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OCCURRENCE AND IMPACT ANALYSIS FOR TIME-RELATED RISKS IN MALAYSIA PUBLIC INFRASTRUCTURE PROJECTS

TING SIM NEE*, JARIT BEATRICE AND LEE YEE YONG

Department of Civil Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia.

**Corresponding author: snting@unimas.my*
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Abstract: The public works sector in Malaysia has generally executed construction projects that are highly complex, requiring multiple components and involving a large scale of resources and management. Many construction works are carried out in rural settings with challenges and constraints in terms of site access, transportation and material availability. Hence, the problem of timely delivery of projects persists. It is critical to identify and manage schedule-related risks rigorously to ensure a successful and timely project delivery which is a precursor for the nation's sustainable development. This study, part of efforts to set up a Malaysia-based risk registry, involves the identification of key risks related to scheduling in Malaysia's public works infrastructure projects and the analysis of their occurrences and impacts. A total of 111 of 123 projects from the Sarawak state's Public Works Department are studied via the case study method. The selection of projects was based on whether a project's completion date was extended due to the occurrences of delay events. The number of occurrences is calculated based on the number of times a delay event occurred in the 111 projects. The impact analysis is carried out based on the total delay over the overall project delay for a project. The findings show that the most frequently occurring risk in the 111 projects is "exceptionally inclement weather", "whereas risks related to land blockage", "obstructions by others and approval from other authorities" are risks that caused high severity in terms of delay in schedule. Information obtained from this research is part of key effort for risk data and knowledge retention and dissemination which can be used for further risk analysis for future construction projects.

Keywords: Risks, occurrences, impacts, infrastructure, sustainable construction.

Introduction

According to the statement published by the Department of Public Works Malaysia in 2016, its major functions and roles involve planning, designing, managing and supervising infrastructure projects, such as roads, government buildings, airports and jetties, as well as implementing infrastructure development and maintenance in the country. All infrastructure projects are designed and constructed with the vision of sustainable nation development while aiming to fulfil the public's needs.

However, infrastructure projects are generally large and uncertain, have higher complexity and are larger in scale (Eldash & Monem, 2004; Khodeira & Nabawy, 2019). Staats (2014) further suggested that infrastructure projects are usually multi-disciplinary as they are outsourced to multiple contractors and subcontractors for the completion of the multiple components within the project. These projects are, therefore, subjected to more risks and uncertainties related to the economic, social and environmental conditions with impacts to schedules, cost and quality of the projects (Eldash & Monem, 2004).

In addition, as evidenced by the Department of Statistics Malaysia (2021), 46% of the population still live in the rural areas of Sarawak and Sabah and, hence, as a developing nation, carrying out infrastructure projects in rural settings in the country is needed. Challenges associated with rural projects include the availability of construction materials, access to sites and logistic constraints (Tran *et al.,* 2014). As further mentioned by Ramli *et al.* (2017), besides the usual concerns related to construction techniques, suitable designs, contractual liabilities, weather and soil conditions, political-economic environment, rural settings can also pose additional concerns to the execution of infrastructure projects, especially with respect to timely project delivery.

In all construction projects, time is defined as a measure of periods of activities along with the intervals between them (Christopoulos, 2014). The activity duration is the amount of time assigned for the completion of a particular activity. Once the duration of each activity is determined, the entire project's duration can be calculated to determine its start and finish time. It is important to plan for time because it determines when the project is supposed to start, the duration of the project and its.

In the context of project time management, time planning is the major planning item as it directs into the execution of the project (Chin & Hamid, 2015). Without that, the project will only bluntly commence without proper time management, which will later have a negative effect on the project (Ismail *et al.,* 2013). It is, hence, imperative to accurately determine the time at the very beginning of the project to minimise the possibilities of adverse effects, like delays.

Time is unique in engineering projects due to deadlines (Anuar & Ng, 2011). Timely project delivery is a critical success determinant for a construction project, aside from its cost and performance (Hendradewa, 2019). Time management is crucial especially in project management (Memon *et al.,* 2014). Effective time management is necessary for the project to be completed on time (Memon *et al.,* 2014).

However, the scheduling "ideal" is seldom easy to achieve. Problems with delays in construction are a global phenomenon (Sambasivan & Yau, 2007). Malaysia, with its construction industry contributing to 3.3% of its GDP and employing 600,000 workers (Malbex, 2005), faces the same issues as its global counterparts, with time overruns and the missing of planned time targets. Delays in timely delivery of all types of projects including infrastructure projects are common. Delays or more seriously, undelivered projects which is the inability to complete the project within the stipulated time frame and beyond are some of the most prevalent problems in the Malaysian construction sector (Sambasivan & Yau, 2007).

Based on the research carried out by the authors in part, even though there are various time scheduling methods commonly used in Malaysia, most schedules are developed with their activity time set in a deterministic manner (Luu *et al.,* 2009). In addition, a schedule by itself often contains significant uncertainties (Nasir *et al.,* 2003). Schedulers generally fail to address the links between "risks/uncertainties" with the duration of project activities.

The above explains the intrinsic relationship between determining the uncertainties/risks of any construction project, more so for infrastructure projects, to improve project time determination. Ultimately, achieving the time requirements of a construction project greatly depends on good and accurate time planning, which is determining the duration and activity takes and rigorous and disciplined time control, which is the management of the said time duration.

Many construction projects fail to achieve completion under the stipulated time due to ineffective planning and scheduling (Assaf & Al-Hejji, 2006; Molholland & Christian, 1999). Ineffective planning and scheduling have been recognised as a major cause of construction project delays. As mentioned by Abdul Rahman *et al.* (2015), reasonable and good accurate time determination during planning will enhance construction project scheduling and the management of such schedules. Reasonable and accurate time determination first and foremost requires the anticipation and understanding of the risks and uncertainties inherent in the projects.

