, because all phases in this project was delayed. As the objective of this research is: 1) To assessing the factors causing delays in 4 phases of this project, 2) Analyze the impact of the risk factors causing the delay, and 3)Recommend risk responses. Risk Management in the construction sector is essential to achieve the objectives of the project (time, cost, quality and safety), the risk management system assists project managers in prioritizing resource allocation and also helps them in decision-making more reliable, thus contributing to project success and achieving objectives.

## LITERATURE REVIEW

Zidane and Andersen (2018) investigated top 10 universal delay factors in construction projects. On his research, questionnaire was designed and distributed among the participant groups (customers, consultants, contractors, subcontractors, and suppliers). They identified the following main reasons for delays: improper planning and scheduling; slow/bad decision-making process; internal administrative procedures within the project organization; shortage of resources (human resources, machinery, equipment); communication and coordination between all parties Poor; slow quality inspection process for completed work; design changes during construction/change orders. They also conducted an in-depth systematic literature study on key universal delay factors based on their research and 103 existing studies covering 46 countries around the world. Based on the survey results, they ranked the most frequently cited delay factors and obtained the top 10 common delay factors in the construction industry. They are design changes/changes during construction Order; late payment to contractor; poor planning and scheduling; poor site management and supervision; incomplete or improper design; contractor's inexperience/construction methods and methods; contractor's financial difficulties; sponsor/owner/client's economy Difficulties; shortage of resources (human resources, machinery, equipment); and low labor productivity and skills shortages.

There are two types of delay: unforgivable delay and forgivable delay (Tumi, Omran and Pakir, 2009; Hamzah et al., 2011; Ibironke et al., 2013). Unforgivable delays are delays that caused by the contractor or its suppliers, not due to the fault of the owner. For example: difficulties in financing projects by contractors, poor site management and supervision by contractors, poor communication and coordination by contractors with other parties, and inadequate planning and scheduling (Hamzah et al., 2011). Meanwhile, the forgivable delay is divided into two: compensable delay and non-compensable delay. Time overrun is also affecting the cost, therefore risk management of time overrun must be applied on every construction. According to Umum (2007), there are 4 steps in risk management:

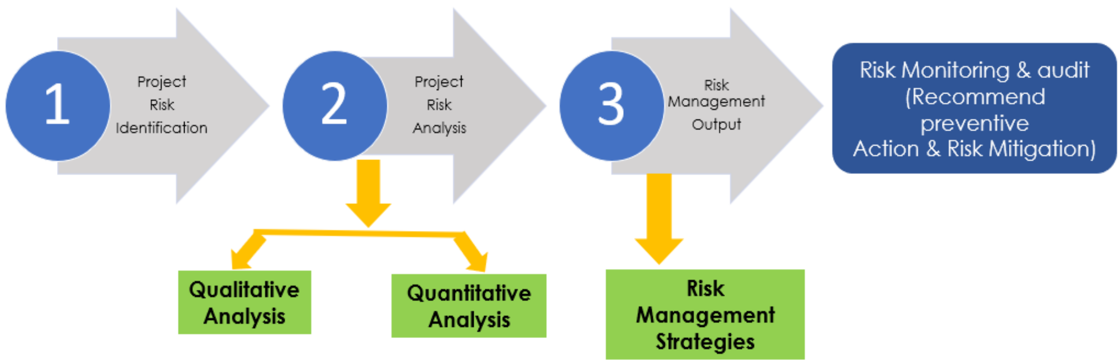


Figure 1. Risk Management Stage

## RESEARCH METHOD

This research begins with a research gap to find methods and objects of research. After that, the research title is obtained for further research objectives, problem formulations and research limitations. Then, the research instrument is compiled in the form of variables collected through pilot surveys, primary data collection such as minutes of meetings, drawings, variation order, site memos, planning schedules, implementation schedules, revision of implementation schedules, project budgeting, and other data that can be used as a reference in analyzing the factors. Then the secondary data collection is in the form of literature study.

After that the variables that have been collected are analyzed for their causes and effects with a bow-tie analysis, the risks rated by index scale rating of the probabilities and impacts with a probability impact matrix. The final step of the research is to formulate solutions and to prevent risks in the phase with the highest impact. Below is the research flowchart diagram:

