

## Decision Support System of Project Delay for Improving Project Performance in Construction Project

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DOI: <https://doi.org/10.30880/jtmb.2025.12.01.010>

### Article Info

Received: 24 September 2024

Accepted: 8 August 2024

Available online: 30 June 2025

### Keywords

Construction project, decision support system, project delays, project performance

### Abstract

Malaysia's construction industry continues to play a significant role in the country's economy, and faces problems such as material shortages, quality control, payment disputes, communication breakdowns, and delays in making decisions. Project performance is always affected by project delays due to ineffectively managed construction projects. Thus, this research aims to provide a mechanism for a Decision Support System (DSS) in improving construction project performance. Therefore, the research objectives are to explore the critical factors of project delay affecting project performance improvement and examine decision support requirements for mitigating project delays. Furthermore, a DSS for mitigating project delays to improve project performance in construction projects will be developed. This research used a qualitative approach for primary data collection, with semi-structured interview questions used for data collection. The respondents involved in this research include contract managers, construction managers, project managers, and site engineers from G7 contractors located in Selangor and the Federal Territory of Kuala Lumpur. Data collection from respondents' feedback was analyzed through content analysis. Significant findings from this research identified the critical factors of project delay: material shortages, quality control, payment disputes, communication breakdowns, and delays in making decisions. Additionally, human, financial, and materials were significantly identified for decision support requirements. Google Slides and Google Spreadsheets were used for DSS development, and the system has undergone testing for the system application. In conclusion, this research enables the application of a DSS during the decision-making process to minimize G7 contractors' project delays.

## 1. Introduction

A construction project can be defined as a project that focuses on the design, planning, retrofit, renovation, and construction of a building. During a construction project, different parties must deal with different contract documents. Every project is set up with a schedule, budget, and expected quality (Islam & Trigunaryah, 2017). According to Ali and Wen (2011), construction projects of poor quality are likely to occur worldwide. Based on Hamzah *et al.* (2011), poor management, poor communication, and a lack of practical expertise are also issues that occur during project performance. Numerous construction defect cases resulted in disagreements between customers, property owners, and construction partners, particularly contractors. Olumuyiwa *et al.* (2024) stated that construction defects also contribute to poor quality, which increases the time and cost of major repairs. An effective management system improves workmanship, while inadequate site management deters motivation and impedes collaboration between the main contractor and subcontractor, leading to discrepancies (Yap *et al.*, 2017). Even with the use of high-tech systems and innovative working methods for each building project, many runs' projects still start and conclude with issues because the issues cannot be addressed appropriately (Harif, 2012). Many issues have a connection with project delays, including delays in material supply (Reddy & Rao, 2022), financial problems, and slowness in the decision-making process (Assaf *et al.*, 2006) in a construction project. They have developed a broad variety of software applications and decision support systems (DSS) to assist construction professionals in the analysis of risks associated with construction (Taroun, 2012). Therefore, the aim of this study is to seek information on the development of DSS for project delay to improve construction project performance.

In construction projects, each phase must be completed successfully for the construction to be finished on time. Problems that happen in construction projects are caused by delayed payment, financial difficulties, economic problems, and transportation can bring more problems that are unpredictable (Hamzah *et al.*, 2011). Additionally, construction projects are financially intensive and rely on a steady flow of funds to accomplish their objectives (Okereke *et al.*, 2022). The performance of a construction project can determine whether a building meets aspects such as quality, time, and cost. The problems, such as decisions on the project site, might be slowed down by a lack of coordination and management (Al-Hazim *et al.*, 2017). Determining the critical factors of project delays can reduce the risk of the building or construction being abandoned, and it can also improve the project performance in construction projects. Many problems led to abandoning the project, such as financial problems. Before being abandoned, financial problems are the accumulated consequence of the four sets of factors. For example, a lack of comprehensive feasibility assessment to establish the appropriate sort of development and an unappealing marketing approach, which eventually impacts sales and therefore leads to financial problems (Yap *et al.*, 2010). It is possible with the assistance of the system; it can reduce the impact of the problem from happening. When developing DSS, the problems that can happen need to be taken into consideration to prevent making an error in the system. The issue with the data collection and analysis is that it does too much analysis and ends up creating too many options, which is the exact reverse of what was intended (Thug, 2022). A DSS might help decision-makers by supporting managerial decisions that would otherwise be dependent on intuition and experience (Rashidi *et al.*, 2018). From this study, the construction industry can be helped by minimizing crucial reasons for project delays and improving project performance by utilizing the DSS. Therefore, this study aims to explore critical factors, examine decision support requirements, and develop a DSS for project delay to improve construction project performance.

## 2. Literature Review

### 2.1 Overview of Construction Project

The construction process methods enable us to approximate the difference between the deformations created after structure completion and the total deformations induced by the additional operating loads in construction. There are three stages in the construction process which are pre-construction, construction, and post-construction. Each stage has its challenges depending on the project size and scope. The pre-construction stages support construction project managers to more effectively monitor and control the critical parts of the project, the schedule, and the budget (Al-Reshaid *et al.*, 2005). Next, the construction stage is the preparation of whether the project will succeed or not during the execution phase. The project management, architecture, and engineering teams invest a lot of work into a project before any construction ever starts. Finally, the post-construction stage includes the time after construction is finished and before the project is turned over to the owner. Numerous processes and activities take place during this time, and it is required to clean up the mess at the construction site after finished.

A construction project includes all materials and work required for the construction of a finished building for the client's occupancy (Musa, 2013). Quality in construction projects is an important issue, but is usually ignored in the initial stages of construction. According to Ali & Wen (2011), one of the barriers to a successful project is quality, which is frequently the result of subpar construction work and a worldwide occurrence. According to

Tshele & Agumba (2014), the lack of essential skills is having a considerable impact on a nation's economic growth and development. Some previous studies revealed the consequences of selecting and employing unskilled labor in the construction sector. Communication issues in construction projects are a major cause of project delays. These issues can manifest in a variety of ways, including delays in the transmission of information, misdirection of communication to the incorrect person or location, and miscommunication resulting in miscommunication or misinterpretation. A wide range of communication issues have been identified, with a particular emphasis on within-supplier communications within the construction industry; between demand and supply during the design stage; and between and within the construction lifecycle (Hoezen *et al.*, 2006).

