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Effects of the COVID-19 Pandemic on Construction Work Progress: An On-Site Analysis from the Sarawak Construction Project, Malaysia

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Abstract: The spread of the COVID-19 pandemic has impacted the economy of the world as well as the construction industry in Malaysia. Many projects were plagued with time and cost overruns due to the COVID-19 pandemic. Site work progress came to an abrupt halt, and productivity stagnated. With that in mind, this study was conducted on the basis of first-hand experience in dealing with the COVID-19 pandemic and how it has affected the construction industry. This study investigated the effects of the COVID-19 pandemic on construction projects in Sarawak, Malaysia. The target respondents were the clients, consultants, and contractors involved in projects under the purview of the Public Works Department Sarawak. The purpose of the research was to obtain a better understanding of the current situation, in readiness for a similar situation in future. To achieve the objectives of the research, a questionnaire survey of current ongoing projects was used for this study's data collection purpose. To analyse the data, SPSS version 26 and the Analytical Hierarchy Process (AHP) method were used to achieve frequency analysis and to determine the priority importance of the effects of this pandemic on those construction projects. The findings of this study provide necessary information to construction stakeholders in Sarawak on how to deal with such pandemics in the future and to create awareness, foster resiliency, connote preventive measures, avert delays, and manage progress control.

Keywords: COVID-19; site work progress; construction project delays; future awareness

1. Introduction

The world is facing the deadly coronavirus, which is better known as the COVID-19 outbreak. The outbreak of the COVID-19 pandemic has impacted the world economy, and the construction industry is among the most affected in its productivity and supply chain. At the time of this writing on 30 July 2021, Malaysia has recorded 1,095,486 confirmed cases and 8859 deaths (KKM daily report on COVID-19 via MySejahtera), and the highest number of daily cases was recorded on 29 July 2021, with 17,170 confirmed cases. From March 2021 to June 2021, the daily number of confirmed cases ranged between 4000–6000 cases and can be seen in Figure 1. There were various Standard Operation procedures (SOP) introduced to curb this pandemic. The government has imposed Movement Control Orders (MCO, MCO2, MCO3, EMCO, RMCO, CMCO, and TMCO) nationwide as a preventive measure to circumvent the pandemic. Besides that, there was a State of Emergency proclamation

(12 January to 1 August 2021) to curb the alarming rise of COVID-19 cases in Malaysia. Only essential economic sectors were allowed to operate. As for the construction industry, only critical activities and critical projects are allowed to operate. To resume operation, the approval of the Ministry of International Trade and Industry (MITI) must be obtained with strict SOP to comply. A team of enforcement on duty checks for the SOP compliance is conducted from time to time to make sure it is abiding by the SOP and to minimize the spread of the COVID-19 virus. Therefore, the study on the effects of the COVID-19 pandemic on the Sarawak construction project is essential in preparing for how to deal with such a pandemic in the future.

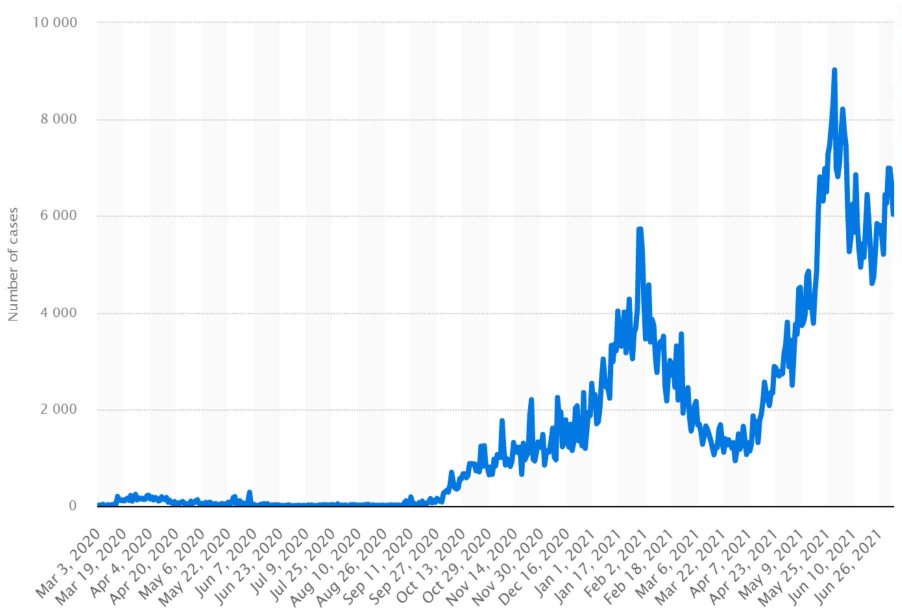

Figure 1. Daily number of confirmed COVID-19 cases in Malaysia between March and June 2021 as reported by the Ministry of Health Malaysia.

The construction industry plays an important role in Malaysian economic development and growth. There would be a significant impact on the economy if the construction projects are being delayed. The alarming situation impacting the construction industry badly includes road projects, buildings, and infrastructure projects. Shared accommodation at a construction site was identified as one of the causes of the spread of COVID-19 at project sites [1]. Studies by many researchers concurred that the COVID-19 pandemic has impacted the construction industry worldwide [2]. Working from home may be impractical in the construction industry as a physical activity must be held at project sites [3]. The economic growth was affected as almost all of the construction projects experience critical delays. The Movement of Control Order (MCO) and the Standard Operating Procedure (SOP) imposed by the Malaysian Government restrict the construction activity from operating in full swing. The contractor had since encountered financial problems, a shortage of materials, a lack of manpower, as well as losses due to the pandemic outbreaks.

Project progress delay is a global phenomenon for construction projects, including Malaysia's. However, a significant number of construction workers who tested positive for COVID-19 further delayed the project work progress [4]. The COVID-19 pandemic has caused a disruption in major construction activities, and many construction sites were significantly impacted with the end being nowhere in sight. Meanwhile, the outbreak of the COVID-19 pandemic has added a tremendous negative impact and worsened the industry where the whole world was experiencing project delays and time and cost overruns [5]. On-going construction project progress went haywire. Besides that, construction projects idled down due to lockdowns, shortage of manpower as well as deferred material delivery [6]. Due to these unprecedented situations and uncertainties, the project work progress was delayed and may cause a time overrun. In work progress monitoring, these delays consequently cause projects to deviate from their original scheduled completion stated in the contracts due to lockdowns and social distancing rules at construction sites [7]. This study focused the attention on battling the effects of uncertainties during construction that may affect the construction projects and investigated the strategy to resiliently deal with such issues in the future.