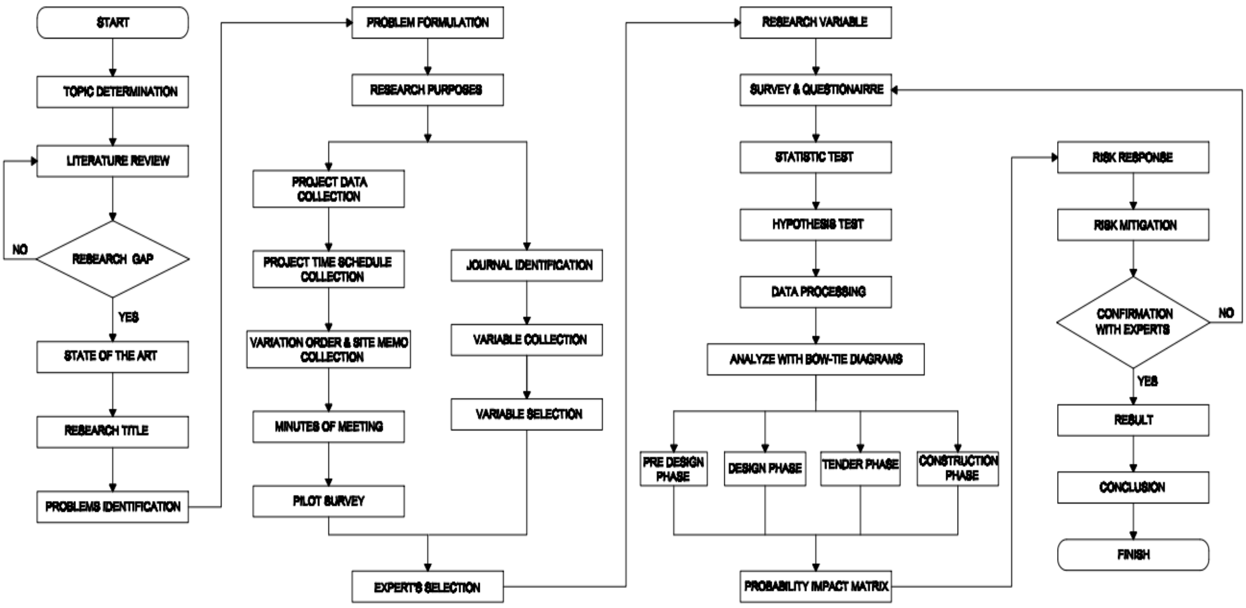


Figure 2. Research Flowchart Diagram

### Bow-Tie Analysis

Baddredine (2014) explained, the Bow-tie Analysis Method was developed by the Shell company to describe the entire accident scenario. This model has proven its efficiency in several real applications such as; risk management, risk analysis, risk assessment and implementation of security barriers. So that this model can be used for various branches of risk management, including in the construction sector.

According to Ruijter and Guldenmund (2016), there is a historical development of the formation of the Bow-tie Analysis method, namely the merger of Fault Tree Analysis, Event Tree Analysis, Cause Consequence

Diagrams and Thought Limitations. The application of bow-tie analysis is briefly described in the image below:

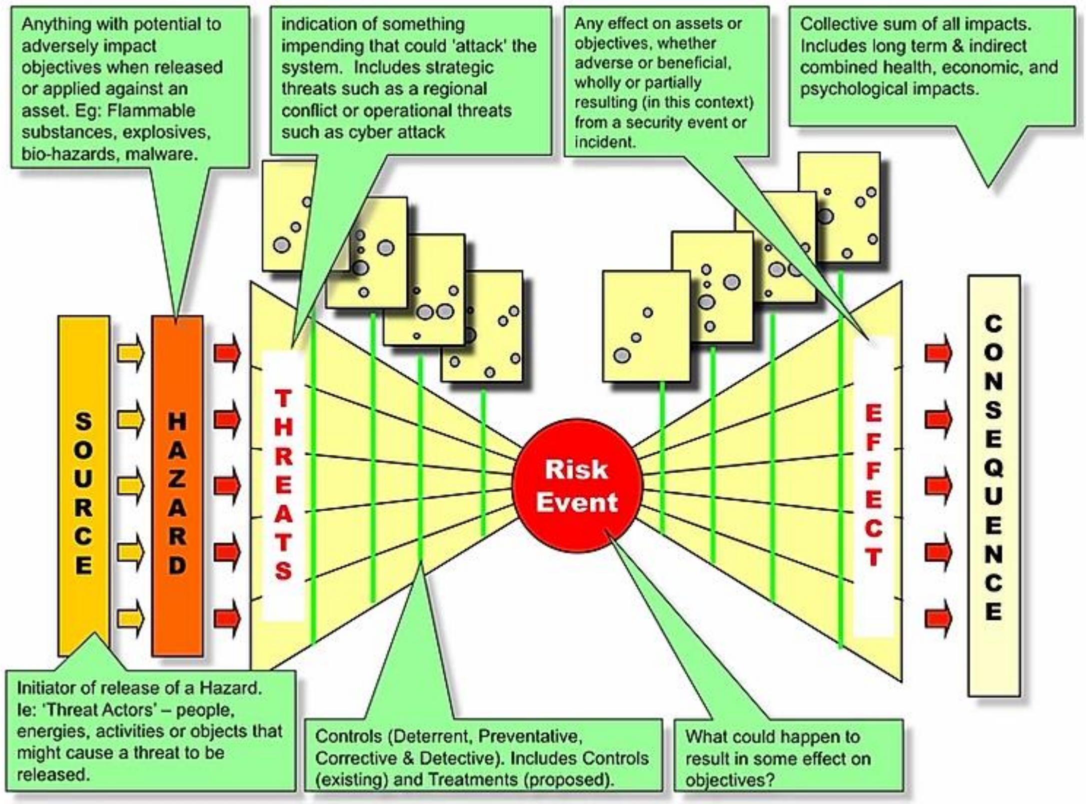


Figure 3. Research Flowchart Diagram

The bow-tie analysis method is a quantitative analysis used in this study. This method is the initial stage in variable data analysis. The initial stage of making a Bow-tie Analysis is determining the source/hazard. Next stage is determine the initiating event, which is taken from the variables collected in table 1-4, then look for the causes why the incident happened, looking for a way to solve the problem, and analyze consequences of the event.