## 2.2 Decision Support System in Construction Performance

A Decision Support System (DSS) is a computer-based information system that supports complex decision-making and enhances its effectiveness by being interactive, flexible, and adaptable (Tripathi, 2011). An information system, referred to as a DSS, is a tool that assists a business in making decisions that necessitate judgment, decision-making, and a set of steps. The DSS assists mid and senior-level management of an organization in analyzing large amounts of unstructured information and collecting data that can help resolve issues and assist in making decisions. A DSS thus enhances the complexity of decision-making and enhances its effectiveness. The core of a DSS design is composed of the user interface, data management, and a model management system. The user interface is essential for facilitating direct communication between decision-makers and the system (Shim *et al.*, 2002). A user-friendly interface is essential for achieving intensive interaction between the decision-maker and the computer. The data management system assists in the collection of predictions based on the input provided to the system during the initial stages of the process. Additionally, it is used to store and retrieve internal and external information. The model management system provides the system with analytical capability by forming data.

A DSS is a tool to aid in decision-making. This application can help employees create more intensive project plans that ensure the possibility of success by making a new process or changing working strategies. There are five main approaches to DSS, which are defined according to the input they can process and the type of decision-making processes they can support, including knowledge-driven, communication-driven, data-driven, document-driven, and model-driven DSS. According to Marin (2008), knowledge-driven is a broad category encompassing a wide variety of systems that are intended to be used by users within an organizational setting, but which may also be used by other stakeholders in the organization. A communication-driven DSS facilitates multi-person collaboration on shared projects. The data-driven DSS model emphasizes the collection of data that is then processed to meet the requirements of the decision-maker. DSS that are document-driven are more popular and cater to a wide range of users. The goal of a document-driven DSS is to index web pages and locate documents based on a particular set of search terms or keywords. A model-driven approach focuses on the access to and control of financial, optimization, or simulation models (Marin, 2008).

## 2.3 Critical Factors of Project Delay in Project Performance

Critical factors are those elements that are essential for making decisions. These elements are decisive in determining the success or failure of a choice. The following is the discussion on the critical factors affecting project delay in project performance.

### (a) Material Shortages

As Malaysia's economy continues to grow at a rapid rate, the supply of raw materials is often insufficient to satisfy the demand, leading to an increase in prices. The crucial factor in this scenario may be a sudden rise in the cost of raw materials, which could be due to a rise in demand for a particular material, a monopoly on a particular material, or difficulties in importing or exporting enough of the material (Assbeihat, 2016). Another factor is due to a lack of essential materials such as sand, cement and stones, bricks, and iron (Sambasivan and Soon, 2006). The construction industry is heavily reliant on workers in all stages of construction, from material production and transportation to loading and unloading on construction sites. When sales of a product or commodity are not supported by local market demand, it is known as inconsistent demand (Rahman *et al.*, 2017). Patel and Rajgor (2024) highlighted that delays in material procurement can also contribute to project delays.

### (b) Quality Control Issues

According to Wai and Cho (2013), faulty performance is the most frequent occurrence in construction projects, increasing rework. Similarly, unclear drawings, standards, and a lack of coordination between project participants have similar negative impacts on quality. Installing a data collection system may help the construction to organize data. Quality control is the process of ensuring that a given product or service conforms to a defined quality standard, and the lack of a quality control system results in significant quality deficiencies. Consequently, a company needs to have a specialized team with a systematic methodology for determining which services do not

satisfy a company's set quality requirements. Subsequently, lack of adequate inspection, supervision, and construction techniques all have the same impact and are primary determinants of low quality (Wai and Cho, 2013). Moreover, construction defects have also led to poor quality and adversely affected project performance (Olumuyiwa *et al.*, 2024).

#### *(c) Payment Disputes*

According to Harris and McCaffer (2001), payment failures or late payment is used to describe a paymaster's failure to make a payment within the contractual term for certificate honor. Disagreements regarding payment terms, requests for alteration, or the quality of the work may lead to legal proceedings and delays. Delayed or withheld payments can lead to cash flow issues for contractors, which can impede their ability to make timely payments. This is in line with the findings of a previous study conducted by Abdul Rahman *et al.* (2006), in which it was noted that a lack of financial resources could impede the cash flow of the project and delay the possession of the site, thus resulting in delays in the overall project. The lack of financial resources is due to the difficulty of obtaining loans from banks and the insufficient budget allocation of the government. While awaiting payment resolution, contractors may divert funds to other projects, resulting in the current project being understaffed and causing delays. In addition, claim disputes occur when the client does not agree with the contractor's assertion and there are differences in interpretation (Sakate and Dhawale, 2017). For instance, if the contractor does not complete the project on time or within a reasonable time and it is established that the delays are the result of the contractor's negligence, the client may file a claim for Liquidated Ascertained Damages (LAD) to recoup the cost incurred by the contractor. The claim will be filed as a fee and may be calculated daily, weekly, or monthly. Delays may occur if there is disagreement as to the legitimacy or amount of such damage. Kahro *et al.* (2023) also identified financial problems as factors contributing to delays in decision-making.

