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Multiphase Project Risk Management on Food Factory Building Construction: Consultant Perspective

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Abstract: This article reports on 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 have a better understanding of the optimisation of the risk management and the risk mitigation, a multiphase risk management is proposed, which is divided into four phases, namely pre-design, design, tender and construction. 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 made the response for each risk easier to plan. The probability impact matrix is then used to identify the risk score and to evaluate the risk. This research began by giving questionnaires to 45 qualified respondents. It was found that 45 factors that caused the delay in all phases were divided into nine 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 the risk management process, there are various responses in this research depends on their final assessment based on the scores and the questionnaire results. Factory building construction is quite different from the other type of building construction because machine design also being an important part that affects the structural, architectural, mechanical and electrical aspects.

Keywords: Time overrun, Industrial buildings, Flour mills, Bow-tie analysis, Probability impact matrix, Risk management

INTRODUCTION

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

According to the previous study by Ullah et al. (2017), an appropriate in-depth study of time and cost issues in the construction industry is needed, which can identify the alternative solutions and measure the level of possible solutions to ensure the successful completion of construction projects. Based on the Project Management Body of Knowledge (PMBOK) 6th edition (2017), the project management process

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consists of five stages: initiating, planning, executing, monitoring and controlling and closing. However, this research will focus only in 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 mobilisation process, availability of materials and workers (Ministry of Public Works and Housing, 2020). During the pandemic or in any situation, food production must continue for human survival, thus time overrun on flour mills factory building construction and other food factory buildings needs to be reduced. To minimise the risk, a project manager should monitor the project carefully and find the way to minimise the delay so that the project runs on time and the costs can be well controlled. Delays will lead 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, 2013). Sudirman and Hardjomuljadi (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 the research is an eight-storey flour factory building that located in an industrial area in Indonesia. This building was chosen because of its high complexity and the risk management can be applied in all phases as all phases in this project were delayed. The objectives of this research are: (1) to assess the factors causing the delays in four phases of this project, (2) to analyse the impact of the risk factors causing the delay and (3) to recommend the 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 prioritising the allocation of resources and also helps them in making more reliable decisions, thus contributing to project success and achieving the objectives.

LITERATURE REVIEW

Zidane and Andersen (2018) investigated the top 10 universal delay factors in the construction projects. On their 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 or bad decision-making process, internal administrative procedures within the project organisation, shortage of resources (human resources, machinery and equipment), poor communication and coordination between all parties, slow quality inspection process for completed work and design changes during construction/change orders. They also conducted an in-depth systematic literature study on the key universal delay factors based on their research and other 103 existing studies covering over 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/order changes during construction, late payment to the contractor, poor planning and scheduling, poor site management and supervision, incomplete or improper design, inadequate contractor experience/building methods and approaches, contractor's financial difficulties, sponsor/owner/client's economy difficulties, shortage of resources (human resources, machinery and equipment) and low labour productivity and skills shortages.

There are two types of delay, namely 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 suppliers, and not due to the fault of the owner. For example, difficulties in financing the projects by contractors, poor site management and supervision by contractors, poor communication and coordination between contractors and other parties and inadequate planning and scheduling (Hamzah et al., 2011). Meanwhile, forgivable delays are 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 in every construction. According to Departemen Pekerjaan Umum (2007), there are four steps in risk management, as shown in Figure 1.

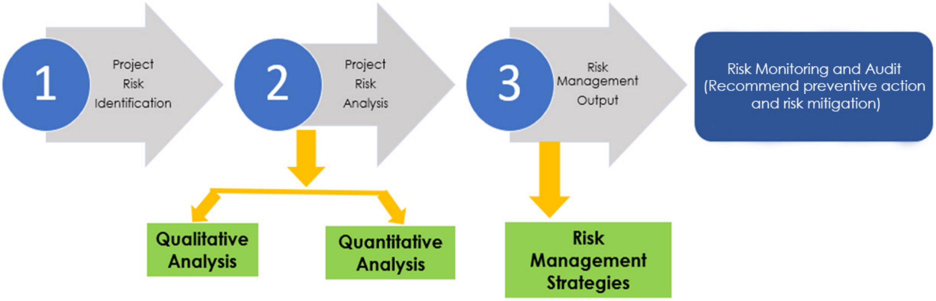


Figure 1. Risk management steps

RESEARCH METHOD

This research began with a research gap to find the methods and the objects of the research. After that, the research title is obtained for further research objectives, problem formulations and research limitations. Then 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 analysing the factors. Then the secondary data collection is in the form of literature study.