The selection of Sarawak as a case study is based on the number of projects delays during the pandemic under JKR Sarawak (Public Works Department Sarawak), as illustrated in Figure 2. Sarawak has 21 critical projects compared to 92 projects for all of the states in Malaysia (Datuk Seri Mustapa Mohamed, Minister in Prime Minister's Department, New Straits Times, 12 February 2022) [8], which has contributed 22.8% of the critical projects during the pandemic. The data show that there is a need for the study and a readiness for a similar situation in the future. Unlike the other public works departments in the other states in Malaysia, the Public Works Department of Sarawak is not under the purview of Federal Public Works, which is administered by the State of Sarawak. Sarawak has its own interpretation ordinance 2005 under Chapter 61, Sarawak Law. The structure and organization are also different from the Federal Ministry of Public Works in Peninsular Malaysia.

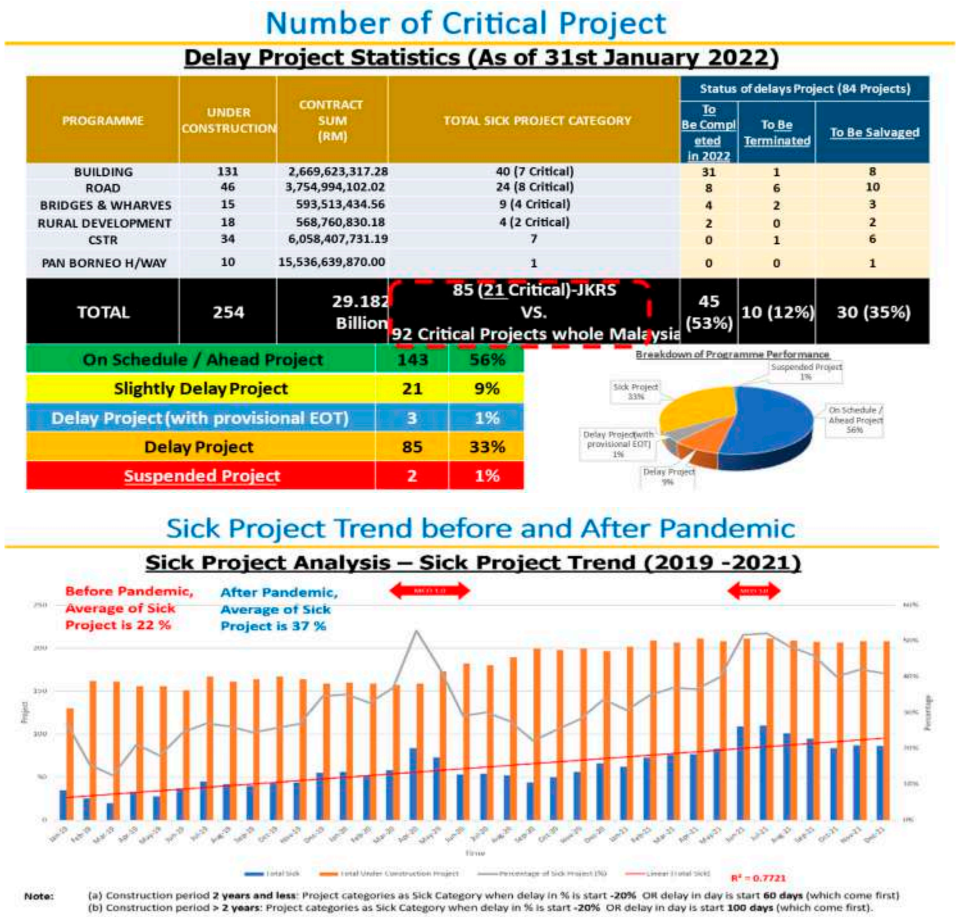

Figure 2. Project delays (critical/sick) and the trend of project delays during the pandemic.

The development project in Sarawak is highly challenged by the geographical location. The projects have been scattered over rural and urban regions, and, during the pandemic, the travel distance is very challenging. The ability of the data is one of the criteria to ensure the study could be completed on time. Hence, the positive impacts of the COVID-19 pandemic increase the utilization of online businesses and the latest advanced technology to be explored for business survival [9]. The pandemic created new opportunities to fast track projects and buildings and opens up opportunities for retraining semi-skilled workers [4]. The negative impact of COVID-19 could be reduced if those involved in the construction industry, such as stakeholders, project managers, contractors, engineers and subcontractors, appropriately responded to the pandemic [6]. The COVID-19 pandemic, which spread across the world, demanded proper crisis management and timely warning systems development to reduce damage or unsustainable consequences to construction businesses. The construction players should learn from these difficult times to determine the appropriate measures to recover the construction supply chain from challenges such as financial difficulty as well as to find a way out from the severe effects of the pandemic.

Nevertheless, the COVID-19 pandemic outbreak has severely hit the construction industry with job losses and companies closing down their business. Several lockdown and travel restrictions forced construction projects to downsize and fold. Apart from that, many lives were at risk in an unprecedented number of deaths and hospitalizations [4]. In order to flatten the curve, governments and employers have encouraged workers to work from home [3]. With a nationwide lockdown imposed by the government, people were made to stay at home except for those in essential services. This posed a major dilemma to the construction projects in Malaysia, where construction site activity simply cannot operate or work from home. The workers will not be paid if they do not turn up on site for work. In addition, the construction industry also experiences a shortage of material and manpower as most construction workers are foreigners. Since there is a limited study focusing on the impact of the COVID-19 pandemic in Malaysia on construction projects, especially in Sarawak, this study was aimed to discover the effects as well as to offer solutions in the event of a similar situation in the future.