#### *(d) Communication Breakdowns*

The lack of communication between the project team and the client can lead to misunderstandings and discrepancies, which cause delays. According to Valithern and Rahman (2014), the communication barrier at Malaysian construction sites found that the language barrier was the most significant in construction sites, with supervisors having difficulty communicating and providing information. In the construction industry, communication is managed through channels in all organizations. It is the responsibility of each department or unit within the organization to disseminate relevant information to create a comprehensive communication infrastructure (Fichet and Giraud, 2007). According to Lee and Bernold (2008), efficient communication is significantly hindered in the construction industry by a lack of accepted data channels, wrong channels, and incorrect data transfers. These can lead to project delays. Therefore, standardizing communication channels within the construction industry is essential to streamline the communication process. Many construction project managers do not adequately inform the project team of the purpose of a particular project, the objectives of the project, the client involved, the timeline, the limitations, and the essential success elements. The lack of this essential information affects the attitudes of project participants and the project's success (Opara and Opara, 2020). Effective communication among all stakeholders is essential to prevent misunderstandings and project delays, ensuring timely and successful delivery (Patel & Rajgor, 2024).

#### *(e) Delay in Making Decision*

According to Alaghbari *et al.* (2007), these factors are major factors that cause delays in construction projects in Malaysia by owners and clients. During the decision-making process, the client will traverse a series of critical decision points or gateways, at which they evaluate the project's state of development and evaluate whether it supports their strategic goals is cost-effective, provides value, and tolerates risk. Slow decision-making will affect the entire building process. Decision-making has been delayed due to the significant physical distance between parties involved in the construction project in rural construction areas (Deng *et al.*, 2001). A study conducted in remote areas revealed that project supervisors made extensive use of mobile phones, digital cameras, and electronic communication to monitor the progress of the project, which extended decision-making time (Sidawi, 2012). According to Owolabi *et al.* (2014), poor information and inadequate risk management lead to increased project costs, delayed project completion, and even premature projects. Kahro *et al.* (2023) noted that delays in decision-making by relevant stakeholders can negatively affect project performance. Table 1 shows the critical factors of project delay in project performance.

**Table 1** Critical factors of project delay in project performance

No.	Critical Factors of Project Delays	Authors
1.	Material Shortages	• Assbeihat (2016), Sambasivan and Soon (2006), Rahman <i>et al.</i> (2017), Patel & Rajgor (2024)
2.	Quality Control Issues	• Wai and Cho (2013), Olumuyiwa <i>et al.</i> (2024)
3.	Payment Disputes	• Harris and McCaffer (2001), Abdul Rahman <i>et al.</i> (2006), Sakute and Dhanale (2017), Kahro <i>et al.</i> (2023)
4.	Communication Breakdowns	• Valitherm and Rahman (2014), Fichet and Giraud (2007), Lee and Bernold (2008), Opara and Opara (2020), Patel & Rajgor (2024)
5.	Making Decision Delay	• Alaghbari <i>et al.</i> (2007), Deng <i>et al.</i> (2001), Sidawi (2012), Owolabi <i>et al.</i> (2014), Al-Hazim <i>et al.</i> (2017), Kahro <i>et al.</i> (2023)

## 2.4 Decision Support System Requirement in Mitigating Project Delays for Project Performance

Project delays often have a significant impact on construction projects. To mitigate these delays and enhance project performance, it is crucial to identify the requirements for a DSS. The following discussion focuses on these essential requirements.

### (i) Human

The first decision support system requirement in mitigating project delay for project performance improvement in construction projects is based on factor management, communication, and decision-making. The role of management is to plan, organize, lead, inspire, monitor, and manage the organization. According to Masood and Farooqui (2009), the management system is a set of tools intended to support the administration in carrying out its responsibilities effectively and efficiently. Communication methods should be based on an in-depth understanding of how people work together in group activities, fundamental ideas of social dynamics and learning theories, and how people convey, receive, and interpret words and visuals (Aulich, 2013). To make effective decisions, it is essential to have a thorough comprehension of reality and social context (Vasilescu, 2011). Ideally, individuals make decisions by recognizing and comparing alternatives to decide which one is most suitable for a particular set of conditions. Furthermore, Last Planner System (LPS) and collaborative meetings have a high influence on mitigating delays for construction project managers to improve overall project efficiency (P'erez *et al.*, 2024).

### (ii) Financial

Next, financial resources are the finances and assets that support the operations and investment of an organization. All building projects require financing to be successful. According to Okereke *et al.* (2022), building projects are capital-intensive and require a consistent flow of funds to achieve project goals and objectives. Cash flow management is a fundamental component of modern corporate management, and it is an essential tool for monitoring and managing the day-to-day operations of an organization (Milojevic and Miletic, 2014). A well-executed cash flow statement, as well as its interpretation, is essential for the successful management of cash flow. Building projects are complex and hazardous. Even profitable construction businesses, as documented in the literature, may fail due to a lack of cash flow (Liu *et al.*, 2009). According to Staiti *et al.* (2016), the project owner may have initiated change orders due to budgetary constraints, a lack of understanding or concept, or simply a reassessment of the financial impact on the customer to the high value of the project which means 10 % to 30% of the change in cost can cost the client. Conversely, change order can be minimized if all construction partners are adequately prepared before commencing work, if sufficient time and budget are available, a defined scope is established, proper coordination is established, and communication is consistently maintained.

### (iii) Materials

According to Loganina (2020), quality control in construction materials and regulated parameters are determined and compared to acceptable levels by current regulatory standards. In the event of selective control, only a proportion of the overall set is used. Based on the measurement results, a determination is made as to the

suitability or rejection of the product. To minimize waste and environmental impact, improved logistical efficiency is necessary (Matouzko, 2015). When working on large-scale construction projects, a temporary building logistics hub, or temporary warehouse, can be an effective solution to store all the commodities flow that arrives at the site. Inventory management plays an important role in the completion of construction projects successfully and on time. The primary purpose of the inventory is to ensure that the necessary materials, such as finished products, spare parts, and tools, stored on-site are available when needed. According to Malik and Sharma (2022), the inventory management system is composed of various components, such as finding suitable materials, the procurement process of these materials, the transportation of these materials, and the cost of materials on the construction site can be approximately 50-60% of the total project, thus it is essential to manage the materials systematically. Table 2 shows the decision support requirement in mitigating project delays for project performance improvement in construction projects.