## SURVEY & QUESTIONAIRRE

From the literature review, a questionnaire was prepared, and a pilot survey was conducted to check the applicability of the questionnaire in this project. 45 questionnaires were presented to experts and other parties that participated in Flour Factory design & development. Respondents were selected based on their abilities and experiences in the project as consultants. Questionnaire data was collected by distributing questionnaires to stakeholders who were directly involved in the planning and implementation which is responsible for the flour mill building work. In the survey conducted, the number of questionnaires returned by 45 respondents. Other 13 result cannot be used as research data because it is incomplete, so it is not eligible. The dissemination of the survey is carried out evenly to all parties who is responsible in this project, with different work experience. As many as 11% of respondents have 0-5 years experience, 31% experience for 6-10 years, 31% experience for 11-17 years and 27% experience over 20 years.

The main variable in this research is the construction phase which consists of the pre-design phase (Xa), design phase (Xb), the tender phase (Xc) and the construction phase (Xd). The main variable is then searched through a pilot survey and variable selection from previous research. Primary and secondary data collection is also required to classify sub variables for each main variable.

## DATA COLLECTION

The final questionnaire had an introduction of the respondent covering their name, qualifications and experience in the construction industry. 45 major risks were identified in this research. 20 risks were adopted from Gunduz et al. (2013), and other risks were identified from the input of experts in the pilot survey. Finally, each questionnaire incorporated a five-point Likert-type scale. Data collection in this research is construction progress reached 90% and close to completion of the project. The construction time starts from August 2019 and undergoes several time schedule revisions due to delays. In this research, questionnaire method is used by conducting direct interviews or through filling out questionnaires to stakeholders who are directly responsible in the construction work stage of this flour mill building.

Table 1. Pre-design phase factors

| Var | Phase | No. | Var | Main Factor | Var | Sub Factor |
|---|---|---|---|---|---|---|
| **Xa** | **Pre-Design** | **1** | X1a | Building Permit | X1a1 | Building permit data is different from site conditions |
| | | **2** | | | X1a2 | Lack of open spaces on site |
| | | **3** | | | X1a3 | Changes in development regulations |
| | | **4** | X2a | Owner | X2a1 | Issuance of Purchase Order and Late progress payments |
| | | **5** | | | X2a2 | In-depth feasibility study |
| | | **6** | X3a | Supporting Data | X3a1 | Incomplete As Built Drawing |
| | | **7** | | | X3a2 | Design idea changes |
| | | **8** | X4a | Coordination | X4a1 | Consultant presentation |
| | | **9** | | | X4a2 | The process of tendering and the implementation of new site |

Table 2. Design phase factors

| Var | Phase | No. | Var | Main Factor | Var | Sub Factor |
|---|---|---|---|---|---|---|
| **Xb** | **Design** | **10** | X1b | Consultant | X1b1 | Differences in idealism with foreign consultants |
| | | **11** | | | X1b2 | Design Errors |
| | | **12** | | | X1b3 | The machine plan has not been fixed |
| | | **13** | | | X1b4 | Delay in production of drawings & tender documents |
| | | **14** | X2b | Owner | X2b1 | Late progress payment from owner |
| | | **15** | | | X2b2 | Late of design approval from owner |
| | | **16** | | | X2b3 | Changes from owner |
| | | **17** | | | X2b4 | Waiting for owner's decision |
| | | **18** | X3b | Coordination | X3b1 | Coordination meetings between consultants |
| | | **19** | | | X3b2 | Poor communication and coordination with other parties |
| | | **20** | X4b | Software | X4b1 | Drawing Information is in PDF format |
| | | **21** | | | X4b2 | Use of different software |
| | | **22** | X5b | Regulatory Standards | X5b1 | Differences between local and foreign regulations |
| | | **23** | X6b | Scope of work | X6b1 | Unclear scope of work |

Table 3. Tender phase factors

| Var | Phase | No. | Var | Main Factor | Var | Sub Factor |
|---|---|---|---|---|---|---|
| **Xc** | **Tender** | **24** | X1c | Schedule | X1c1 | Determination of the long tender schedule |
| | | **25** | | | X1c2 | Many stages of clarification |
| | | **26** | X2c | Tender Documents | X2c1 | Post-meeting design revision |
| | | **27** | | | X2c2 | Design Changes |
| | | **28** | X3c | Supporting data | X3c1 | Machine technical data appears after tender |
| | | **29** | | | X3c2 | Tenders are carried out separately per scope of work |