This research study aimed to determine the effects of the COVID-19 pandemic on Sarawak construction projects. It is also hoped that the research would help Sarawak construction projects to recover from severe financial losses due to the pandemic and to explore new strategies. Therefore, it is important to find out practices that can be adopted by the construction industry to respond to this challenging time. The findings are expected to be useful for the construction industry's survival, preserving the job security and maintaining the construction progress as well as productivity in anticipation of future pandemic reoccurrences.

2. Effects of COVID-19 and Efforts to Curb the Effects of COVID-19

Zamani et.al [5] conducted a study on the effect of COVID-19 on building construction projects, [9] the impacts of COVID-19 on infrastructure projects, [10] the risk of tunnel projects' progress during the COVID-19 pandemic, and [11] the COVID-19 pandemic lockdown to project success in Malaysia. The causes of delays were a lack of materials, a shortage of workers, changes in design, financial problems, a lack of machinery, workers' problems, requirements of the local authority, requirements of the client, contractor management, and consultants. However, that study did not specify the effects of delays caused by pandemics such as COVID-19. Therefore, this study is important to determine how the site work progress was delayed by the COVID-19 pandemic and the way forward for sustainable construction if such delays occurred in the near future. Preparing the construction industry with new norm construction methods and adopting new guidelines and standard operating procedures (SOP) at project sites are essential.

Project delays, a shortage of manpower, an increased cost, and a shortage of materials were the effects of COVID-19 [6]. Effectively controlling manpower and materials, avoiding reworks, and adopting social distancing are the efforts to curb the effects of the pandemic [9]. Whilst the lesson learnt from the COVID-19 pandemic would be used to improve the existing systems, more fast-track projects create new opportunities if a similar situation occurred, create awareness, foster resiliency, connote preventive measures, avert delays, and manage progress control [4]. According to [12], inadequate funding, the inadequacy of resources, and project variations were the major project delay factors. However, competency, commitment, continuous involvement in the project development, the relationship with other project stakeholders, and the adaptability to changes in the project plan are critical factors affecting project planning, scheduling, and communication to prevent project delays. Besides that, the project team leader's ability to manage the relationship with stakeholders is important as well. Adequate design details and specifications, skillful workers, involvement in monitoring the project progress, and project budget monitoring are the factors determining the success of the project [13]. In order to improve the project performance, the construction industry needs to look into strategies that alleviate opportunistic behaviors and promote a better working relationship among project stakeholders [14].

The above-discussed causal factors for project delays are described further by Table 1 on its definition and code that were later used in the AHP analysis.

Table 1. Causal factor for project delays.

Code	Causal Factors	Definition	References
E1	Project delays	Failure of implementing the project effectively. The project encountered time overrun.	[5,7,12,15]
E2	Shortage of manpower	Less productivity as the demand of skilled manpower is constrained.	[5,15]
E3	Increased project cost	Project costs more than as expected.	[11,16]
E4	Logistics problems	Delivery delays would cause the project delays.	[5]
E5	Financial constraints	Project delays due to financial problems.	[5,10]
E6	Price escalations	The price of materials rising rapidly.	[4,5]
E7	Payment delays	Delays in payment occurring during the pandemic.	[5,7]
E8	Shortage of materials	Slow work progress due to material problems.	[5,7,10]
E9	Delayed inspection and approval	Slow in inspection and approval causing project delays.	[4]
E10	Increase in disputes and claims	Delays caused by the pandemic increase disputes and claims.	[4,7]

The challenges of the COVID-19 pandemic offer the above causal factors of project delay. The project management team have to overcome the challenges and risk by developing the strategy to curbing COVID-19, adopting new safety measures including social distancing, and rigorously managing the project risks. One of the options is adopting smart site work progress monitoring.

2.1. Smart Site Work Progress Monitoring

Site work progress monitoring is one of the most challenging tasks during the construction stage due to the uniqueness and the complexity of projects. It is challenging for the construction industry players to continue monitoring the site work progress during this COVID-19 pandemic. With new normal and unprecedented measures, monitoring the project site is not an easy task. A closed site work progress monitoring is important during construction-phase activities to ensure compliance to the drawings, contract specifications, time, cost, and quality required by the clients. Tracking progress, productivity, and performance is one of the most important duties of the superintendent to ensure the entire project meets the project schedule [15]. It is to determine the actual project progress as compared to the planned project schedule. Accurate measurements, analysis, visualization, and videos of as-built status (actual) are critical tasks in ensuring successful project monitoring. Automated project monitoring systems are necessary to ensure project delivery excels and the updated schedule, progress, cost, and performance of the project are timely and comprehensive to facilitate good decision making [16].

With the availability of many smart technologies to capture images for automated progress measurement and monitoring nowadays, they could be utilized during this COVID-19 pandemic's restricted movement. New advanced technologies such as drone technology with 3D systems are used to calculate and track the construction site work progress efficiently for better monitoring. However, according to [15], the construction industry still facing challenges from a lack of holistic, automated, and real-time monitoring systems to address the construction issues. The authors [17] had developed methods for aerial data capturing and 3D reconstruction using Augmented Reality (AR) for construction site monitoring and documentation to allow relevant information to be accessed directly from sites. To this extent, the AR system has to be registered to the physical world environment based on remote localization and online tracking to visualize actual progress and real-time information.

During the COVID-19 pandemic, the site work progress assessment and supervision were also directly done from photos captured by the Unmanned Aerial Vehicles (UAV). The UAV drone with the latest remote sensing technologies was the perfect choice for automated productivity measurements. High-level computing devices, new app technologies, artificial neural networks, and IoT are smart tools to assist in the calculation and progress assessment. For example, in road construction, the measurements were based on volumes, areas, and linear measurements, which are matched perfectly using UAV drone technology. The project manager will be frequently checking the work program and monitoring; however, site works monitoring requires multiple approaches due to the nature of longitudinal infrastructures. Any deviations to the work schedule definitely may incur cost and time overruns. Besides monitoring the time and cost, the project manager's duty is also to ensure that the project quality, safety, and Standard Operating Procedures (SOP) are implied.