**Table 2** DSS requirement in mitigating project delays for project performance improvement in construction projects

No.	Decision Support Requirement	Author
1.	Human	<ul style="list-style-type: none"> <li>Masood and Farooqui (2009), Aulich (2013), Vasilescu (2011), P'erez <i>et al.</i> (2024)</li> </ul>
2.	Financial	<ul style="list-style-type: none"> <li>Okereke <i>et al.</i> (2022), Milojevic and Miletic (2014), Lin <i>et al.</i> (2009), Staiti <i>et al.</i> (2016)</li> </ul>
3.	Materials	<ul style="list-style-type: none"> <li>Loganina (2020), Matouzko (2015), Malik and Sharma (2022)</li> </ul>

### 3. Research Methodology

#### 3.1 Research Design

A qualitative research strategy (i.e., semi-structured face-to-face interview) and an inductive approach were adopted (Ebekozian *et al.*, 2021). A qualitative method was utilized for this research. Interviews with individuals who hold appropriate positions in the construction industry will form the basis of the qualitative method of data collection. Secondary data were gathered by evaluating data from sources such as books, journals, articles, websites, and any reports connected to the study on the DSS of project delay for improving project performance in construction projects. Table 3 shows the research objectives vs the method adopted in this study.

**Table 3** Research objectives vs method

No.	Research Objectives	Method
1.	To explore the critical factor of project delay affects the improvement of project performance in construction projects.	<ul style="list-style-type: none"> <li>Literature Review</li> <li>Qualitative</li> </ul>
2.	To examine the decision support requirements in mitigating project delays for project performance improvement in construction projects.	(Semi-structured Interview)
3.	To develop a decision support system to mitigate project delays and improve project performance in construction projects.	<ul style="list-style-type: none"> <li>Rapid Prototype</li> </ul>

The research process is structured into five phases to get feedback on the importance of DSS for mitigating project delays and improving performance. Phase 1 focuses on researching and debating the problem statement. This includes the research background, problem statement, questions, objectives, scope, significance, and methodology. Next, Phase 2 is the literature review, which examines previous studies on DSS for project delays to enhance project performance in construction projects. Information is collected from various sources such as journals, newspapers, articles, books, and publications to achieve research objectives. In addition, Phase 3 involves data collection. There are two types of data: primary data, which is qualitative and gathered through semi-structured interviews, and secondary data, sourced from books, journals, articles, and research publications. The construction industry professionals, such as project managers, construction managers, contract managers, and site engineers, are involved and located in Selangor and Kuala Lumpur. Moreover, Phase 4 is dedicated to data analysis and results. The findings from interviews are used to analyze recorded data in media, text, or physical items. Content analysis is typically used to interpret the interviewee's comments based on the research questions. Lastly, Phase 5 involves drawing conclusions and making recommendations. At this stage, all data analysis is summarized, and recommendations, along with plans for further research, are provided.

### 3.2 Data Collection

Data collection is the process of obtaining and analyzing information about certain system factors to acquire more thorough and evidence-based data to evaluate the outcomes. According to Kabir (2016), all data should be collected to produce rich data analysis that can be utilized to provide plausible and persuasive answers to research questions. The data collection was separated into two categories: primary data and secondary data. As a result of utilizing these methods, the data collection was extremely thorough. Taieh *et al.* (2020) stated that secondary data sources might include both internal and external informational resources that could provide information on a variety of topics, such as conferences, magazines, websites, and other sources. Furthermore, primary data are those that are gathered specifically for the study subject using methods that work best for the research problems (Hox and Boeijs, 2005). Photographs and interviews with industry personnel, including managers and workers, as well as surveys and conversations, were used to document the working environment of the various industries (Taieh *et al.*, 2020).

According to Stuckey (2013), the opportunity to get an in-depth understanding of the subject of interest is essential for developing pertinent and meaningful semi-structured interviews and is frequently preceded by observation, informal interviewing, and unstructured interviewing. The interview questions consisted of THREE (3) sections: Section A: Respondent Background, Section B: Critical Factors of Project Delay Affecting the Improvement of Project Performance in Construction Projects, and Section C: Decision Support Requirements in Mitigating Project Delays for Project Performance Improvement in Construction Projects. In Section A, the background of respondents, such as the company's name, position, years of experience in construction projects, level of study, and scope of work, was asked. Furthermore, in Section B the questions such as material shortages, quality control, payment disputes, communication breakdowns, and delay in making decisions have been asked to gain information about critical factors of project delay that affect the improvement of project performance in construction projects. The purpose of Section C is to gain information related to decision support requirements in mitigating project delays by asking respondents about human, financial, and material factors.

For this study, the G7 contractors registered with the Construction Industry Development Board (CIDB) have been chosen as a population to achieve the study objectives. Purposeful sampling is a term used to describe a range of non-predictive sampling procedures in which the study sample is selected from the population. G7 contractors were chosen because they are the most prestigious category in CIDB registration and are thus more likely to be awarded extremely large contracts. Furthermore, the professionals, such as project managers, construction managers, contract managers, and site engineers, are the target respondents for this study due to their appropriate expertise and knowledge. Selangor and Kuala Lumpur will serve as the area for the investigation because in the fourth quarter of 2022, the value of construction work conducted in Selangor and Kuala Lumpur amounted to roughly 60% of the total value of construction work performed in Malaysia (DSOM, 2023). The duration of data collection to get feedback related to the study objectives is two months. A pilot test was conducted to evaluate the interview questions as a research instrument, and feedback from the participating construction practitioners was used for improvement. According to Teijlingen and Hundly (2010), the advantages of conducting a pilot test may include early warning of potential areas where the primary research project may not be successful, where research procedures may not be adhered to, or where planned methodologies and instruments may not be suitable or overly complex.