The Principles of Project Risk Management

It is important to note that even though risk inherence is not unique to the construction industry alone, it is, however, more prominent and serious for the construction industry. Due to the unique features arising from the complexity of projects and the number of stakeholders with different interests involved, time taken to complete projects can become an uncertainty (Dosumu, 2018). Uncertainties and risks are undeniable in all construction projects which highlight the important role of project risk management to ensure a project's success.

As outlined by the Project Management of Institute (PMI) (2017a), project risk management is built on the framework of processes that include risk identification, qualitative/quantitative risk analysis, risk response planning, risk response implementing and risk monitoring and controlling. According to the Project Management Body of Knowledge outlined by PMI (2017a), project risk management includes the processes of scheduling, defining, evaluating, preparing for response and managing the risks in a project.

As mentioned by PMI (2016), risk management is about maximising the probability and consequences of positive events and minimising the probability and consequences of adverse events to project objectives while the Association of Project Management (2012) stated that risk management includes the decision-making process to accept known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence. Rahmana and Adnana (2020) summarised that risk management serves to carry out risk identification, evaluation and control of the exposure of particular risks that hinder a project's success. Risk management serves two independent variables: Risk identification and risk analysis (Rahmana & Adnana, 2020).

The above literatures on project risk management highlighted the core of project risk management frameworks with the following elements:

- risk identification,
- risk analysis that includes the evaluation of the frequency of risk occurrences and the impacts of such occurrences and
- understanding the risk profile and then planning the risk response, implementation and control.

Bañuls *et al.* (2017) conducted a study that stated that by giving managers a structured process to predict the impact of the occurrence of multiple risks that can affect project performance, it will help them better understand how the different risks influence each measure of a project's performance. Similarly, Husin *et al.* (2018), in their research that assessed the risk importance within the time aspects of construction implementation, stated that risks needed to be recognised by analysing the relationship between frequency of risk occurrences and the impacts that may arise on the construction time completion. Similar studies were also carried out by Santos and Jungles (2016) and Toth and Sebestyen (2015) involving the analysis of time risks using quantitative analysis methods. The superposition of frequency and impact will indicate the risk importance of various risk factors.

According to Ramli *et al.* (2017), 79.5% and 66.7% of 359 public and private projects, respectively, were not completed within the time specified in the contracts in Malaysia. As mentioned by Abdul Rahman *et al.* (2015), the implementation of risk management processes in the Malaysian construction industry is still at a low level as most construction firms in Malaysia do not apply formal risk management in their projects. This is mainly due to the fact that most construction employees involved in risk management are not fully aware of the available risk management techniques that can be applied in construction projects. In view of this lack of risk management due to a lack of familiarity, the aim of this study is to collect risk data related to project scheduling (the risks that occurred, their occurrences and impacts on projects) focusing on government infrastructure projects, including those carried out in rural settings. This research is a significant risk study in Malaysia as it looks into collecting and compiling useful risk data that can be retained for future risk management processes in construction projects in the country.

Based on the project risk management principles of risk identification and risk analysis of risk occurrences and impacts, this study, first and foremost, collects and compiles project schedule-related risks and uncertainties that occur in Malaysian infrastructure projects, including those conducted in the rural settings. Then the occurrences and impacts of the risks related to time and schedules detected in these projects are analysed. By understanding the time-related risk profiles of infrastructure projects, the data, if properly retained, can be used for future project schedule and risk management. Another more important reason is that the study serves as a precursor to create a Malaysian risk registry that compiles and retains all different categories of project risks and uncertainties previously anticipated/occurred. Project proponents can access this registry and refer to the various types of risks and uncertainties that may be relevant to their projects to create their own projects' risk profiles that can be incorporated into their project schedule, cost and work performance management. Ultimately, it is hopeful that with sufficient risk data and knowledge retained and disseminated, it can prompt project proponents to implement risk management process in construction projects.

This paper presents risk data identified from PWD with its infrastructure project-centric works. The data collected is related to project time management, schedule and delays and their occurrences and impacts related to scheduling and time determination. The objectives of the proposed study are as follows:

(a) To collect scheduling risks data for public works-related construction projects
(b) To analyse the occurrences and impact of such risks on project scheduling
(c) To retain the data collected for future risk registry, ready to be disseminated to project proponents and risk analysts for future risk data.

It is noted that the design and creation of the risk registry is not within the scope of this paper. The results of this study can contribute to any Malaysia-based registry, if available. A risk registry is the way forward for risk management processes in Malaysia and hence further development and research of risk registry models, methods and techniques are required.

Research Methods

Sarawak is the largest state in Malaysia and is located just north of the equator. It stretches about 800 km along the northwest coast of the island of Borneo. Due to the vastness of its land that is saturated with rainforests, swamps and mountainous topography, planning, designing, executing and maintaining the state's infrastructure projects has always been mired with uncertainties and complexities.

The case study method involving multiple cases is selected as the research strategy to investigate the risks associated with projects in their real-life contexts and this allows cases to be individually studied in depth, looking across cases for similarities and differences (Santos & Jungles, 2016). There are a total of 123 completed projects in the Sarawak's Public Works Department document archive from 2014 to 2019. A total of 111 out of 123 projects were identified to be suitable for the case studies based on the selection criteria of (a) when the overall contract duration was extended, which signifies the impact of the delay event/said risk and (b) when delay events which signifies the risks have occurred. All data were collected from the project files and documentations, including all project correspondences, on-site instructions and meeting minutes.

Each project is studied using a checklist containing various construction risks obtained from extensive literature reviews on schedule-related risks. Three checklists were prepared according to the scope of the projects, i.e., structure projects, civil work projects and other civil engineering projects. Among the information that will be gathered from the documents are the type of projects, their year, predicted start date and final date, actual start date and final date, total days of extension of time (EoT), categories of risks, reasons given for the delay and additional information related to the particular delay events. The causes of delay in the checklist highlighted in the project documents will be checked off.