After that, the variables that have been collected are analysed for their causes and effects with a bow-tie analysis while the risks are rated by index scale rating of the probabilities and impacts with a probability impact matrix (PIM). The final step of the research is to formulate the solutions and to prevent risks in the phase with the highest impact. Figure 2 shows the research flowchart diagram.

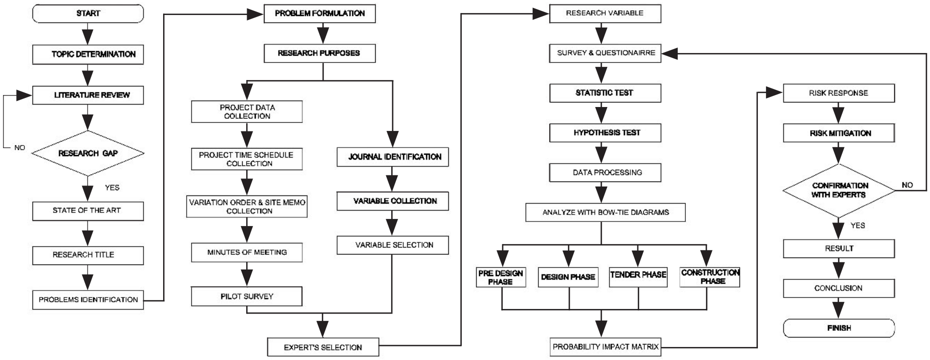


Figure 2. Research flowchart diagram

Bow-Tie Analysis

Badreddine et al. (2014) stated that 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. Therefore, 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 the bow-tie analysis is briefly described in Figure 3.

The bow-tie analysis method is a quantitative analysis used in this research. This method is the initial stage in variable data analysis. The initial stage of making a bow-tie analysis is to determine the source or hazard. The next stage is to determine the initiating event, which is taken from the variables collected in the data, then look for the causes of the incident happened, find the solutions for the problem and analyses the consequences of the event.