### 3.3 Data Analysis

The process of data analysis involves purification, transformation, and modeling of data to identify relevant information for business decisions. Data analysis involves the extraction of useful information from the data and the decision-making based on the information, as well as the application of logical and analytical reasoning to the evaluation and analysis of data. According to Joel (2014), data analysis is the process of using data to solve a search query. It is essential for the resolution of research questions. Another important aspect of the research involves the interpretation of data. This is done by analyzing the data and drawing inferences and conclusions. For this study, content analysis was used as a method to identify the configurations of conditions that lead to research objectives. The content analysis was conducted to obtain information for Objective 1: to identify the critical factors of project delay affecting the improvement of project performance in construction projects, and Objective 2: to analyze the decision support system requirements in mitigating project delays for project performance improvement in construction projects. Content Analysis is a powerful analytical technique used to interpret the subjective content of qualitative data systemically and contextually. It is increasingly being used by researchers in a variety of fields where content analysis is used as a research technique to evaluate the presence of particular words, topics, or concepts within qualitative data (Selvi, 2019). Content analysis offers a promising approach to unravel the complexities associated with the interaction of multiple conditions that affect an outcome and how these conditions interact with each other. Content analysis is a method of measuring and analyzing the presence, meaning, and association of particular words, topics, or ideas.

### 3.4 Prototype Development

Prototyping is a process of building an experimental system quickly and inexpensively for demonstration and evaluation so that the users can better determine information requirements (Laudon and Laudon, 2002). A rapid prototyping methodology was used in the development of the prototype system. According to Turban and Aronson (1998), the key strengths of prototyping include: short development time; short user reaction time (feedback from user); improved user understanding of the system, its information needs, and its capabilities; and low cost. Several iterations to refine and enhance the prototype can be done before completing the final operation, because the prototype can be developed quickly and inexpensively. Therefore, the stage of formative evaluation has been undertaken in this study to improve the intervention, assess the strengths and weaknesses of the specific program, and capture further improvements through built-in monitoring or continuous feedback on a program used for prototype system development.

According to Kordon and Luqi (2002), prototypes enable the requirements phase of any type of software when the requirements have evolved from the preceding version, which is typically the case. To construct the system, the prototypes will use Google Slides and Google Spreadsheet as a platform. Prototypes can be used to demonstrate system scenarios to people as a means of collecting criticism and feedback for the updated requirements. They can also be used to identify deviations from user expectations early, monitor the evolution of requirements, and provide early warnings of discrepancies between software and the conceptual structure of requirements. An evolutionary prototype model methodology is illustrated in Fig. 1, demonstrating the full potential of this approach. Refinement in Fig. 1 is mainly concerned with requirements, and a model prototype is a precise and comprehensive description of a system that serves as a foundation for both assessment and program development.

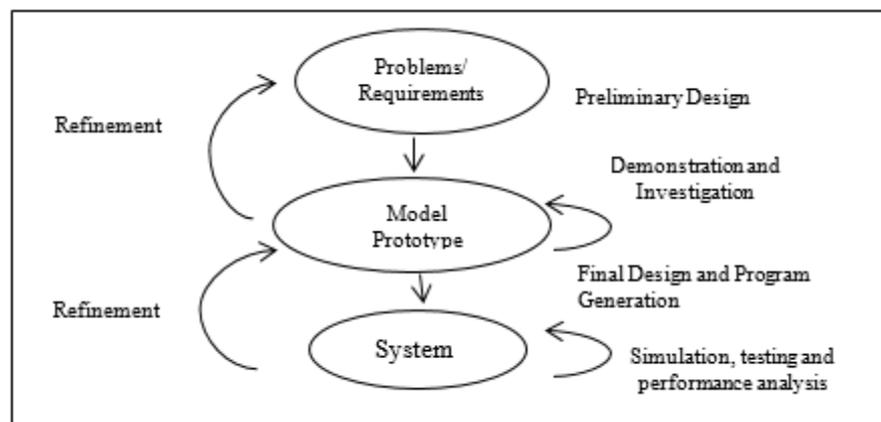


Fig. 1 Evolutionary prototype model methodology (Kordon and Luqi, 2002)

## 4. Results and Discussion

### 4.1 Respondent's Background

The data for this study was gathered through physical interviews and virtual interview sessions, which included communication by WhatsApp, mobile phone, Microsoft Teams, and any other tool that contributed to the data collection. Microsoft Word was one of the software programs utilized to transcribe the information that was collected. During the preliminary phases of this study, the identification of respondents was based on the construction organisation that had been registered with the Construction Industry Development Board (CIDB) and classified as a G7 contractor. The selection of G7 contractors as respondents in this study was established with their involvement in the construction project and willingness to interview. The personnel from G7 contractors involved in the interview session are in positions such as contract manager, construction manager, project manager, and site manager. The selection of respondents' positions was recognised from their sufficient expertise and knowledge in managing construction projects. The collected data were obtained for two months and five days from 1st November 2023 until 6th December 2023, as all the data from five respondents were collected. Five respondents for each G7 contractor have been identified based on their willingness to give feedback and participate in the interview. The respondents are located in Selangor and Kuala Lumpur. The analysis was based on the information offered and provided by the five respondents who agreed to cooperate, and the outcome of this interview session was delivered. Subsequently, the content analysis method was used to analyze the data gathered from five respondents. Table 4 shows the demographics of the respondents, including the respondents' profiles and information about their companies. Those respondents hold an essential and significant position

within the company, and they are directly involved in construction projects. According to this analysis, the respondents had appropriate and sufficient expertise and knowledge to participate in this study.