The data collected was tabulated in Microsoft Excel to facilitate the evaluation of the data. Figure 1 shows the data tabulation.

Based on the risk management procedure as described in Principles of Project Risk Management by PMI (2017a), Ramli *et al.* (2017) and Rahmana and Adnana (2020), risk identification is carried out first. The risk that occurs in the three types of projects will be identified and grouped under the respective risk category such as weather risk, site risk, design risk and so on.

Fikkiwubg risk identification, risk analysis as described by Rahmana and Adnana (2020) and Abdul Rahman *et al.* (2015) is carried out. Firstly, the frequency of the risk occurring in the project is recorded and counted for all the 111 projects to examine the probability of occurrences. For instance, under weather risk, the number of times an event involving exceptionally inclement weather occurs in the 111 projects will be recorded. Next, the impacts of the said risk also referred to as the consequences of the risk are analysed. The formula designed to compute the risk impact analysis is based on the total number of days of delays as shown:

Total no. of days of delay = final contract duration – original contract duration **(1)**

Overall delay in % = (Total no. of days of delay/original contract duration) x 100% **(2)**

The percentage recorded is the impact of the delay on the overall schedule. Duijm (2015) in his study on the recommendations on the use and design of risk matrices, the impact category is designed and described as negligible, minor, marginal, moderate or major with the following ranges:

- Negligible impact: 0% - 19%
- Minor impact: 19.1% - 39%
- Marginal impact: 39.1% - 54%
- Moderate impact: 54.1% - 75%
- Major impact: 75.1% and above

The ranges are designed using the Likert method, which is commonly used as a standard psychometric scale to measure responses (Li, 2013). The following section presents the results of the collected data and the related analysis.

Results and Discussion

Type of Projects

Data were collected from 111 projects that have delay occurrences and their contract period extended. The projects are categorised as structure projects, civil work projects and others. The category with the highest number of projects was civil work projects, comprising 52 of the 111 projects or 47%. This is followed by structure projects at 38 entries or 34%. The rest consisted of projects such as the construction of sub-stations, airports, electrical/power-

Project No.	Type of Project	Location of Project	Original Contract Duration (months)	Original Contract Duration (days)	Final Contract Duration (months)	Final Contract Duration (days)	Total No. of Delay (days)	No. of EOT (days)	Overall delay (%)	Type of Risk	Reason for Delay	Consequence	Impact
1	Civil works	Kanowit	30 m 4 d	916	30 m 15 d	927	11	6	1.2	Weathe r	Exceptionally inclement weather	55%	Negligible Impact

Figure 1: The instrument designed for risk data collection

related systems, jetties, RC pontoons, riverine terminals and playgrounds which made up 21 the total 111 projects (19%). Figure 2 below shows the distribution of projects in the different categories.

Year of Project

The projects studied in this paper cover the span of six years, from 2014 to 2019. The total number of projects obtained from 2014, 2015, 2016, 2017, 2018 and 2019 were 11, 21, 34, 25, 18 and 2, respectively. The year with the highest number of granted EoT was 2016 which involves 34 projects or 31%. This is followed by the year 2017 with 25 projects granted EoT (22%) and the year 2015 with 21 projects granted EoT (19%). Then, in years 2018 and 2014, 18 and 11 projects were granted EoT which is equivalent to 16% and 10%, respectively. Lastly, projects in 2019 had the lowest number of projects granted EoT at only two, which is less than 2% of the total amount. The numbers show that all 111 projects had some form of delay to the schedule. Figure 3 shows the distribution of the number of projects with EoT with respect to the year of project execution.

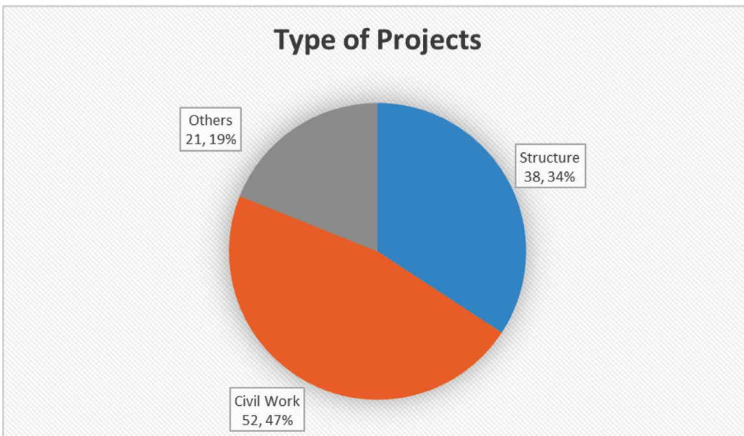

Figure 2: Types of projects

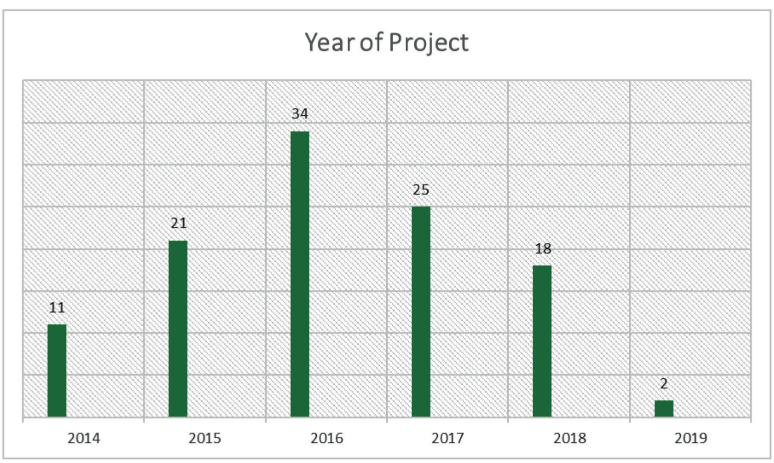

Figure 3: The year the project commences construction

Risk Identification in Infrastructure Construction Projects

As observed in the 111 projects, several categories of risks were detected, which can be grouped under the weather risk, the site risk, the material risk, the design risk, the client risk, the consultant risk and the contractor risk. Risks that could not be grouped falls under the category of other risks. Table 1 shows the categories of risk and the details of risks as identified from the collected data.