Table 4. Construction phase factors

| Var | Phase | No. | Var | Main Factor | Var | Sub Factor |
|---|---|---|---|---|---|---|
| **Xd** | **Construction** | **30** | X1d | External | X1d1 | Weather factors |
| | | **31** | | | X1d2 | Soil conditions |
| | | **32** | | | X1d3 | Late delivery of imported materials / machinery |
| | | **33** | | | X1d4 | Regional regulations |
| | | **34** | X2d | Owner | X2d1 | Owner request |
| | | **35** | | | X2d2 | Decision Making |
| | | **36** | | | X2d3 | Variation Order Price |
| | | **37** | X3d | Implementation | X3d1 | Additional work due to |

| | | | | |
|---|---|---|---|---|
| | | | | damage of existing buildings |
| **38** | | | X3d2 | Unfinished work. |
| **39** | | | X3d3 | Unclear scope of work |
| **40** | X4d | Project Resources | X4d1 | Number of workers |
| **41** | | | X4d2 | Material delivery |
| **42** | | | X4d3 | Heavy equipment damage |
| **43** | X5d | Design | X5d1 | Machine design changes |
| **44** | | | X5d2 | Design changes during construction |
| **45** | | | X5d3 | Differences in structure, architecture and ME drawings |

## RESULT AND DISCUSSION

The validity test results were carried out with SPSS software. With the validity test, it is believed that each question in this questionnaire provide valid results, with the provision that r Count > r Table. The result of SPSS test found that r Count is > 0,294 which means all the factors were valid. The results of the reliability test on all variables tested in this study stated that Cronbach's alpha was higher than the baseline value, namely 0.944> 0.60. These results prove that all statements of variables tested on the questionnaire were reliable.

Hypothesis is tested by using multinomial regression coefficient test, which is used to determine whether the independent variables (Xa, Xb, Xc and Xd) in this study have a significant effect on the dependent variable (Y).There are 4 hypothesis in this research (**H1** : Xa affects Y, **H2** : Xb affects Y, **H3** : Xc affects Y and **H4** : Xd affects Y). The results of the multinomial regression test output produce a sig <a (0.05). The p value for H1 is 0.000, the p value for H2 is 0.001, the p value for H3 is 0.018 and H4 is 0.001 where The four statements are <a (0.05) so that all statements H1, H2, H3 and H4 are accepted.
In this study, a bow-tie model was created to see the sequence of events that causes the delay, starting from finding all sources of problems in this project, looking for preventive steps from the source of these problems, and looking for steps to reduce the impact of risks that have already occurred.

### Bow-Tie Diagram

There are 4 main consequences that will be discussed further, namely delays in the pre-design phase, delays in the planning phase, delays in the tender phase and delays in the construction phase. The source of the problem are the building was modified without changing the building permit, error in site measurement, change of local government resulting in difficulties in processing building permit documents, miscommunication between owners, consultants and contractors, lack of an owner team who understands the project, rush in planning projects, tight design schedule, human error, force majeure, lack of coordination, many changes from the owner and the complexity of the project. In this study, a bow-tie model was created to see the sequence of events that causes the delay, starting from finding all sources of problems in this project, looking for preventive steps from the source of these problems, and looking for steps to reduce the impact of risks that have already occurred. Below is the bow-tie diagram:

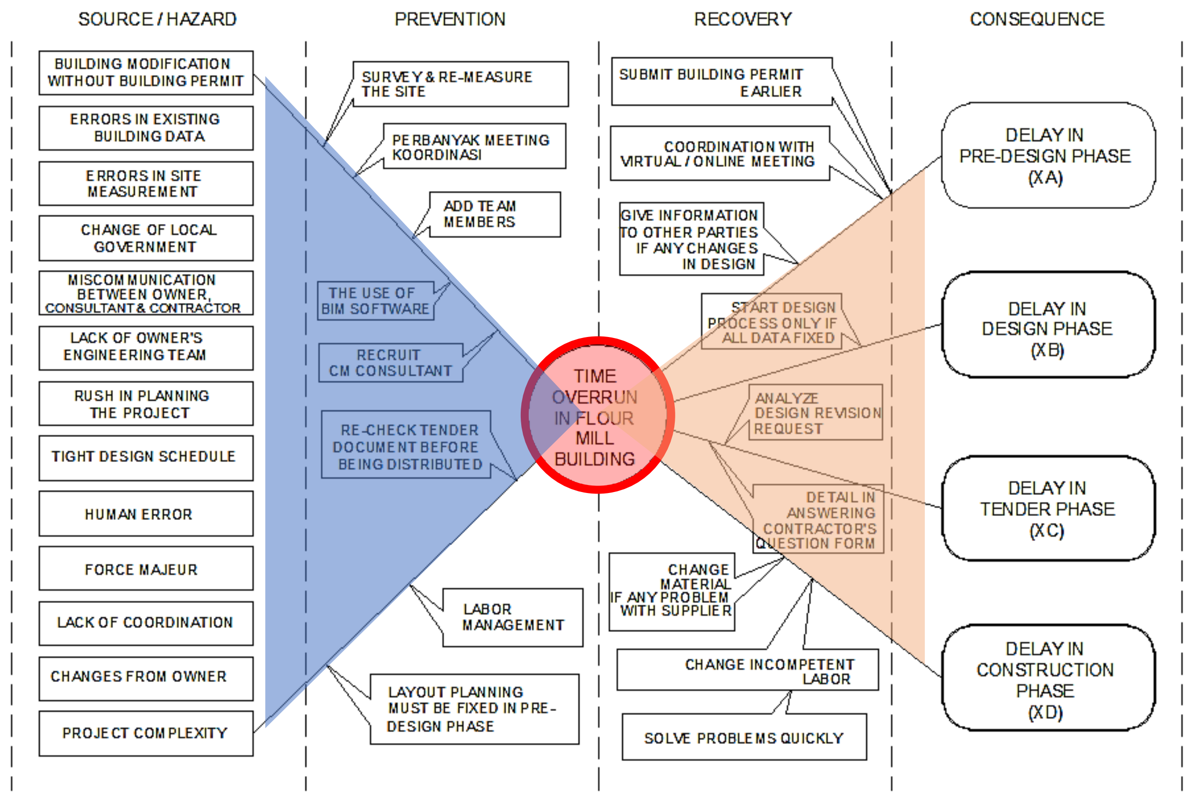


Figure 4. Bow-Tie diagram

Furthermore, the consequences arising from this bow-tie analysis will be assessed using the Probability Impact Matrix so that it can be seen how long the percentage of the project's setback time is from the resulting effects.

## Probability Impact Matrix

Risk assessment is carried out based on probability and its consequences / impacts, to provide an assessment of the probability of each risk and impact. According to Njogu (2015), construct a matrix to assign risk ratings (very low, Low, medium, high, and very high) or based on a combination of probability and impact. risk Those with high probability and high impact should be further analyzed, including Qualification of the project team and active risk management. Qualitative risk analysis tools and techniques include risk data quality assessment, risk probability and impact assessment, probability, and impact matrix (PIM), risk urgency assessment, and risk classification (El-Shehaby et al., 2014). According to PMBOK 6$^{th}$ Edition (2017), risk index is used in determining the choice of action from various risks that may occur:

$$\text{Risk Index} = \text{Probability} \times \text{Impact}$$

To measure the level of risk, a questionnaire was previously conducted on the same 45 respondents regarding the frequency and how much impact it had on project delays in each phase. The questionnaire was assigned a scale of 1-5 (very rare - very frequent) for an assessment of the frequency of events / probability and a scale of 1-5 (very low impact - very impactful) for an impact assessment. After obtaining the frequency and impact assessment, the questionnaire results are converted into the following index scale values:

Table 5. Probability Index

| Index | Value | Probability |
|---|---|---|
| Very High | 0,9 | Always happen |
| High | 0,7 | Often |
| Medium | 0,5 | Sometimes |
| Low | 0,3 | Rarely happen |
| Very low | 0,1 | Very rarely happen |

Table 6. Impact Index

| Index | Value | Impact |
|---|---|---|
| Very High | 0,8 | Very high loss |
| High | 0,4 | High loss |
| Medium | 0,2 | Medium loss |
| Low | 0,1 | Small loss |
| Very low | 0,05 | Very low loss |

After the probability value, impact, and level of importance of the risk are known, the next step is to enter the risk score indicator into the risk matrix. The risk matrix can be seen in the following table:

Table 7. Probability Impact Matrix Pre-Design and Design Phase

| | Risk Score | | | | |
|---|---|---|---|---|---|
| Probability | Threats | | | | |
| 0.9 | 0.05 | 0.09 | 0.18 | 0.36 | 0.72 |
| 0.7 | 0.04 | 0.07 | 0.14 | 0.28 | 0.56 |
| | | | | X1a1 | |
| | | | | X2a1 | |
| | | | | X2a2 | |
| | | | | X3a2 | |
| 0.5 | 0.03 | 0.05 | 0.10 | 0.20 | 0.40 |
| | | | X1a2 | X1a3 | |
| | | | X3a1 | | |
| | | | X4a1 | | |
| | | | X4a2 | | |
| 0.3 | 0.02 | 0.03 | 0.06 | 0.12 | 0.24 |
| 0.1 | 0.01 | 0.01 | 0.02 | 0.04 | 0.08 |
| | 0.05 | 0.10 | 0.20 | 0.40 | 0.80 |

| | Risk Score | | | | |
|---|---|---|---|---|---|
| Probability | Threats | | | | |
| 0.9 | 0.05 | 0.09 | 0.18 | 0.36 | 0.72 |
| | | | | X2b4 | X2b2 |
| 0.7 | 0.04 | 0.07 | 0.14 | 0.28 | 0.56 |
| | | | X1b2 | X1b4 | X1b3 |
| | | | | X2b3 | X2b1 |
| | | | | X4b1 | X3b2 |
| | | | | X6b1 | X5b1 |
| 0.5 | 0.03 | 0.05 | 0.10 | 0.20 | 0.40 |
| | | | X1b1 | X3b1 | |
| 0.3 | 0.02 | 0.03 | 0.06 | 0.12 | 0.24 |
| | | | | | X4b2 |
| 0.1 | 0.01 | 0.01 | 0.02 | 0.04 | 0.08 |
| | 0.05 | 0.10 | 0.20 | 0.40 | 0.80 |