**Table 4** Respondent's background

Respondents (R)	Organisations	Positions	Years of Working Experience in Construction Project	Academic Qualification	Scope of Work
R1	Company A	Contract Manager	23 years	Master	<ul style="list-style-type: none"> <li>Responsible for Managing Contract</li> <li>Estimating and Managing Construction Costs</li> </ul>
R2	Company B	Construction Manager	13 years	Bachelor Degree	<ul style="list-style-type: none"> <li>IBS</li> <li>Monitoring and Managing IBS Components</li> <li>Oversee the Planning and Delivery of Construction Projects</li> </ul>
R3	Company C	Project Manager	6 years	Diploma	<ul style="list-style-type: none"> <li>Manage Construction</li> <li>Project Architecture</li> </ul>
R4	Company D	Project Manager	15 years	Bachelor Degree	<ul style="list-style-type: none"> <li>Engineer</li> <li>Manage Project</li> </ul>
R5	Company E	Site Engineer	10 years	Bachelor Degree	

## 4.2 Critical Factors of Project Affect the Improvement of Project Performance in Construction Project

To achieve the objective, it is necessary to determine whether the respondents have experience and knowledge about critical factors of project delays in the construction industry. This will allow the respondents to comprehend the questions and responses to give in the data. This is done to guarantee and verify that respondents are aware and have an opinion regarding the project delays. All of the respondents answered and responded to the question, proving that all respondents are aware of project delays. Based on Table 5, there are five (5) factors which were material shortages, quality control, payment disputes, communication breakdowns, and delays in making decisions. In material shortages, lack of materials was most agreed upon by all the respondents, while costs of raw material were only responded to by R3 and R4, and for inconsistent material, all respondents agreed except R5. Next, quality control is an important factor in construction. By looking at the statement, all respondents (R1, R2, R3, R4, & R5) acknowledged that the lack of adequate inspection caused delays to the construction project.

**Table 5** Statement of critical factors of project delay affecting the improvement of project performance in construction project

Statement	R1	R2	R3	R4	R5
<b>(i) Material Shortages</b>					
• Lack of Materials	✓	✓	✓	✓	✓
• Costs of Raw Materials			✓		✓
• Inconsistent Material	✓	✓	✓	✓	
<b>(ii) Quality Control</b>					
• Unclear Construction Drawing	✓		✓		✓
• Lack of Quality Control Procedures	✓	✓		✓	✓
• Lack of Adequate Inspection	✓	✓	✓	✓	✓
<b>(iii) Payment Disputes</b>					
• Variation Order	✓	✓	✓	✓	✓
• Payment Failure		✓	✓	✓	✓
• Claim Disputes	✓				✓
<b>(iv) Communication Breakdowns</b>					
• Language Barriers	✓	✓			✓
• Misunderstanding of Project Specification	✓			✓	
• Lack of Essential Information	✓			✓	
<b>(v) Delay in Making Decision</b>					
• Distance between Decision-Makers	✓	✓	✓	✓	✓
• Inadequate Risk Management	✓		✓	✓	
• Consequences of Delays in Making Decision	✓	✓	✓	✓	✓

### 4.2.1 Material Shortages

The respondents highlighted critical factors leading to project delays due to material shortages and ways to improve project performance in construction projects. They indicated that preventing material shortages can help mitigate these delays by collecting data from suppliers and keeping informed with government news, placing bulk orders in advance, and ensuring clear communication with suppliers regarding materials and deliveries. Guaranteeing the availability of materials when needed can significantly enhance project performance. This result aligned with the previous study in Alaghbari *et al.* (2007). The respondents' detailed statements on material shortages are included below.

*“Project delays happen because of the fluctuation in materials prices after COVID-19. Materials like cement and steel were increased over time. The prices in the project contract before COVID-19 are different; it's going to be difficult because of severe price fluctuations. By booking the material in a bulk order, the contractor and supplier will be included in a contractual agreement where the price of the material is going to be the same or decrease. Usually, the supplier decreases the prices when ordering in bulk.”* (R3 & R5)

*“Inconsistent materials can also create project delays. The best way to minimize this is by communicating with the supplier regarding the materials and deliveries. To avoid problems, our company normally orders or books the material in bulk in advance to ensure its availability. It's better to have more than less.”* (R1, R2, R3, & R4)

### 4.2.2 Quality Control

The respondents provided insights on how quality control, as a critical factor in project delays, influences the improvement of project performance in construction projects. They emphasized that frequent inspections are essential to ensure workers adhere to specifications and maintain project quality. The statement indicates that while quality control can lead to delays, it is crucial for upholding construction standards. The respondents' detailed statements on quality control are included below.

*"Quality control is the most important part of the construction. The impact can cause project delays. The project needs more time if the drawing were unclear, it would bring miscommunication and misinterpretation between project teams. Humans are not all perfect sometimes they make errors."* (R1, R3, & R5)

*"Conducting the quality control is supposed to be from the start until the end of the construction project. It causes reworks if some of the tasks are not achieving the standard quality. It can also be dependent on the construction project if there is more investment in quality control, the quality can be the highest good quality, but it can cause increased time and costs."* (R1, R2, R4 & R5)

*"The lack of adequate inspection affected the project performance, the dispute between project teams, and Increased works and times on documentation and approval. If the worker were not following the specification of the drawing, the project would be delayed and increase the reworks on the same task."* (R1, R2, 23, R4 & R5)

### 4.2.3 Payment Disputes

The respondents' statements on critical factors causing project delays, particularly related to payment disputes, are presented below. Financial disputes, whether originating from the client, main contractor, or other parties, are identified as the primary contributors to these delays. The statements highlight that managing costs is crucial for the successful execution of construction projects.