Table 1: Risks identified in the 111 projects

Category of Risk	Risks
Weather risk	Exceptionally inclement weather
	Flooding event
	King tide flood
	Erosion
	Extremely low water level
	Occurrence of haze
	High river water level
Site risk	Delay in site possession
	Unforeseen reasons on site
	Site/land blockage from existing facilities
	Site condition
	Suspension of work due to disputes
	Issues with land acquisition
	Delay in site clearing
Material risk	Late delivery of materials on site
	Engineer's instruction to change project specification
	Failure to deliver materials on site due to material change
	Material shortage
Design risk	Realignment of overall building layout
	Design changes
Client risk	Request to change design
	Late decision-making
	Late to obtain approval of licenses
	Changes at the start work chainage
	Change of schedule
Consultant risk	Changes in design
	Late in issuing drawing
	Delay in decision-making

Contractor risk	Incompetent contractor
	Contractor's selection and contractual matters
	Relocation of existing facilities
	Suspension of work due to dispute
	Additional works
	Rework and repair
	Lack of coordination
Other risks	Delay in obtaining other authorities' licenses
	Authorities' final inspection and approval
	Non-completion of certain parts of the work
	Delay on testing and commissioning work
	Superintending officer's ad-hoc instructions
	Unforeseen reasons from external project environment
	Obstruction of third party
	Stoppage of work due to external factors
	Late start of work

Under weather risk, there are several reasons that causes delay to the projects, namely exceptionally inclement weather, flooding events, king tide floods, erosions, extremely low water levels, haze and high river water level. Exceptionally inclement weather occurs when the rainfall quantity is above 10 mm while low water level is defined as levels less than 9 m. Both cases will render projects unworkable, which involves stoppage to the project on site due to interruption to movements within the site and the mobilisation of machinery, material and labour in and out of the site. Projects affected by weather-related risks concurred with Ramli *et al.* (2017) and Tran *et al.* (2014).

For site risk, among the reasons for delays observed are delay in site possession, unforeseen reasons on site, obstruction by a third party, site/land blockage from existing facilities, site condition, suspension of work, land acquisition and delay in site clearing. Meanwhile, the reasons that contributed to materials risk are late delivery of materials to the site, engineer's instructions to change material specifications, failure to deliver materials due to change in material and material availability which is the shortage of certain materials. Similar results were seen in the studies by Sambasivan and Yau (2007) and Rivera *et al.* (2020).

Next, there are only two main risks under design risk from the data collected, namely the realignment of the overall building layout and design changes. Both are unique to projects. Risks that fall under the client risk category were also found during data collection. Even though the initial idea stems from the client and their representatives should provide a clear instruction to the project team, there are several incidents highlighted, namely client's request to change the design, late decision-making and delay in obtaining approval of related licences, as well as requests to change the start chainage and change of schedule. The results concurred with the study by Yang and Wei (2010) on delays caused by issues in planning and design.

As seen in Table 1, there are risks stemming from consultants and contractors as well. The reasons for delay due to consultants are changes in design during construction, late in issuing of drawings and/or instructions and delay in decision-making, which concur with Yang and Wei (2010). Meanwhile, contractor risk is contributed by contractors' own lack of due diligence and incompetence. It also involves issues with the contractor selection process and related contractual matters, relocation of existing facilities, suspension of work due to disputes, additional works, reworks and repairs and a lack of coordination among the different group of workers. This category of risk is also seen in Sambasivan and Yau (2007), Ramli *et al.* (2017) and Rivera *et al.* (2020).

Lastly, there are also reasons for delay that could not be grouped in any of the discussed risk categories and they are grouped under the category of other risks. Among the reasons under this category are delays in obtaining licences from other authorities such as wayleaves, delay in obtaining other authorities' final approvals and inspections, non-completion of certain parts of the work, delays in testing and commissioning work, instructions given by the superintending officer, obstruction by a third party, stoppage of work due to external factors, late start of work and unforeseen reasons due to external elements from the project environment. Although some of these risks are unique to projects, most can be seen in the study carried out by Rivera *et al.* (2020).

Based on the risk identified and grouped under the various categories, occurrence and impact analysis are then carried out and the results are discussed below.

Project Risks and Year of Occurrence

For 2014, weather risk occurs most frequently, with 10 out of 11 projects affected by it. This is followed by site risk and other types of risk which affected only three projects each. Contractor risk only involved two projects and material risk affected only one.

In 2015, there were 21 delayed projects. The most occurring cause of delay involves the weather risk, comprising 16 out of 21 projects. Contractor risk is the second most frequently occurring risk, affecting 12 projects. This is followed by other types of risk, which affected four projects. Client risk and consultant risk share the same number of affected projects which are three each. Site risk contributed to the delay in two projects. Lastly, design risk affected one project.

For the subsequent year 2016, in the 34 delayed projects, the most frequently occurring risk is the weather risk, which occurred in all 34 projects. Site risk ranked the second most occurring risk with eight affected projects. Contractor risk affected eight projects. Other types of risk affected five projects, client risk affected two and material risk and consultant risks ranked the lowest as both risks only affected one project each.

In 2017, with 25 delayed projects in total, weather risk once again ranked the highest occurring risk that causes delay in a project. The number of projects affected by weather risk is 21 projects. This is followed by risks that fall under the category of other risk, with seven affected projects and site risk with five projects. Client risk and contractor risk affect the same number of projects, which is three. Lastly, consultant risk is the lowest occurring cause of delay as it only affected one project.