2.2. Smart Construction Using Unmanned Aerial Vehicles

In the traditional project monitoring process, the availability of accurate real-time data in showing the site work progress is very limited. Many projects still practice this traditional method. However, a smart construction monitoring system is based on more-organized real-time data, which are collected using Unmanned Aerial Vehicles (UAVs) mounted with sensors such as a photo or a video camera, a thermal imaging camera, and new advanced infrared sensors. The data collected are then analyzed using advanced software for better monitoring and decision making. The data from UAVs are analyzed using various software to extract useful information for project monitoring and a better decision-making process [18].

In addition, the UAVs data can be useful for construction scheduling, costing, real-time recording, reporting, verification, and planning. The UAVs' data acquisition may significantly reduce the traditional construction monitoring as well as provide convenient and smart methods of site work progress management, planning, operation, and monitoring. The important applications of UAVs in construction include:

i 3D Map Creation

The UAVs provide real-time data and aerial construction monitoring through 3D object creation and area orthophoto graphic maps. This serves as a better control over the site activities for closer monitoring of the construction work progress. The management or the clients are able to access the most recent visual information for fresh work progress updating. The project team or the management can detect deviations from the original schedule.

ii Aerial Photography and 3D Scanning of Construction Projects

Aerial photos and videos can be used to provide project team visualizations or tracking of site progress at the early construction stage for better rectification and monitoring of any defects or deviations to the work schedule.

iii Routing Construction Progress Monitoring

During the construction phase, the UAVs can visualize the site and activities by recording how the project is going. The assessment of construction progress is determined by a work-in-progress from the photos or videos recorded from the UAVs. Road construction is spread over a long distance; the use of a traditional method may be time-consuming, but the use of UAVs can shorten the time for inspection or assessment. Before the start of the construction activity, the UAV images and video can be used to perform site planning and layout management.

iv Volumetric Measurement

Photogrammetry techniques on a large area such as a road, the volume of work (earthworks), and productivity can be measured or calculated in a more accurate manner where the differences may be in centimeters. Using this technique, the mission can be accomplished quickly, cost-effectively, and with minimal disruption to the daily work at the site. Besides that, the photos and videos can be analyzed with modern software such as Pix4D to calculate the length, area, or volume of the work done. Using UAVs works for one week can be done in days. The amount of material (earthworks) moved, excavated, and filled along the road construction can be calculated to determine the work volume and productivity. The inspection, tracking, and monitoring jobs are much easier with the new technology such as UAVs.

3. Methodology

The study was conducted on the projects under the purview of Public Works Sarawak (JKR Sarawak), where the data collection was for the month of July 2021 to determine the seriousness of the pandemic's impact on the construction, especially for the ongoing projects. To achieve the objectives of the study, quantitative data were obtained through a google questionnaire survey distributed to the target respondents. The questionnaires were sent to the client (JKR), the contractor and the consultants involved with the project under JKR Sarawak supervision. The data obtained from the survey questionnaires were analyzed using SPSS version 26. There were 37 respondents to this questionnaire survey. The results were presented using tables and charts for easier comprehension by the readers. The AHP analysis was used to present the analysis of the results. AHP analysis has the advantages to check, determine the logical priority, and rank the results as well as to help and support the analysis from SPSS. Even though the AHP analysis is an old method, it is still relevant in this study. This study used a sample size of 37 respondents, which claimed the sample size is enough for this research. Once again, the AHP analysis method has no general rule on the sample size, whereby it is not necessarily a large sample, and it range from 5 to 9000. Some researchers argued that AHP is a subjective method for research focusing on a specific issue; hence, it is not necessary to employ a large sample [19], it is define by statistical methods [20]. Others also argued that because AHP is based on expert judgments, judgments from even a single qualified expert are usually representative [21–24].

The AHP analysis method was used to rank the effects of the pandemic and efforts in curbing the pandemic as the accuracy of pairwise comparison is more reliable. The relative importance of every finding was analyzed and presented, which may have a significant impact on the construction industry. The criteria used in AHP techniques were collected through a questionnaire survey.

Figure 3 illustrates the research frameworks as a guideline to the researcher so that the research can be conducted systematically and following the research methods and research stages. First, the research needs to define the problem of why the study is needed. Then, the objective of the study, the literature review, data collection, as well as data analysis using SPSS version 26 and AHP analysis to determine the results from the study need to be set up. Finally, the conclusion and recommendation from the study are tabled. The respondents of the study were the construction players currently involved with projects affected by the COVID-19 pandemic. Their experience during the pandemic is useful to make the study more relevant, and the results of the study can later be used as preparation if a similar situation arises in the future.

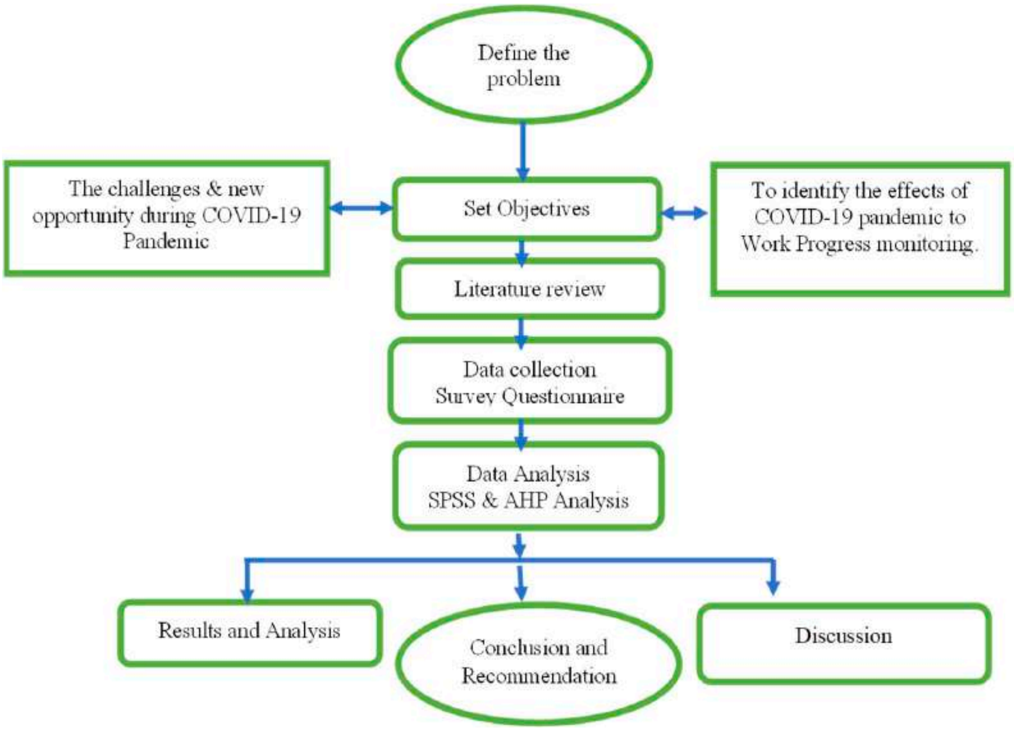

Figure 3. Study methodology flow chart.