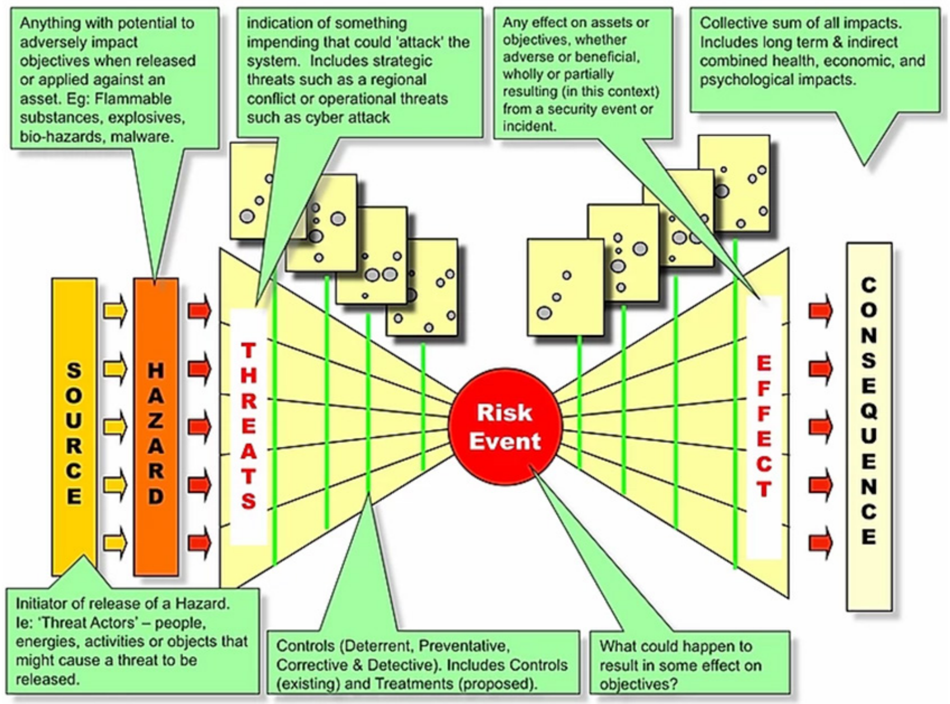


Figure 3. Bow-tie analysis diagram

SURVEY AND QUESTIONNAIRE

From the literature review, a questionnaire was prepared and a pilot survey was conducted to check the applicability of the questionnaire in this project. Fifty-eight questionnaires were presented to experts and other parties that participated in the flour factory design and 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 of the flour mill building work. In the survey conducted, only 45 questionnaires returned were viable for this study while the other 13 results cannot be used as research data due to its incompleteness making it not eligible. The dissemination of the survey is carried out evenly to all parties who were responsible in this project, with different duration of work experiences. As many as 11% of the respondents have less than 6 years of experience, 31% with 6 years to 10 years of experience, 31% with 11 years to 17 years of experience and 27% with over 20 years of experience.

The main variable in this research is the project phases which consists of the pre-design phase (Xa), the 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 work experience in the construction industry. There are 45 major risks were identified in this research. About 20 risks were adopted from Gündüz, Nielsen and Özdemir (2013) while the others were identified from the input of experts in the pilot survey. Finally, each questionnaire is incorporated into a five-point Likert-type scale. Data collection in this research involved a construction which progress has reached over 90% and close to the completion of the project. The construction time started from August 2019 and underwent several time schedule revisions due to the 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. Tables 1 to 4 show the factors that caused the delays in each phase.

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 and tender documents
		14	X2b	Owner	X2b1	Late progress payment from owner
		15			X2b2	Late of design approval from owner
		16			X2b3	Changes from owner

(*Continued on next page*)

Table 2. (*Continued*)

Var	Phase	No.	Var.	Main Factor	Var.	Sub-factor
		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 or 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

(*Continued on next page*)

Table 4. (*Continued*)

Var.	Phase	No.	Var.	Main Factor	Var.	Sub-factor
		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 mechanical and electrical (ME) drawings

RESULTS 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 factors were valid. The results of the reliability test on all variables tested in this research 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 in 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 research have a significant effect on the dependent variable (Y). There are four hypotheses 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. < α (0.05). The *p*-value for H1 is 0.000, for H2 is 0.001, for H3 is 0.018 and for H4 is 0.001. The four hypotheses are < α (0.05), therefore all H1, H2, H3 and H4 are accepted.

Bow-Tie Diagram

There are four main consequences that will be discussed further, namely delays in the pre-design phase, delays in the design phase, delays in the tender phase and delays in the construction phase. The sources of the problem are such as 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 the projects, tight design schedule, human error, force majeure, lack of coordination, many changes from the owner and the complexity of the project. In this research, 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, as shown in Figure 4.