In the following year, 2018, there are 18 delayed projects. A total of 10 projects had delays due to weather risk. The second most frequent occurring risk is site risk with six affected projects. This is followed by other types of risk at three projects. Finally, design risk and contractor each affected only one project.

In 2019, only two projects were studied as most projects were either still ongoing and/or have yet to be delayed and/or granted EoT at the time of the study. Hence, for 2019, only three categories of risks were detected and they are the weather risk, site risk and other risks. Each risk affected only one. The reason for weather risk is exceptionally inclement weather. Meanwhile, the reason for site risk is site possession and lastly, the other risk involved land acquisition and delay in site clearing. Table 2 below summarises the occurrence of risk in each year in the specific category in relation to the projects affected by the risks in the particular category.

Table 2: Number of project risks according to year

Year	Total No. of Projects	Risk	No. of Projects Affected by Risk
2014	11	Weather	10
		Site	3
		Material	1
		Contractor	2
		Others	3
2015	21	Weather	16
		Site	2
		Design	1
		Client	3
		Consultant	3
		Contractor	12
		Others	4
2016	34	Weather	34
		Site	8
		Material	1
		Client	2
		Consultant	1
		Contractor	6
		Others	5
2017	25	Weather	21
		Site	5
		Client	3
		Consultant	1
		Contractor	3
		Others	7
2018	18	Weather	10
		Site	6
		Material	2
		Design	1
		Contractor	1
		Others	3
2019	2	Weather	1
		Site	1
		Others	1

Occurrence Analysis in Infrastructure Projects

Out of the 111 projects, 92 projects were affected by weather risk, especially due to exceptionally inclement weather. Extremely low water level affected 14 projects, followed by the occurrence of haze in two projects. Flooding events, king tide floods, erosion and high river water level affected one project each.

For site risk, 25 projects were affected by risks that fall under this category. The highest occurring reason for delays under site risk is delay in site possession. A total of 16 projects were delayed due to site possession. This is followed by delays due to site condition, which affected five projects while four projects were delayed due to site/land blockage from existing facilities, traffic, buildings and so on. The other reasons under site risk are delays due to unforeseen reasons on site, suspension of work, land acquisition and delay in site clearing, which all affected one project each.

For other types of risk, 23 projects were delayed due to risks under this category. The delays due to unforeseen reasons due to elements external to the project environment ranked the highest with nine affected projects. It is followed by ad-hoc instructions given by the superintending officer, which causes seven projects to be delayed. Delays in obtaining license ranked third place with three projects affected. Delays caused by obstructions by a third party had five projects. Delays due to other authorities' final inspection and approval and delay due to non-completion of certain parts of the work caused two projects each to be behind schedule. The following reasons influenced only one project each and they are delays seen in testing and commissioning work, stopping work late start of work.

In addition to that, eight projects delays were due to client risk. The most frequent cause of delay under this category is lateness in decision-making, involving three projects. Concurrently, changes in design causes two projects to run into delays while the remaining three reasons, namely lateness of issuance of licence by other authorities, changes at start work chainage and change of schedule, affected one project each.

For consultant risk, it has caused delays in five projects. Changes in design delayed four projects overall. Subsequently, lateness in receiving drawings and delay in decision-making affected one project each. There are 25 projects delayed under contractor risk and the delay is mainly due to contractor selection during tendering and the related contractual matters, affecting nine projects. Incompetent contractors, especially late responses to instructions and non-cooperativeness, ranked second with five projects affected while suspension of work due to disputes is observed in four projects. The remaining reasons are relocation of work/misalignment of works which affected two projects and additional work, rework and repair, lack of coordination with other contractors, each delaying one project.

Risk involving materials were observed in four projects. There are four reasons for delay in material-related risk and the highest occurring one is late delivery of materials on site, which affected two projects. Meanwhile, engineer's instructions to change specifications in pile length, failure to deliver materials on site due to material change and material shortage all contributed to one project each. Design risk affected only two projects. They occurred due to the realignment of the overall layout and design changes, where each reason contributed to one project being delayed.

Table 3 indicates the frequency of occurrences of the causes of delays in the specific categories of risk in the 111 projects selected for this study.

From the occurrence analysis, it is noted that exceptionally inclement weather occurs very frequently among the 111 projects observed. Adverse weather will jeopardise the construction process, especially when it rains nonstop. Heavy rainfall also causes flooding, which renders sites unworkable due to limitations in movement around the site and mobilisation of equipment, material and labour in and out of the site. On the

Table 3: Frequency of risks occurring in the 111 studied projects

Category of Risk (No. of Project Affected)	Specific Reasons for Delay	No. of Occurrence Out of 111 Projects
Weather (92)	Exceptionally inclement weather	92
	Flooding event	1
	King tide flood	1
	Erosion	1
	Extremely low water level	14
	Occurrence of haze	2
	High river water level	1
Site (25)	Delay in site possession	16
	Unforeseen reasons on site	1
	Site/land blockage from existing facilities	4
	Site condition	5
	Suspension of work due to disputes	1
	Issues with land acquisition	1
	Delay in site clearing	1
Material (4)	Late delivery of materials on site	2
	Engineer's instruction to change project specification	1
	Fails to deliver materials on site due to material change	1
	Material shortage	1
Design (2)	Realignment of overall building layout	1
	Design changes	1
Client (8)	Request to change design	2
	Late decision-making	3
	Late obtaining of approval of licenses	1
	Changes at the start work chainage	1
	Change of schedule	1
Consultant (5)	Changes in design	4
	Late in issuing drawing	1
	Delay in decision-making	1
Contractor (25)	Incompetent contractor	5
	Contractor's selection and contractual matters	9
	Relocation of works/misalignment	2
	Suspension of work due to dispute	4