The findings from a total of 37 respondents to the questionnaire were presented. Participants comprised both genders with different backgrounds, age groups, levels of education, working positions, and experience in the construction industry. The data and information from the findings were gathered to determine the effects of the COVID-19 pandemic on the construction industry as well as project sites. Table 2 shows the demography of respondents in terms of the organizations they represented. Firstly, the analysis was conducted with SPSS from the survey questionnaire on the actual working conditions of the project under supervision of the Public Works Department, Sarawak. The AHP analysis was conducted to check and determine the logical priority, to rank the results, and to help support the analysis from SPSS. The validity and reliability of the questionnaires were checked with a Cronbach's Alpha coefficient of 0.814, which indicates a high reliability. This indicates that the questionnaire was developed with no ambiguities and that it avoids jargon questions.

Table 2. Demographic analysis.

Demography	Respondents	Frequency	Percent	Valid Percent	Cumulative Percent
Respondents' organization	Government Agency	15	40.5	40.5	40.5
	Consultant	2	5.4	5.4	45.9
	Contractor	20	54.1	54.1	100.0
	Total	37	100.0	100.0	

Table 2. *Cont.*

Demography	Respondents	Frequency	Percent	Valid Percent	Cumulative Percent
Designation in the company	Managing Director	2	5.4	5.4	5.4
	Project Director	3	8.1	8.1	13.5
	Project Manager	13	35.1	35.1	48.6
	Project Engineer	8	21.6	21.6	70.3
	Other	11	29.7	29.7	100.0
	Total	37	100.0	100.0	
Academic qualification	Diploma	7	18.9	18.9	18.9
	Bachelor	21	56.8	56.8	75.7
	Master	8	21.6	21.6	97.3
	Other	1	2.7	2.7	100.0
	Total	37	100.0	100.0	
Construction experiences	Less than 5 years	5	13.5	13.5	13.5
	5–10 years	11	29.7	29.7	43.2
	11–20 years	14	37.8	37.8	81.1
	More than 20 years	7	18.9	18.9	100.0
	Total	37	100.0	100.0	
Highest contract amount involved	Less than 5 million	2	5.4	5.4	5.4
	5–10 million	5	13.5	13.5	18.9
	10–50 million	14	37.8	37.8	56.8
	50–100 million	5	13.5	13.5	70.3
	100–500 million	6	16.2	16.2	86.5
	More than 500 million	5	13.5	13.5	100.0
	Total	37	100.0	100.0	

4. Respondent's Demographic

Based on Table 2, there were 20 or 54.1% respondents who are contractors; 15 respondents or 40.5% respondents were from government agencies; and 2 or 5.4% respondents were from consultant organizations. Table 1 also illustrates the positions of the respondents in the company that they represent. The majority of respondents were in senior positions, such as project manager roles, representing 35.1% or 13 respondents out of 37 respondents who took part in the survey. Project Engineers were 21.6%; Project Directors were 8.1%; and Managing Directors were 5.4%; the rest were from other groups or job positions. In terms of academic qualification, 56.8% or 21 out of 37 respondents were graduates with bachelor's degrees; 21.6% held a master's degree level of education; and 18.9% or 7 respondents were diploma holders. Meanwhile, one respondent was a high school graduate with significant experience in the construction industry. Only 13.5% of the respondents had less than five years' experience in construction, while another 86.5% showed well-experienced respondents in construction projects who participated in this questionnaires survey. Those respondents split, with 29.7% of them in the range of 5–10 years, 37.8% between 11–20 years, and 18.9% with more than 20-years' experience in the construction industry, especially in Sarawak. The majority of respondents had been involved with contracts of more than RM 5 million at 94.6%. While 13.5% were involved with project amounts between RM 5 million to RM 10 million, 37.8% of them were involved with project amounts in the range of RM 10 million to RM 50 million. Respondents involved in projects between RM 50 million to RM 100 million were 13.5%. For RM 100 million to RM 500 million, 16.2% of respondents were involved, and for projects greater than RM 500 million, 13.5% of respondents were involved.

The main objectives of this study were to determine the construction players' point of view on the effects of the COVID-19 pandemic, the efforts to curb and manage the pandemic, as well as to determine and look for new opportunities to gain from the pandemic. The lessons learnt from the pandemic were useful for our readiness in the event of such a pandemic occurring in the future. Hereby, the findings of the study will be important for construction players' future referrals. Meanwhile, the AHP techniques intensity scale was used for AHP pairwise comparison by Saaty (1995) as the basis for the analysis in this study [21,25].

5. The Effects of the COVID-19 Pandemic on the Site Work Progress Using the Analytical Hierarchy Process (AHP)

In order to determine the ranking and hierarchy of the findings, the Analytical Hierarchy Process (AHP) method analysis was used. In pairwise comparisons, the identified factors were assessed against the hierarchical effects of the pandemic, efforts to manage it, and the new opportunities to gain from the pandemic. The AHP pairwise comparison was used as the hierarchy of the results for greater accuracy and reliability. Table 3 shows the intensity scale used for the AHP pairwise comparison.

Table 3. Intensity scale for AHP pairwise comparison as used by Saaty (1995).