*"Variation orders are new tasks that are going to be input on the existing construction project. It causes delays in the project because it needs time to prepare the documentation and approval from the client. It also disturbs the duration of the existing project based on the order of whether it is going to be an addition or alteration. If the client were fine with the additional costs and time, everything going to be easy."* (R1, R2, R3, R4, & R5)

*"Disruption of cash flows will delay the payments and it affects the project to progress smoothly. These reasons are like the domino effect to the project which if one work is stuck and the following tasks are also stuck. The client not releasing the funding is also a reason for the payment failures. Some contractors don't have a modal to start the tasks. They need the money to order the material and equipment."* (R2, R3, R4, & R5)

*"Project delays are 80 % money-related. The disputes between clients and contractors are usually about claims and conflicts about ideas and views of points. The contractor needs to deposit about 5% to start the work by buying the mobilization and material. If this cannot be given, it will affect the duration."* (R1 & R5)

### 4.2.4 Communication Breakdowns

The statement from respondents highlights communication breakdowns as a key factor in project delays that impact the improvement of performance in construction projects. While language barriers are not a major issue if workers can understand the communication, misunderstandings and a lack of proper confirmation can make communication breakdowns a critical problem. Ensuring workers understand the importance of accurate information is essential for project success.

*"It usually happens if the project teams have different native languages such as Korean, Japanese, and African. Although using one language which is usually English it can be hard if the nuance for their native language is thick. The information on the project needs to be understood, the misunderstanding or misinterpretation can cause the project delay."* (R1, R2, & R5)

*"It is rare to happen in construction projects, but human error cannot be said. The discrepancies between drawings like architecture, structure, and mechanical and electrical cause misunderstandings between project teams which of the drawings need to be followed. Yes, it causes the project delay because the project manager needs time to recheck and confirm with the consultant about the drawing. This misunderstanding also can happen if the worker were to study on a different course. For example, quantity surveyors did not know the technical terms that were used in the architecture drawing."* (R2 & R4)

*"It affects project performance if the lack of essential project information such as contract, specification, and others are not in detail. It causes the workers to do double work and the construction project will cost overruns. The double works are going to affect the moral worker for doing their job."* (R1 & R4)

### 4.2.5 Delay in Making a Decision

The following statement emphasizes the impact of decision-making delays on project performance in construction projects. These delays typically occur during critical work phases. To prevent exacerbating project delays, it is essential to manage the gap between decision-makers and risk management effectively. Failure to do so can result in serious consequences, such as additional delays and cost overruns.

"Delays in making a decision usually happen at the site. It stressed out the supervisor and project manager by waiting the feedback from the higher-ups. Issues usually occur when the decision-maker is away from the site. Miscommunications happen when sometimes the site manager doesn't know the details of the contract and does the job by following his understanding and when the project manager checks the work it is different from the specification, it needs to be reworked and it could project delays." (R1, R2, R3, R4, & R5)

"Inadequate risk management not only compromises project outcome but also contributes directly to potential hazards. If one worker is neglecting the potential risks, it can contribute the risks to other workers. These risks need to be identified before the planning to bring safety to the construction site." (R1, R3, & R4)

"The consequence of delay in deciding is cost overruns when unforeseen challenges affect the budget. While waiting for the decision, some tasks had to be held and it caused the continued task to need to be on hold. It concluded that the project will be delayed." (R1, R2, R3, R4, & R5)

### 4.3 Decision Support Requirement in Mitigating Project Delays for Project Performance Improvement in Construction Project

The decision support requirement in mitigating project delays for project performance improvement in construction projects can be implemented into the decision support system. The feedback that was collected during the interview is going to be input into the system as the answer. To make effective decisions, it is essential to have a thorough comprehension of reality and social context (Vasilescu, 2011). Table 6 shows the statement of decision support requirements in mitigating project delays for project performance improvement in construction projects.

As shown in Table 6, the statement of decision support requirement in mitigating project delays for project performance improvement in construction projects was divided into three (3) categories, which were human, financial, and material. In human categories, all respondents except R3 acknowledged the requirement and strategies for management, while the communication-only respondents (R2 & R4) responded, and in making decisions, two respondents (R2 & R3) responded. Next, financial categories consist of financial resources, cash flow management, and variation order. Cash flow management was acknowledged by all respondents (R1, R2, R3, R4, & R5), while the other point, financial resources, only had three respondents (R1, R2, & R4), and for variation order, respondents (R2 & R3) responded. For the last category, which is material, the quality control (R2, R3, R4 & R5) and logistic efficiency (R1, R2, R3, & R5) have the same number of respondents, but one of each respondent is different. For the inventory management (R1, R3, & R4), the respondents agree with this point. The decision support requirement in mitigating project delays for project performance improvement in the construction projects section was answered well by the respondents, which included three requirements that have been discussed, such as human, financial, and material.

**Table 6** Statement of decision support requirement in mitigating project delays for project performance improvement in construction projects

Statement	R1	R2	R3	R4	R5
<b>(i) Human</b>					
• Management	✓	✓		✓	✓
• Communication		✓		✓	
• Making Decision		✓	✓		
<b>(ii) Financial</b>					
• Financial Resources	✓	✓		✓	
• Cash flow Management	✓	✓	✓	✓	✓
• Variation Order		✓		✓	
<b>(iii) Material</b>					
• Quality Control		✓	✓	✓	✓
• Logistic Efficiency	✓	✓	✓		✓
• Inventory Management	✓		✓	✓	

### 4.3.1 Human

The following feedback from respondents addresses the decision support requirements for mitigating project delays and improving project performance in the construction sector, specifically in the Human Category. The statement highlights that effective management, clear communication, and preparedness in decision-making are key strategies to address project delays. This statement is in line with the previous research in P'erez *et al.* (2024). These strategies will be incorporated into the decision support system within the Human Category.