	Additional works	1
	Rework and repair	1
	Lack of coordination	1
Others (23)	Delay in obtaining licence	3
	Authority inspection and approval	2
	Non-completion of work	2
	Delay on testing and commissioning work	1
	Superintending officer's ad-hoc instruction	7
	Unforeseen reasons from external project environment	9
	Obstruction from a third party	5
	Stoppage of work	1
	Late start of work	1

other hand, the dry season and low water levels can also frequently cause delays in infrastructure projects. Low water levels will make it hard for equipment and material to be mobilised to the site, especially if the project sites are in remote areas, such as Kapit, Belaga and Balingian where riverways are the only mode of transportation. This commonly causes a delay in heavy machinery (which require barges) and a large quantity of material movement, which is also one of the top causes of delays involving structure projects. This result concurred with Senouci and Mubarak (2016), who stated that 45% of all construction projects are affected, to some degree, by weather, resulting in billions of dollars in additional costs worldwide on an annual basis. Schuldt *et al.* (2021) also support this in their review, which focused on the impact of adverse weather events on construction projects, specifically focusing on the weather's impact on task feasibility.

Factors such as site/land blockage and obstructions by a third party were also identified as some of the more frequently occurring risks. This usually involves the need to remove certain existing facilities that are in the way of construction work, problems of site conditions previously undetected and the failure to obtain permission to construct projects on said site or part of the site. Obstructions by a third party are commonly related to interference from third parties, with some delays involving third parties who physically obstruct and refuse to allow access to the construction site. Factors related to other authorities, such as the police, Fire and Rescue Department and the City Council, have also been observed to cause delays. The problems usually occur when the authorities are late in giving wayleaves and/or carrying out final joint inspections, or in providing approval to use the end products. These findings support the study by Aziz and Abdel Hakam (2016) on the causes of delay by road construction projects in Egypt which had the participation of 389 respondents and they found that unexpected ground conditions and physical obstructions were ranked 20 and 18 out of 293 important causes of delay while problems caused by other regulatory authorities were ranked 26.

Prolonged issues related to certain land, title and ownership that go unresolved will frequently lead to delays in site possession and, more seriously, suspension of work which can be seen as somewhat frequent occurring risk that affects the schedule in infrastructure projects. As mentioned by Hardjomuljadi (2014), the delay in site possession will require a scheduling change, which will have a significant effect on the project completion schedule. This risk is one of the more frequently occurring risks among the studied 111 projects, happening 16 times.

Yap *et al.* (2021), who sought to identify the primary delay causes of construction projects, stated that the five most critical causes of delays are "lack of proper planning and scheduling", "too many change orders by clients", "incompetent site management and supervision", "incompetent sub-contractors" and "financial problems of contractors". Changes in design made the list as one of the frequently occurring risk factors in this study and it usually involved delays from all three parties: The client, consultant and contractor. Having changes in the design frequently or at the very last minute can create time- and cost-related issues to the engineers on site, besides impacting the workflow and work methods of the contractors and sub-contractors which often translate into more time and cost as the project progresses. Top risks that may cause project cost overruns and schedule delays are related to changes from the client side (Ochieng *et al.,* 2015; Rosenfeld, 2014). This concurs with Halou *et al.* (2019) who identified risks and costs related to the change in management in construction projects and found that design changes, especially client- and contractor-related design changes are some recurring risks in the change in management in construction projects.

It was also found that superintending officer's instructions are also a frequent cause of delay in infrastructure projects, concurring with Yap *et al.* (2021) on incompetent site management and supervision. Oftentimes than not, this due to delays in delivering instruction or last-minute changes to the construction design, method and material, which causes the project duration to be extended. Late decision-making by client is also seen as one of the reasons for delays.

The listing of incompetent sub-contractors and financial problems with contractor by Yap *et al.* (2021) matches up with the contractor-related risks observed in this study. Contractor incompetency leading to reworks and repairs, suspension of their works and problems with contractor selection during the procurement process and related contractual matters are also some of the frequently occurring risks that cause schedule delays during construction. Delays in resolving contractual issues will cause delays in the commencement of work. However, signing contracts without finalising the design and contractual aspects will inevitably give rise to other issues later in the project which need more time to be resolved. For example, tendering based on an incomplete design, which then require changes during construction, has been found as the key reason of the adjustments in cost and time of projects (Halou *et al.,* 2019).

Other recurring risk factors identified in the study that frequently cause schedule delays include unforeseen reasons from elements external to the project environment and environmental issues, like the occurrence of haze.

Impact Analysis for Infrastructure Construction Projects

The range of impact is grouped according to the overall delay. Based on the Table of Impact and Consequences of Risks in 111 Infrastructure Projects as shown in the appendix, the lowest impact of a specific delay in a specific risk category is 1.8% of schedule overrun, which occurred in a project in Kota Samarahan. The delay is caused by exceptionally inclement weather under the weather risk category. On the other hand, the highest overall impact to the schedule is 160.8% of schedule overrun, which also occurred to a project in Kota Samarahan and it is caused by several delays from several risk categories. Among the risk factors are unforeseen reasons, changes in design, authority inspection and approval and exceptionally inclement weather and the impact are 31%, 5%, 60% and 4%, respectively. The results concurred with Ramli *et al.* (2017) and Rivera *et al.* (2020).

In terms of impact or severity, the most severe impact to the schedule comes from risks related to third parties such as other authorities' final inspection and approval, delays in obtaining the licence from other authorities like wayleaves, land or physical blockage due to existing facilities, obstructions by a third party and site possession delays, such land ownership issues not being fully resolved. Even though the frequency of occurrences may not be high in occurrence analysis, their impacts are certainly strong in almost all the delay cases.

Low water levels and issues with contractors also tend to cause moderate impact on the project schedule. However, these factors can also lead to other more serious factors such as suspension of work, unforeseen reasons caused by external elements to project environment and late start work date. Excessive rainfall and exceptionally inclement weather, even though they occur frequently, tend to have marginal to moderate impacts as shown in the impact analysis. This is supported by Sambasivan and Yau (2007) and Rivera *et al.* (2020).