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another.
5	Essential or strong importance	Experience and judgment strongly favor one activity over another.
7	Very strong or demonstrated importance	Activity is strongly favored, and its dominance is demonstrated in practice.
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values	When a compromise is needed.
1/3, 1/5, 1/7, 1/9	Values for inverse comparison	

Table 4 presents the variables on the effects of COVID-19 on the construction industry, efforts to manage the pandemic during the challenging time, and new opportunities gained from the pandemic. Table 5 displays the results of the Random Index, and further analyses were taken. Table 6 is for the AHP pairwise comparison matrix calculation in order to determine the priority or ranking of the research findings on factors affecting site work progress during the COVID-19 pandemic.

Table 4. Results and findings of the current pandemic study.

	Effects of the COVID-19 on the Construction Projects	Efforts to Manage the Project during the Time of Pandemic Challenges	New Opportunities Gained from the Pandemic
The goal that needs to be achieved from the study Effects of the COVID-19 pandemic on construction work progress	Project delays	Managing the project risks	Ability to secure loans and low-interest rates
	Shortage of manpower	Adopted new safety measures in the construction industry	Surplus of skilled workers in the market
	Increase in project cost	Social distancing	More fast-track projects, medical projects, and transportation projects
	Logistic problems	Developed a strategy to address the challenges of COVID-19	Lesson learnt in improving the existing systems
	Financial constraints		
	Payment delays		
	Shortage of materials		
	Delay in inspection and approval		
	Increase in disputes and claims		

Table 5. Random Index.

Size of the Matrix (*n*)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Random Consistency (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 6. AHP pairwise comparison matrix calculation table to determine the priority or ranking of the research findings.

Pairwise Comparison Matrix										
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**E10**
E1	1.00	2.00	1.00	0.50	3.00	1.00	3.00	0.50	1.00	3.00
E2	0.50	1.00	1.00	1.00	0.33	1.00	1.00	1.00	0.33	0.50
E3	1.00	1.00	1.00	0.33	1.00	1.00	2.00	1.00	3.00	1.00
E4	2.00	1.00	3.00	1.00	2.00	0.33	1.00	1.00	0.11	3.00
E5	0.33	3.00	1.00	0.50	1.00	1.00	1.00	3.00	0.50	1.00
E6	1.00	1.00	1.00	0.33	1.00	1.00	0.33	1.00	1.00	1.00
E7	0.33	1.00	0.50	1.00	1.00	3.00	1.00	1.00	1.00	1.00
E8	2.00	1.00	1.00	1.00	0.33	1.00	1.00	1.00	0.11	2.00
E9	1.00	3.00	0.33	0.33	2.00	1.00	1.00	0.11	1.00	1.00
E10	0.33	2.00	1.00	0.33	1.00	1.00	1.00	0.50	1.00	1.00
Sum	**9.50**	**16.00**	**10.83**	**6.33**	**12.67**	**11.33**	**12.33**	**10.11**	**9.06**	**14.50**

Table 6. *Cont.*

Normalised Pairwise Comparison Matrix												
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**E10**	**Sum**	**Criteria Weight**
E1	0.11	0.13	0.09	0.08	0.24	0.09	0.24	0.05	0.11	0.21	1.34	**0.13**
E2	0.05	0.06	0.09	0.16	0.03	0.09	0.08	0.10	0.04	0.03	0.73	**0.07**
E3	0.11	0.06	0.09	0.05	0.08	0.09	0.16	0.10	0.33	0.07	1.14	**0.11**
E4	0.21	0.06	0.28	0.16	0.16	0.03	0.08	0.10	0.01	0.21	1.29	**0.13**
E5	0.04	0.19	0.09	0.08	0.08	0.09	0.08	0.30	0.06	0.07	1.06	**0.11**
E6	0.11	0.06	0.09	0.05	0.08	0.09	0.03	0.10	0.11	0.07	0.78	**0.08**
E7	0.04	0.06	0.05	0.16	0.08	0.26	0.08	0.10	0.11	0.07	1.00	**0.10**
E8	0.21	0.06	0.09	0.16	0.03	0.09	0.08	0.10	0.01	0.14	0.97	**0.10**
E9	0.11	0.19	0.03	0.05	0.16	0.09	0.08	0.01	0.11	0.07	0.89	**0.09**
E10	0.04	0.13	0.09	0.05	0.08	0.09	0.08	0.05	0.11	0.07	0.78	**0.08**
CI and CR												
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**E10**	**Sum**	**Sum/Weight**
E1	0.13	0.27	0.13	0.07	0.40	0.13	0.40	0.07	0.13	0.40	2.14	**16.00**
E2	0.04	0.07	0.07	0.07	0.02	0.07	0.07	0.07	0.02	0.04	0.56	**7.67**
E3	0.11	0.11	0.11	0.04	0.11	0.11	0.23	0.11	0.34	0.11	1.41	**12.33**
E4	0.26	0.13	0.39	0.13	0.26	0.04	0.13	0.13	0.01	0.39	1.87	**14.44**
E5	0.04	0.32	0.11	0.05	0.11	0.11	0.11	0.32	0.05	0.11	1.31	**12.33**
E6	0.08	0.08	0.08	0.03	0.08	0.08	0.03	0.08	0.08	0.08	0.68	**8.66**
E7	0.03	0.10	0.05	0.10	0.10	0.30	0.10	0.10	0.10	0.10	1.09	**10.83**
E8	0.19	0.10	0.10	0.10	0.03	0.10	0.10	0.10	0.01	0.19	1.01	**10.44**
E9	0.09	0.27	0.03	0.03	0.18	0.09	0.09	0.01	0.09	0.09	0.96	**10.78**
E10	0.03	0.16	0.08	0.03	0.08	0.08	0.08	0.04	0.08	0.08	0.72	**9.17**
												11.27

Lambda max = 11.27; CI = 0.14; CR = 0.09; CI = Lambda max $-$ n/n $-$ 1; CR = CI/RI; Consistency Ration = 0.9 < 0.1 Then OK. Legend: E1—Project delays. E2—Shortage of manpower. E3—Increased project cost. E4—Logistic problems. E5—Financial constraints. E6—Price escalations. E7—Payment delays. E8—Shortage of materials. E9—Delayed inspection and approval. E10—Increase in disputes and claims.