In pre-design phase, there are 4 medium risk (X1a2, X3a1, X4a1 and X4a2) and 5 high risk categories (X1a1, X2a1, X2a2, X3a2 and X1a3). In design phase, there are 1 medium risk (X1b2), 6 high risk (X2b4, X1b4, X2b3, X4b1, X6b1 and X3b1), and 6 very high-risk category (X2b2, X1b3, X2b1, X3b2, X5b1 and X4b2).

Table 8. Probability Impact Matrix Tender and Construction phase

| | Risk Score | | | | |
|---|---|---|---|---|---|
| **Probability** | **Threats** | | | | |
| 0.9 | 0.05 | 0.09 | 0.18 | 0.36 | 0.72 |
| | | | | | |
| | | | | | |
| 0.7 | 0.04 | 0.07 | 0.14 | 0.28 | 0.56 |
| | | | | X2c1 | |
| | | | | X2c2 | |
| | | | | X3c1 | |
| 0.5 | 0.03 | 0.05 | 0.10 | 0.20 | 0.40 |
| | | | | | |
| | | | | | |
| 0.3 | 0.02 | 0.03 | 0.06 | 0.12 | 0.24 |
| | | | | | X1c1 |
| | | | | | X1c2 |
| | | | | | X3c2 |
| 0.1 | 0.01 | 0.01 | 0.02 | 0.04 | 0.08 |
| | | | | | |
| | | | | | |
| | 0.05 | 0.10 | 0.20 | 0.40 | 0.80 |

| | Risk Score | | | | |
|---|---|---|---|---|---|
| **Probability** | **Threats** | | | | |
| 0.9 | 0.05 | 0.09 | 0.18 | 0.36 | 0.72 |
| | | | | X2d2 | X5d2 |
| | | | | | |
| 0.7 | 0.04 | 0.07 | 0.14 | 0.28 | 0.56 |
| | | | X4d1 | X1d1 | X5d1 |
| | | | | X1d3 | |
| | | | | X2d1 | |
| | | | | X2d3 | |
| | | | | X3d2 | |
| | | | | X3d3 | |
| | | | | X4d3 | |
| | | | | X5d3 | |
| 0.5 | 0.03 | 0.05 | 0.10 | 0.20 | 0.40 |
| | | | X1d4 | X3d1 | |
| | | | | X4d2 | |
| 0.3 | 0.02 | 0.03 | 0.06 | 0.12 | 0.24 |
| | | | | | X1d2 |
| | | | | | |
| 0.1 | 0.01 | 0.01 | 0.02 | 0.04 | 0.08 |
| | | | | | |
| | | | | | |
| | 0.05 | 0.10 | 0.20 | 0.40 | 0.80 |

In tender phase, there are 3 high risk (X1c1, X1c2, X3c2) and 3 very high-risk category (X2c1, X2c2 and X3c1). In construction phase, there are 2 medium risk (X4d1 and X1d4), 11 high risk category (X2d2, X1d1, X1d3, X2d1, X2d3, X3d2, X3d3, X4d3, X5d3, X3d1 and X4d2), and 3 very high-risk category (X5d2, X5d1 and X1d2). The matrix described above can help us to determine the selected risk response. Risk response will be explained in the next chapter.

## Integration

The use of Bow-tie analysis and Probability impact matrix is to answer research objective number 2: analyze the impact of the risk factors causing the delay. The combination of these two methods is an implementation of mixed methodology research, which is a procedure for collecting, analyzing, and combining quantitative and qualitative methods in a study or a series of studies to understand research problems (Cresswell & Plano Clark, 2011). The basic assumption is the use of a combination of quantitative and qualitative methods.

The combination of this research method is carried out with BowtieXP software from CGE Risk. First step is to enter a probability value into the Consequences, so that the diagram on the right side of the Consequences will appear to see how much impact the consequences and becomes 1 diagram on each factor. There are 45 diagrams from this method, but only 1 diagram will be described here. The entry matrix model in the software is as shown below:

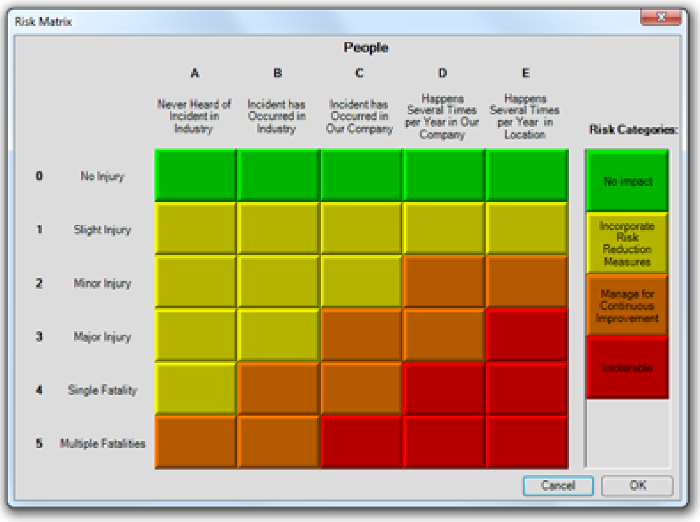


Figure 5. Risk Matrix

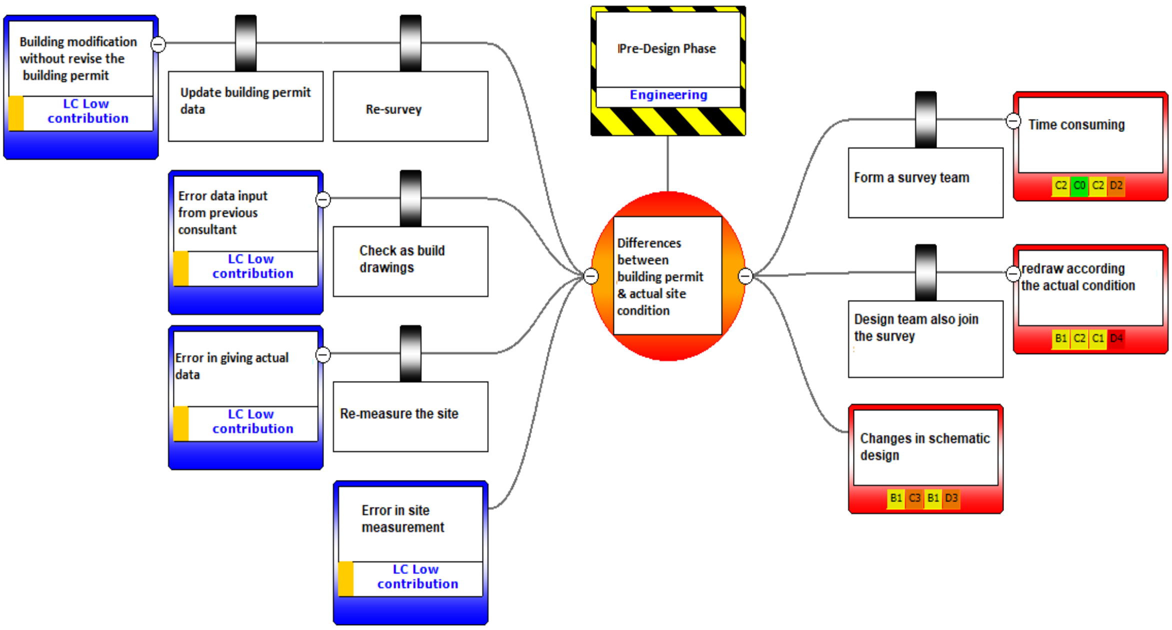


Figure 6. X1a1 diagram

X1a1 is the differences between building permit and site conditions. The cause of this difference is because the building has been modified without changing the building permit data, errors in building permit data entry from previous consultants, errors in providing data from the owner and errors in field measurements. The causes can be seen directly in each diagram so that it can be seen the sequence of events that caused the risk. The consequences arising from this variable are time consuming to re-survey the site, re-draw according to the latest conditions and changes in the schematic drawing of the design. The risk impact can be seen in consequences/right side of the diagram. From each diagram that has been made, a risk mitigation table can be formulated by including risk preventive and recovery action.

Table 9. Risk Mitigation Table

| Var | Sub Factor | Risk Impact | Preventive Barriers | Recovery Actions |
|---|---|---|---|---|
| X1a1 | Differences between building permit & actual site condition | o Time consuming | o Update building permit data | o Form a survey team |
| | | o Changes in schematic design | o Re-survey the location<br>o Check as-built drawings | |
| X1a2 | ... | ... | | |
| X1a3 | ... | ... | | |

## Risk Response

According to Flanagan and Norman (1993) and the COSO Integrated Framework (2004), There are 4 types of responses to risk, namely risk retention, risk reduction, risk transfer, and risk avoidance. If the risks arising from an activity have been identified, then actions are taken to reduce the risks that arise. This action is called Risk Mitigation.