Another issue that could have marginal impacts are instructions by clients and consultants of the projects usually involving response delays, changes in works and drawing inconsistencies. Delays in revising and approving the design by the consultant is among the more severe cause of delays, followed by the consultant's late in decision-making as also seen in Yang and Wei (2010). Cost overruns and delays in site mobilisation also have the tendency to cause severe impacts on projects.

Conclusion

From the study of occurrences and impacts on time-related risks identified in the construction of 111 public works sector-centric infrastructure projects, rainfall and exceptionally inclement weather were the most frequently occurring delay factors. In terms of impact that risks impose, the most severe risks that cause major delays are site-related risks and risks related to third parties. In addition, exceptionally inclement weather, the superintending officer's ad-hoc instructions and/or late responses in providing instructions, delays in drawing revisions and approve the changes in designs all have moderate to high impacts on the schedule.

All the reasons for delays found in this study are inherent risks to projects and should be well identified to begin with. In many cases, as seen in the case studies, risk identification was not practised, even though these delays have repeatedly occurred across multiple projects over the span of five years. The study also points towards the slow receptiveness of large public organisations, like the PWD and the Malaysian construction industry in general, towards risk management. The lack of risk management is partly due to a lack of risk data, familiarity and systematic way of conducting risk identification, assessment and reaction plans.

With 111 out of 123 projects facing delays and project duration extension, it can be concluded that infrastructure projects with large involvements of capital, time and resources set in rural areas require an outlook and understanding of a project's risk profile, especially in the aspect of time management. With the study of occurrences and impacts in terms of severity of the individual time-related risk observed in this study, a risk profile for a particular infrastructure project can be created. More frequently occurring risks can be better anticipated and the management of these risks, including controlling and reducing their impacts, can be rigorously carried out when the risk profile is better understood. If risk data from PWD can be properly retained, project proponents can use the data to create the risk profiles for their future projects to carry out realistic and reasonable project scheduling.

Currently, the study is limited to the state of Sarawak and its infrastructure projects with a significant number of them executed in rural settings. The study can be further expanded nationwide to include cost- and performance-related risks for a holistic approach in construction risk management. Even though the study does not include the creation of a national risk registry, it is the way forward for the construction industry, where all data from project-based risks are captured, stored and made easily available to project proponents. With this study, it is hopeful that more risk data and knowledge can be retained and further disseminated into future projects, enabling project risk analysts and project proponents to carry out risk assessment and management, especially at the planning stage. It is only through successful delivery of construction projects, including infrastructure projects, within the stipulated and budget with good performance, that the development of the nation and the way forward can be made sustainable.

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Appendix

Impact and consequences of risk in infrastructure construction project

Project	Project Location	Category of Risk	Reason for Delay	Total No. of Delay (days)	Overall Delay (%)	Impact
1	Kuching	Material	Delay in material delivery	5	4.2	Negligible impact
2	Kota Samarahan	Site	Site possession	89	26.2	Minor impact
3	Kota Samarahan	Others	Delay in obtaining licence	75	13.7	Negligible impact
4	Sarikei	Weather	Exceptionally inclement weather	16	16.3	Negligible impact
5	Mukah	Weather	Exceptionally inclement weather	9	2.5	Negligible impact
6	Miri	Contractor	Irresponsible contractor	26	7.1	Negligible impact
7	Kanowit	Weather	Exceptionally inclement weather	11	1.2	Negligible impact
8	Limbang	Weather	Exceptionally inclement weather	11	1.2	Negligible impact
9	Kuching	Weather	Exceptionally inclement weather	6	1.6	Negligible impact
10	Mukah	Weather	Exceptionally inclement weather	4	0.5	Negligible impact
11	Kota Samarahan	Others	Authority inspection and approval	587	160.8	Major impact
12	Kota Samarahan	Weather	Exceptionally inclement weather	91	16.6	Negligible impact
13	Sarikei	Site	Site condition	231	36.0	Marginal impact
14	Mukah	Weather	Exceptionally inclement weather	121	22.0	Minor impact
15	Sibu	Weather	Exceptionally inclement weather	119	26.0	Minor impact
16	N/A	N/A	N/A	N/A	N/A	N/A
17	Miri	Others	Non-excusable delay	40	11.0	Negligible impact
18	Kota Samarahan	Weather	Exceptionally inclement weather	45	14.8	Negligible impact
19	Kuching	Contractor	Contractor selection method	84	34.3	Marginal impact

20	Kuching	Contractor	Contractor selection method	58	31.5	Marginal impact
21	Limbang	Contractor	Relocation of works	197	43.1	Moderate impact
22	Limbang	Contractor	Contractor selection method	163	44.5	Moderate impact
23	Mukah	Contractor	Contractor selection method	142	26.0	Minor impact
24	Limbang	Weather	Exceptionally inclement weather	14	1.9	Negligible impact
25	Limbang	Others	Non-excusable delay	114	9.4	Negligible impact
26	Limbang	Site	Site possession	67	13.8	Negligible impact
27	Kuching	Weather	Exceptionally inclement weather	23	3.8	Negligible impact
28	Mukah	Weather	Exceptionally inclement weather	31	3.1	Negligible impact
29	Miri	Weather	Exceptionally inclement weather	65	5.9	Negligible impact
30	Kuching	Others	Unforeseen reason	124	22.7	Minor impact
31	Kuching	Others	Delay in obtaining licence	40	18.7	Minor impact
32	Kuching	Site	Site blockage	337	46.2	Moderate impact
33	Betong	Material	Failure to deliver materials on site	145	31.8	Minor impact
34	Kota Samarahan	Weather	Exceptionally inclementweather	11	2.8	Negligible impact
35	Miri	Others	Unforeseen reason	97	17.7	Minor impact
36	Kuching	Weather	Exceptionally inclement weather	16	2.9	Negligible impact
37	Betong	Client	Delay in decision making	20	2.7	Negligible impact
38	Betong	Contractor	Delay in completing work	132	36.2	Minor impact
39	Sri Aman	Contractor	Irresponsible contractor	17	5.6	Negligible impact
40	Mukah	Client	Change in design	211	28.9	Minor impact
41	Sri Aman	Weather	Erosion	30	6.6	Negligible impact