By applying AHP, the effects of COVID-19 on construction work progress can be prioritized according to the ranking in ascending order as illustrated in Figure 4. The results of the Analytical Hierarchy Process show that project delay (priority vector = 16) is the highest-ranking factor affecting the work progress on-site during the COVID-19 pandemic. This is followed by logistic problems (14.44), financial constraints (12.33), an increased project cost (12.33), payment delays (10.83), delays in inspection and approval (10.78), a shortage of materials (10.44), an increased project cost (9.17), price escalations (8.66), and a shortage of manpower (7.67). The findings from the analysis identified that the COVID-19 pandemic had caused many projects' progress to be delayed and may complete beyond the period stipulated in the contract that has been signed. The construction company have to adjust their schedule in order to avoid major losses. Logistic problems and the inability to access the worksite due to movement restrictions imposed by the government also caused the delay. The COVID-19 pandemic has caused many contractors to experience financial difficulties and constraints.

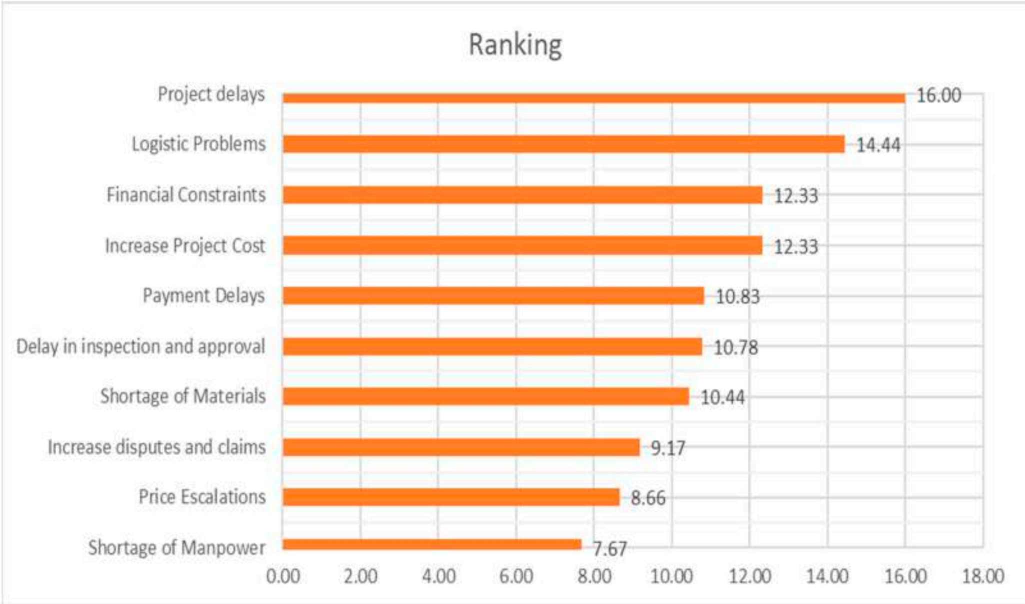

Figure 4. The priority ranking factors affecting site work progress during the COVID-19 pandemic.

In parallel, the project cost may escalate as the price of material increases due to movement control orders and restrictions imposed by the government. Besides that, most contractors experience payment delays due to delays in inspection and approval by the clients. A shortage of materials and manpower with strict SOP imposed by the government and project sites had caused decreased project site productivity and slow progress. The delay may cause a project overrun from the original project schedule and may cause many disputes. In addition, a delay in material delivery and a shortage of materials at the construction site were also experienced by the respondents as a result of social distancing and quarantine requirements that may cause a smaller workforce within the supply chain. An inability to predict the Movement of Control Order and restrictions to be lifted leads to an increase in disputes and the extension of time claims as the contractors are arguing about the impact of the COVID-19 pandemic, which is significantly causing schedule disruptions.

Table 7 portrays the AHP pairwise comparison matrix calculation in determining the priority or ranking of the research findings on the efforts to curb and manage the COVID-19 pandemic.

Figure 5 shows the AHP priority ranking to curb and manage the effects of the COVID-19 pandemic in the viewpoint of construction players on their project site to reduce slow work progress. Generally, AHP calculation shows that managing the project risks is important and ranked first in curbing the pandemic as well as minimizing the low site productivity. The adaptation to social distancing should be practiced on-site during these challenging and unprecedented times. As there was much concern about the spreading of the virus, new safety measures must be adopted at the construction site. New normal safety guidelines and Personnel Protective Equipment (PPE) may help prevent COVID-19. The respondents also believe that better and more realistic strategies are important to address the COVID-19 challenges between construction supply chains. The findings from the analysis also show that project work progress shall be monitored closely despite the fact that the risk of infection by the virus could be high. The advanced new technologies would be useful in managing the project from time to time. Online meetings and smart technology monitoring tools such as UAV utilization in a new normal are essential in managing construction in the future, where advanced technologies including IoT and robotics are new solutions when the movement of control is imposed by the government.

Table 7. AHP pairwise comparison matrix calculation table to determine the priority or ranking of the research findings.

	Pairwise Comparison Matrix					
	EM1	EM2	EM3	EM4	Score	Ranking
EM1	1.00	2.00	3.00	5.00	11.00	1
EM2	0.50	1.00	0.33	5.00	6.83	3
EM3	0.33	3.00	1.00	3.00	7.33	2
EM4	0.20	0.20	0.33	1.00	1.73	4
SUM	2.03	6.20	4.67	14.00	26.90	
	Normalised Pairwise Comparison Matrix					
	EM1	EM2	EM3	EM4	SUM	Criteria Weight
EM1	0.49	0.32	0.64	0.36	1.81	2.20
EM2	0.25	0.16	0.07	0.36	0.84	1.37
EM3	0.16	0.48	0.21	0.21	1.08	1.47
EM4	0.10	0.03	0.07	0.07	0.27	0.35
	CI and CR					
	EM1	EM2	EM3	EM4	SUM	Weights
EM1	2.20	4.40	6.60	11.00	24.20	11.00
EM2	0.68	1.37	0.46	6.83	9.34	6.83
EM3	0.49	4.40	1.47	4.40	10.76	7.33
EM4	0.07	0.07	0.12	0.35	0.60	1.73
						5.38
			Lambda Max		5.38	
			CI		0.10	
			CR		0.08	
			Consistency Ratio 0.08 < 0.1 Hence, OK			