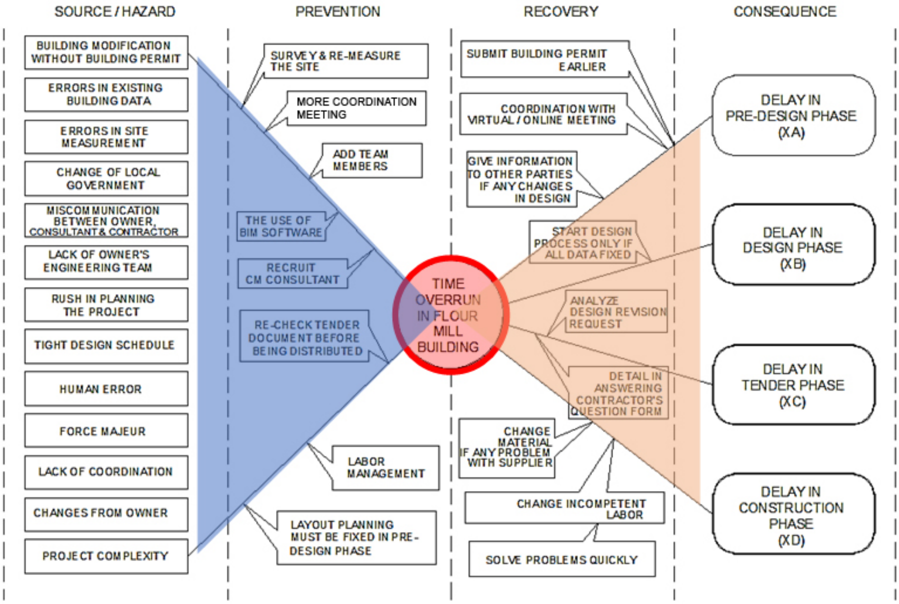


Figure 4. Bow-tie diagram

Furthermore, the consequences arising from this bow-tie analysis will be assessed using the PIM so that it can show 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 the probability and its consequences or impacts to provide an assessment of the probability of each risk and impact. According to Njogu (2015), a matrix is constructed 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 analysed, 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, PIM, risk urgency assessment and risk classification (El-Shehaby, Nosair and El-Moniem, 2014). According to PMI (2017), the 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 to a scale of 1 to 5 ("Very rare" to "Very frequent") for an assessment of the frequency of events or probability and a scale of 1 to 5 ("Very low impact" to "Very impactful") for an impact assessment. After obtaining the frequency and impact assessment, the questionnaire results are converted into the index scale values, as shown in Tables 5 and 6.

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

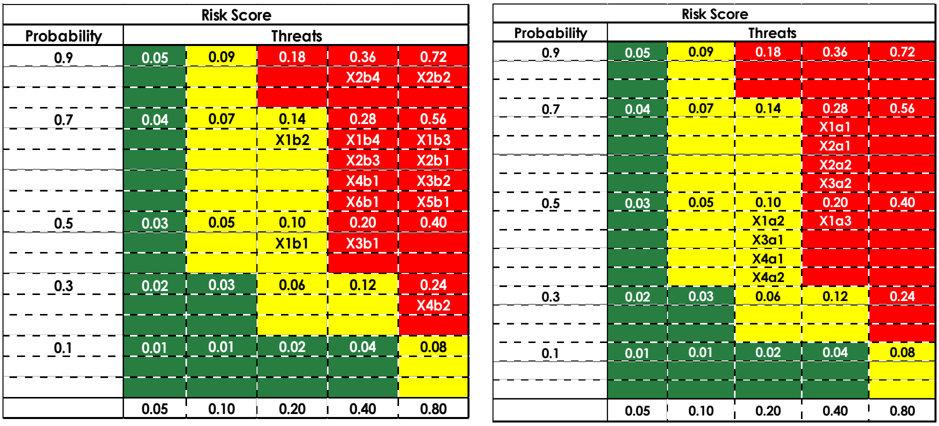
Table 6. Impact index

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 of each phase is shown in Tables 7 and 8.

In the pre-design phase, there are four medium-risk category (X1a2, X3a1, X4a1 and X4a2) and five high-risk category (X1a1, X2a1, X2a2, X3a2 and X1a3). In the design phase, there are two medium-risk category (X1b2), six high-risk category (X2b4, X1b4, X2b3, X4b1, X6b1 and X3b1) and six very high-risk category (X2b2, X1b3, X2b1, X3b2, X5b1 and X4b2).

Table 7. PIM of the pre-design and design phases

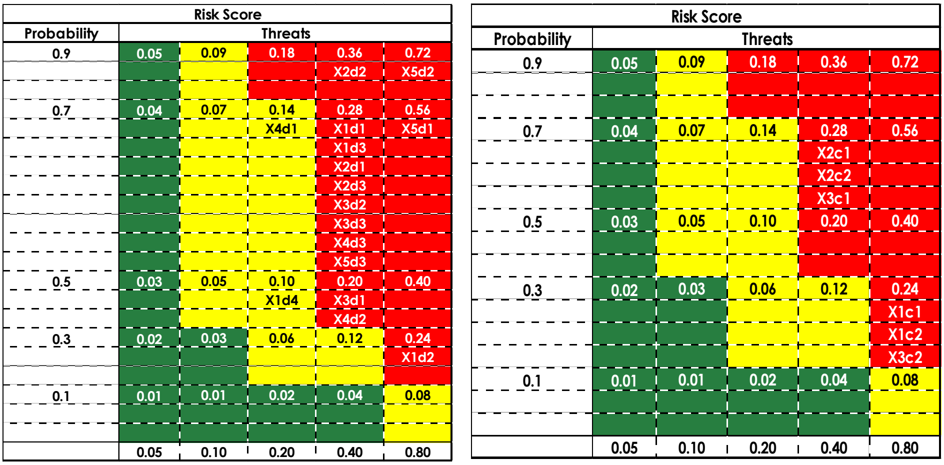


Risk Score					
Probability	**Threats**				
0.9	0.05	0.09	0.18	0.36 X2b4	0.72 X2b2
0.7	0.04	0.07	0.14 X1b2	0.28 X1b4 X2b3 X4b1 X6b1	0.56 X1b3 X2b1 X3b2 X5b1
0.5	0.03	0.05	0.10 X1b1	0.20 X3b1	0.40
0.3	0.02	0.03	0.06	0.12	0.24 X4b2
0.1	0.01	0.01	0.02	0.04	0.08
	0.05	0.10	0.20	0.40	0.80