42	Kuching	Others	Unforeseen reason	194	53.0	Major impact
43	Mukah	Contractor	Suspension of work	109	19.9	Minor impact
44	Sri Aman	Weather	Exceptionally inclement weather	178	19.5	Minor impact
45	Bintulu	Contractor	Additional work	79	17.3	Negligible impact
46	Miri	Weather	Exceptionally inclement weather	99	18.0	Negligible impact
47	Kapit	Client	Changes at starting chainage	253	23.1	Minor impact
48	Kapit	Weather	Extremely low water level	330	30.1	Marginal impact
49	Kapit	Weather	Extremely low water level	297	27.1	Marginal impact
50	Kapit	Weather	Exceptionally inclement weather	297	27.1	Marginal impact
51	Kapit	Weather	Extremely low water level	297	27.1	Marginal impact
52	Kapit	Weather	Extremely low water level	297	27.1	Marginal impact
53	Kapit	Weather	Extremely low water level	331	30.2	Marginal impact
54	Bintulu	Contractor	Reworks and repair	20	6.5	Negligible impact
55	Kapit	Weather	Exceptionally inclement weather	18	4.9	Negligible impact
56	Kuching	Site	Site possession	29	15.8	Negligible impact
57	Kuching	Consultant	Change in design	40	10.9	Negligible impact
58	N/A	N/A	N/A	N/A	N/A	N/A
59	Kuching	Site	Site possession	188	51.4	Major impact
60	Kuching	Consultant	Delay in receiving drawing	45	24.5	Minor impact
61	Kuching	Contractor	Suspension of work	273	74.6	Moderate impact
62	Kuching	Contractor	Obstruction of third party	341	93.2	Major impact
63	Mukah	Contractor	Contractor selection method	95	17.4	Negligible impact

64	Kuching	Contractor	Suspension of work	61	25.2	Minor impact
65	Kota Samarahan	Client	Change of schedule	58	20.9	Minor impact
66	Betong	Contractor	Contractor selection method	88	16.0	Negligible impact
67	Kanowit	Weather	Exceptionally inclement weather	13	1.4	Negligible impact
68	Kuching	Weather	Exceptionally inclement weather	6	5.0	Negligible impact
69	Kapit	Site	Site condition	129	13.7	Minor impact
70	Kapit	Weather	Exceptionally inclement weather	61	4.8	Negligible impact
71	Kota Samarahan	Site	Site condition	159	29.0	Marginal impact
72	Mukah	Others	SO instruction	372	61.1	Moderate impact
73	Sri Aman	Contractor	Obstruction of third party	107	19.6	Negligible impact
74	Mukah	Site	Site condition/land blockage	238	52.3	Major impact
75	Bakun	Weather	Exceptionally inclement weather	102	14.0	Negligible impact
76	Kuching	Contractor	Obstruction of third party	195	106.6	Major impact
77	Kapit	Weather	Extremely low water level	428	46.8	Moderate impact
78	Kapit	Weather	Extremely low water level	252	23.0	Minor impact
79	Kapit	Site	Land blockage	458	50.1	Major impact
80	Kapit	Weather	Extremely low water level	236	21.6	Minor impact
81	Kapit	Weather	Extremely low water level	424	46.4	Moderate impact
82	Kapit	Weather	Extremely low water level	231	21.1	Minor impact
83	Kapit	Weather	Extremely low water level	176	16.1	Minor impact
84	Kuching	Others	Obstruction of third party	154	21.1	Minor impact
85	Sarikei	Site	Site possession	493	58.7	Major impact

86	Kuching	Weather	Exceptionally inclement weather	8	2.6	Negligible impact
87	Lundu	Others	SO instruction	48	15.7	Negligible impact
89	Kuching	Others	SO instruction	89	19.6	Minor impact
90	Kuching	Weather	Exceptionally inclement weather	184	25.2	Marginal impact
91	Miri	Others	Non-excusable delay	126	83.4	Major impact
92	Miri	Site	Site possession	162	89.5	Major impact
93	N/A	N/A	N/A	N/A	N/A	N/A
94	Limbang	Weather	Exceptionally inclement weather	671	183.8	Major impact
95	Kapit	Weather	High river water level	29	9.6	Negligible impact
96	Limbang	Weather	Exceptionally inclement weather	13	5.3	Negligible impact
97	N/A	N/A	N/A	N/A	N/A	N/A
98	Kapit	Weather	Extremely low water level	332	30.3	Marginal impact
99	Miri	Contractor	Contractor selection method	114	20.9	Minor impact
100	Sri Aman	Site	Delay in site clearing	180	26.9	Marginal impact
101	Kanowit	Weather	Exceptionally inclement weather	48	8.7	Negligible impact
102	Limbang	Site	Postponement of site possession	60	21.7	Minor impact
103	Kapit	Site	Site possession	49	9.0	Negligible impact
104	Kota Samarahan	Weather	Exceptionally inclement weather	10	1.8	Negligible impact
105	Kuching	Weather	Exceptionally inclement weather	3	1.7	Negligible impact
106	N/A	N/A	N/A	N/A	N/A	N/A
107	Mukah	Weather	Exceptionally inclement weather	9	2.5	Negligible impact
108	Betong	Weather	Exceptionally inclement weather	14	7.7	Negligible impact
109	Kapit	Others	Late start of work	51	27.9	Minor impact

110	Miri	Weather	Exceptionally inclement weather	18	2.5	Negligible impact
111	Betong	Site	Site possession	97	13.3	Minor impact