To determine the risk response used, authors conducted a questionnaire to 5 experts who were also respondents in determining the variables in early section. The response assessment used scores of 1 (retention), 2 (reduced), 3 (transferred), 4 (avoided). The probability impact matrix described in the previous chapter is very helpful for experts to determine the selected risk response based on the level of risk. Responses can be seen in the following table:

Table 10. Risk Response

| PHASE | Var | Sub Var | Risk | Category | Response |
|---|---|---|---|---|---|
| | X1a | X1a1 | 0,28 | High | Reduction |
| | | X1a2 | 0,10 | Medium | Retention |
| | | X1a3 | 0,20 | High | Retention |
| | X2a | X2a1 | 0,28 | High | Transfer |
| | | X2a2 | 0,28 | High | Transfer |
| | X3a | X3a1 | 0,10 | Medium | Reduction |
| **PRE DESIGN (Xa)** | | X3a2 | 0,28 | High | Reduction |
| | X4a | X4a1 | 0,10 | Medium | Retention |
| | | X4a2 | 0,10 | Medium | Retention |
| | X1b | X1b1 | 0,10 | Medium | Retention |
| | | X1b2 | 0,14 | Medium | Reduction |
| | | X1b3 | 0,56 | Very High | Reduction |
| | | X1b4 | 0,28 | High | Reduction |
| | X2b | X2b1 | 0,56 | Very High | Transfer |
| **DESIGN (Xb)** | | X2b2 | 0,72 | Very High | Transfer |
| | | X2b3 | 0,28 | High | Retention |
| | | X2b4 | 0,36 | High | Transfer |

| | | | | | |
|---|---|---|---|---|---|
| | X3b | X3b1 | 0,20 | High | Retention |
| | | X3b2 | 0,56 | Very High | Avoidance |
| | X4b | X4b1 | 0,28 | High | Transfer |
| | | X4b2 | 0,24 | Very High | Retention |
| | X5b | X5b1 | 0,24 | Very High | Retention |
| | X6b | X6b1 | 0,28 | High | Avoidance |
| **TENDER (Xc)** | X1c | X1c1 | 0,28 | Very High | Transfer |
| | | X1c2 | 0,28 | Very High | Retention |
| | X2c | X2c1 | 0,24 | High | Retention |
| | | X2c2 | 0,28 | High | Retention |
| | X3c | X3c1 | 0,28 | High | Reduction |
| | | X3c2 | 0,24 | Very High | Transfer |
| **CONSTRUCTION (Xd)** | X1d | X1d1 | 0,28 | High | Reduction |
| | | X1d2 | 0,24 | Very High | Retention |
| | | X1d3 | 0,28 | High | Reduction |
| | | X1d4 | 0,10 | Medium | Reduction |
| | X2d | X2d1 | 0,28 | High | Transfer |
| | | X2d2 | 0,36 | High | Transfer |
| | | X2d3 | 0,28 | High | Transfer |
| | X3d | X3d1 | 0,20 | High | Retention |
| | | X3d2 | 0,28 | High | Reduction |
| | | X3d3 | 0,28 | High | Avoidance |
| | X4d | X4d1 | 0,14 | Medium | Reduction |
| | | X4d2 | 0,20 | High | Reduction |
| | | X4d3 | 0,28 | High | Reduction |
| | X5d | X5d1 | 0,56 | Very High | Retention |
| | | X5d2 | 0,72 | Very High | Reduction |
| | | X5d3 | 0,28 | High | Avoidance |

## CONCLUSION

It was found that 45 factors that caused the delay in all phases were divided into 7 factors from the pre-design phase, 14 factors from the design phase, 6 factors from the tender phase and 16 factors from the construction phase. In this study, bow-tie analysis and probability impact matrix are integrated so that the consequences obtained from the bow-tie diagram and the level of risk obtained from the probability impact matrix can be classified into 4 medium risks (X1a2, X3a1, X4a1 and X4a2) and 5 high level risks (X1a1, X2a1, X2a2, X3a2 and X1a3) in the pre-design phase. 1 medium risk (X1b2), 6 high risk (X2b4, X1b4, X2b3, X4b1, X6b1 and X3b1), and 6 very high risks (X2b2, X1b3, X2b1, X3b2, X5b1 and X4b2) in the design phase, 3 high risks (X1c1, X1c2 and X3c2) and 3 very high risks (X2c1, X2c2 and X3c1) in the tender phase, and 2 medium risks (X4d1), X1d4). 11 high risk (X2d2, X1d1, X1d3, X2d1, X2d3, X3d2, X3d3, X4d3, X5d3, X4d3, X5d3, X3d1 and X4d2) and 3 high risks (X5d2, X5d1 and X1d2) in construction phase.

It was found that the impact that occurred due to the delay from the index value of 0.1 (moderate) to 0.72 (very high). This means that no risk was found in the low category. From all the phases, the highest delay was in the construction phase with 14 risks that contains 3 very high categories and 11 high categories. The risks with the highest impact are X2b2 in the planning phase (Late of design approval from owner) and X5d2 (Design changes during construction). Recommendations for risk treatment with 4 options: risk retention, risk reduction, risk transfer or risk avoidance, depends on of the risk level of each factor.

From these findings, coordination between architectural consultant, structure consultant, mechanical electrical and plumbing consultant, machine consultant, owner, and other parties on design phase is the most important of factory building planning and construction. It is very important to start a project by first conducting an in-depth feasibility study. Without an in-depth feasibility study, project planning will be disorganized and will lead to many unexpected items. This will greatly affect the schedule and of course the cost of the project.

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