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 X1a1 X2a1 X2a2 X3a2	0.56
0.5	0.03	0.05	0.10 X1a2 X3a1 X4a1 X4a2	0.20 X1a3	0.40
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

Table 8 shows that in the tender phase, there are 3 high-risk category (X1c1, X1c2 and X3c2) and 3 very high-risk category (X2c1, X2c2 and X3c1). In the construction phase, there are 2 medium-risk category (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 can help us to determine the selected risk response. Risk response will be explained in the next section.

Table 8. PIM of the tender and construction phases



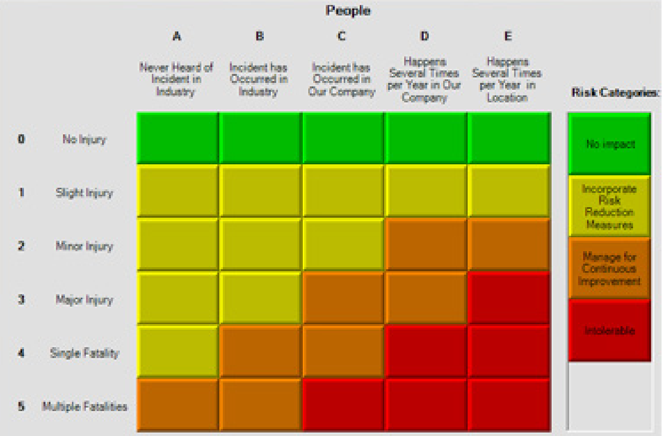
Risk Score					
Probability	Threats				
0.9	0.05	0.09	0.18	0.36	0.72
				X2d2	X5d2
0.7	0.04	0.07	0.14	0.28	0.56
			X4d1	X1d1	X5d1
				X1d3	
				X2d1	
				X2d3	
				X3d2	
				X3d3	
				X4d3	
				X5d3	
0.5	0.03	0.05	0.10	0.20	0.40
			X1d4	X3d1	
				X4d2	
0.3	0.02	0.03	0.06	0.12	0.24
					X1d2
0.1	0.01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

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

Integration

The use of bow-tie analysis and PIM is to answer the second objective of the research, which is to analyse 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, analysing and combining quantitative and qualitative methods in a study or a series of studies to understand research problems (Cresswell et al., 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. The first step is to enter the probability value into the "Consequences", so there will appear another new diagram about how much impact the consequences and becomes one diagram on each factor. The entry matrix model in the software is shown in Figure 5. There are 45 diagrams constructed from this method but only one diagram will be shown and discussed here, which is the first factor, X1a1, as shown in Figure 6.



People

		A Never Heard of Incident in Industry	B Incident has Occurred in Industry	C Incident has Occurred in Our Company	D Happens Several Times per Year in Our Company	E Happens Several Times per Year in Location
0	No Injury	🟩	🟩	🟩	🟩	🟩
1	Slight Injury	🟨	🟨	🟨	🟨	🟨
2	Minor Injury	🟨	🟨	🟨	🟧	🟧
3	Major Injury	🟨	🟨	🟧	🟧	🟥
4	Single Fatality	🟨	🟧	🟧	🟥	🟥
5	Multiple Fatalities	🟧	🟧	🟥	🟥	🟥

Risk Categories:

- 🟩 No impact
- 🟨 Incorporate Risk Reduction Measures
- 🟧 Manage for Continuous Improvement
- 🟥 Intolerable