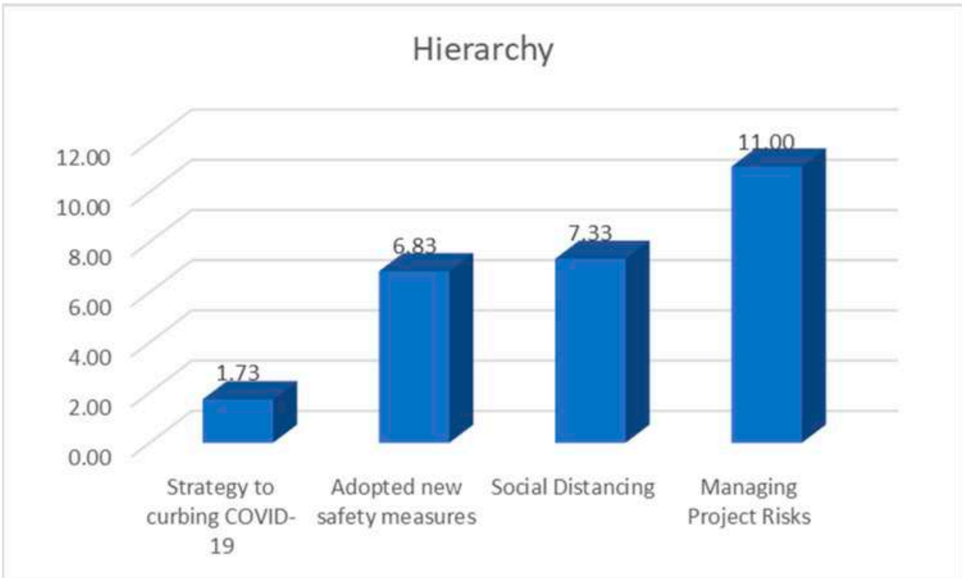

Figure 5. The priority ranking on the efforts to curb and manage the COVID-19 pandemic.

Besides, in these challenging and unprecedented times, the respondents still believe that there are new opportunities to gain amid the COVID-19 pandemic. The lesson learnt during the pandemic creates the systems and improves the current monitoring and managing project systems in Sarawak construction projects. The pandemic could give the prospect for companies to secure loans with low-interest rates even though not many respondents are in favor of that. In addition, there are still respondents who believe in more fast-track projects such as medical-related projects. Due to the COVID-19 pandemic, many people, especially skilled workers, lost their job, and some respondents believe there may be a surplus of skilled workers in the market due to lesser ongoing works and projects during the pandemic.

As mentioned in Tables 4 and 8 and Figure 4, the effects of COVID-19 on the construction industry are severe, and efforts to manage the pandemic during the challenging time and new opportunities gained from the pandemic are a good lesson learned by the industry. In the Construction 4.0 framework, several image processing, software, computer vision, and geometrical processing techniques are developed to generate 3D models from collected images. The 3D UAVs model provides information about the construction process and serves as a valuable tool for decision making and cost control. It is very important to monitor the materials entering and leaving the construction site. The volumetric comparison between the BIM model and the UAVs model at various construction stages is useful to track the material and construction progress.

Table 8. The new opportunity to gain.

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Lesson learnt for improving the existing systems	37	1	5	3.35	1.086	1.179
Ability to secure loans and low-interest rates	37	1	5	2.43	1.119	1.252
More fast-track projects, medical projects, and transportation	37	1	5	2.43	1.237	1.530
Surplus of skilled workers in the market	37	1	4	2.41	1.189	1.414
Valid N (listwise)	37					

6. Conclusions

This research was conducted to determine the effects of the COVID-19 pandemic on project work progress in the Sarawak construction industry. The research focused on the on-site work progress affected during the pandemic. The other performance measurement such as design issues, planning, and scheduling issues were not within this scope. The data were collected from a questionnaire survey distributed via WhatsApp. The AHP pairwise comparison method was used to make the analysis data more accurate and reliable. The objective of the study was to prepare the project site on methods to address the project progress due to lockdowns and new SOP. Despite some limitations in this study, the study captured some important findings related to the effects of the COVID-19 pandemic that may cause delays to the site work progress. There could be some additional effects not captured in this research as the questionnaire was designed based on the experience of the researchers. The findings were from what the respondents experienced during the pandemic from various construction players. Limited responses from only 37 respondents could affect the result of the study.

From the findings, construction projects in Sarawak were badly affected during the COVID-19 pandemic. Many projects were being stopped, slowing site work progress and productivity as all sites operated minimally in compliance with the government's directive of only 30% of workers being allowed on site to maintain social distancing. As a result, many construction sites have experienced financial losses due to project overruns and added costs such as social distancing, site sanitizing, and protective equipment directives imposed by the government. Furthermore, the COVID-19 pandemic has resulted in project grounding as a shortage of materials due to the lockdown caused an inconsistent supply of materials from suppliers. Numerous lockdowns and travel restrictions imposed by the government had caused major disruptions and impacted heavily on the shortage of manpower as well as supply chain activities. With the end nowhere in sight, the construction site has to prepare beyond normal, through a new working system to survive in the industry. Understanding the current situation and the assistance of the findings from this research may help the industry alleviate its suffering from the effects of the COVID-19 pandemic.

In order to reduce the contractors' burden, it was suggested that the government or the clients allow the contractor to claim losses such as overhead costs, machinery maintenances costs, and related costs incurred during the pandemic. The government may introduce some initiatives to address the pandemic impacts, especially on government projects. Detailed discussions on the mechanism to reduce the impacts of COVID-19 should be done between the government and the construction stakeholders involved. The COVID-19 pandemic has opened the construction players' eyes to the importance of embracing new technologies to reduce manpower as well as shorten construction periods. This study was an important contribution to the construction industry, and the findings could be used in the future in the event of another elongated pandemic occurrence. It is with our fervent hope that the study will lead to further improvement and create awareness, foster resiliency, connote preventive measures, avert delays, and manage progress control in the event of a similar situation occurring in the future.

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