Figure 5. Risk matrix

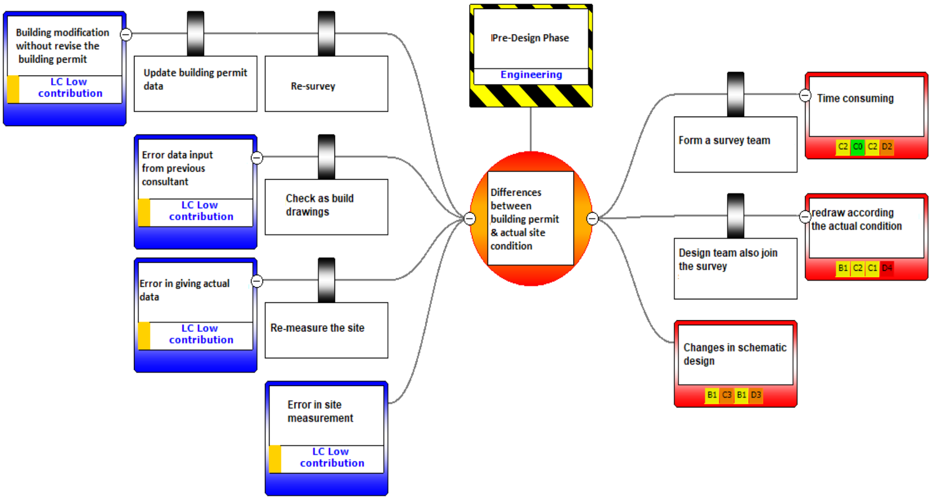


Figure 6. The X1a1 diagram

X1a1 happened in the pre-design phase as there are differences between building permit and the site conditions. The causes of these differences are because the building has been modified without changing the building permit data, errors in building permit data entry from the previous consultants, errors in providing data from the owner and errors in the field measurements. The causes and the sequence of events that caused the risk can be seen directly in each diagram. 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 or on the right side of the diagram. From each diagram that has been made, a risk mitigation table can be formulated by including the risk preventive and the recovery action, as shown in Table 9.

Table 9. Risk mitigation

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

Risk Response

According to Flanagan and Norman (1993) and the COSO integrated framework (2004), there are four 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. This action is called risk mitigation.

To determine the risk response used, authors conducted a questionnaire to five experts who were also respondents in determining the variables in the early section. The response assessment used scores of 1 (Retention), 2 (Reduction), 3 (Transfer) and 4 (Avoidance). The PIM described in the previous chapter is very helpful for experts to determine the selected risk response based on the level of risk. The responses are shown in Table 10.

Table 10. Risk response

Phase	Var.	Sub Var.	Risk	Category	Response
Pre-design (Xa)	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
		X3a2	0.28	High	Reduction

(*Continued on next page*)

Table 10. (*Continued*)

Phase	**Var.**	**Sub Var.**	**Risk**	**Category**	**Response**
	X4a	X4a1	0.10	Medium	Retention
		X4a2	0.10	Medium	Retention
Design (Xb)	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
		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	0.56	Very High	Retention
	X6b	X6b1	0.28	High	Avoidance
Tender (Xc)	X1c	X1c1	0.24	Very High	Transfer
		X1c2	0.24	Very High	Retention
	X2c	X2c1	0.28	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

(*Continued on next page*)

Table 10. (*Continued*)

Phase	Var.	Sub Var.	Risk	Category	Response
	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 project delay in all phases of the factory building were divided into seven 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 research, bow-tie analysis and PIM are integrated so that the consequences obtained from the bow-tie diagram and the level of risk obtained from the PIM can be classified into as such: 4 medium-risk and 5 high-risk categories in the pre-design phase, 1 medium-risk, 6 high-risk and 6 very high-risk categories in the design phase, 3 high-risk and 3 very high-risk categories in the tender phase and 2 medium-risk, 11 high-risk and 3 very high-risk categories in the construction phase.

It was found that the impact that occurred due to the delay range from the index value of 0.1 (moderate) to 0.72 (very high). This means that there is no risk found in the low category. From all the phases, the highest delay was in the construction phase with 14 risks, which are 3 very high-risk and 11 high-risk categories. The risks with the highest impact are X2b2 in the planning phase (late of design approval from owner) and X5d2 in the construction phase (design changes during construction). Recommendations for the risk treatment come with four options, namely risk retention, risk reduction, risk transfer or risk avoidance, depends on 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 in the design phase is the most important in the factory building planning and construction. It is very important to start a project by first conducting an in-depth feasibility study. Without it, project planning will be disorganised and lead to many unexpected mishaps. This will greatly affect the schedule and of course the cost of the project.

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