*"Effective management is the art of assembling not just individuals but diverse talents into good teams. By combining the different talents and viewpoints of a competent Supervisor and Project Manager it can overcome the challenger. Allocate the human resources optimally can affect the performance to be more efficient"* (R1, R2, R3, & R4)

*"Daily meetings lay the foundation of good communication it makes the project team to be more understanding about what to do and solving the problem. Consistent planning can ensure alignment, navigate the challenges, and increase the efficiency of the project. Meetings using an application such as WhatsApp also can be done by communicating and sharing information or documentation. By meeting using the WhatsApp app, all of the conversation can be used as evidence because it is documented."* (R2 & R4)

*"Making decisions not only involves making choices but ensuring preparedness. Making a solid mitigation plan can foresee the problems and strengthen the decision. When faced with uncertainty, a well-planned can serve as the information for successful decision-making."* (R2 & R3)

### 4.3.2 Financial

According to the respondents' feedback, the strategies to be incorporated into the system for the financial category include planning financial resources, managing cash flows and contingency funds, and incorporating variation orders into the planning. The feedback on decision support requirements for mitigating project delays and improving project performance in construction projects, specifically for the financial category, is outlined below.

*"When planning, allocation for contingency funds can be input as a safety net for unforeseen challenges. Adding 20% as extra allocation for contingency funds to the estimate can mitigate project delays that have a problem with the finances. These strategies ensure the preparedness for whatever financial problem may unfold."* (R1, R2, & R4)

*"A good cash flows management involves thorough monitoring of inflows and outflows. By managing it well it can reduce the potential for project delays. It can also guarantee their financial stability and sustainable growth."* (R2 & R3)

*"Input contingency funds into unexpected tasks in cash flow management can strengthen the project's finances. The project may overcome the risks and exploit opportunities by navigating the problems."* (R1, R4, & R5)

*"As said in the previous question, variation order is the flexibility of the client to change the project whether it's an addition or modification to an existing project. Planning the possibilities of variation order at an earlier stage, can let the supervisor or project manager in extra alert and prepare the documentation."* (R2 & R4)

### 4.3.3 Material

The strategies outlined in the statement pertain to the material categories. This feedback from respondents highlights the decision support requirements, including quality control, early inspections, verifying delivery orders for logistical efficiency, and using Excel to track material quantities.

*"Quality control begins with a proactive approach with double-checking materials before and after delivery to ensure the quality achieves the standard. By implementing this, the supervisor can ensure the quality of the material. If the material were not achieving the quality standard, the Supervisor will contact the supplier to reimburse the material."* (R4 & R5)

*"Early inspection for quality material can be input into planning. It can be predicted whether these tasks are going to be the critical path that causes delay or not."* (R2 & R3)

*"Logistic efficiency is dependent on thorough delivery order checks and communication with supplier for timely updaters. Implement that it can reduce delays and ensure the supply chain. and optimizing the project performance."* (R1, R2, R3, & R5)

*"Managing inventory for material can be difficult when using by hand. With the help of tools like Excel, can ensure accuracy in tracking material quantities before and after delivery. By utilizing the technology, it can optimize the operations."* (R1, R3, & R4)

#### 4.4 DSS for Mitigating Project Delay for Improving Project Performance in Construction Projects

Developing a prototype of a DSS for mitigating project delay for improving project performance in construction projects was implemented by using Google Slides and Google Spreadsheet as tools, the data that were collected using a qualitative method, and analyzing the decision support requirement using the content analysis to get the data that were input into the system. A DSS is a computer-based information system that supports complex decision-making and enhances its effectiveness by being interactive, flexible, and adaptable (Tripathi, 2011). According to Agbo & Ogai (2013), the development of the DSS and the utilization of information systems in the public sector are becoming increasingly important in many organizations.

Figure 2 shows the interface of the DSS, where the button starts to move into the next interface. By clicking the start button, it will direct you to other interfaces of categories for the problems. It has three categories, which are human, financial, and material. For example, having a problem with human resources, and this type of problem is more prone to humans, just clicking on human categories will show the interface for the type of problem, which is shown in Fig. 3. Fig 4 (a) shows the type of problems for the Human Category which were management, communication, and making decisions. The function is the same as Fig. 4, where choosing the problem, clicking the type, and it will show the solution for each problem (Fig. 5 (a)), and it has a back button that will go back to the categories of the problem interface. Fig. 5 (b) shows that each problem has a link to the spreadsheets (Fig. 6) at the solution of the problem interface, where this spreadsheet interface will determine the solution that is going to be used. The spreadsheet can be sent to the other decision-makers to take their point of view and experience of the problems to get the best solution. The solution can be changed in Google Slides by the authorized user who handles this system. The steps to use for each category and each type of problem for the Financial Category (Fig. 4 (b)) and the type of problem for the Material Category (Fig. 4 (c)) are the same as the explanation.

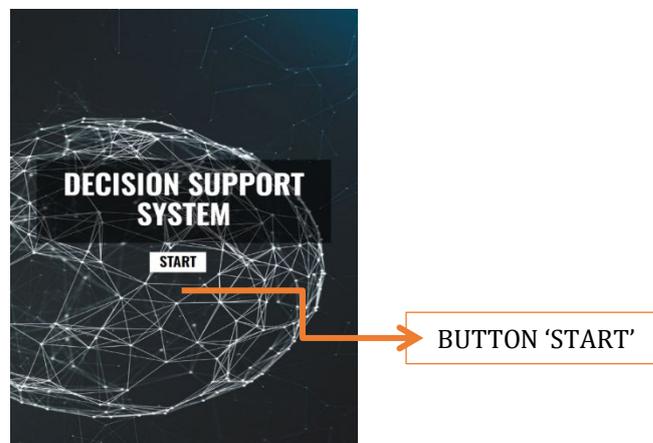


Fig. 2 Front interface of Decision Support System (DSS)

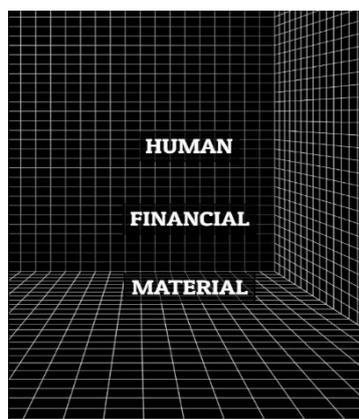
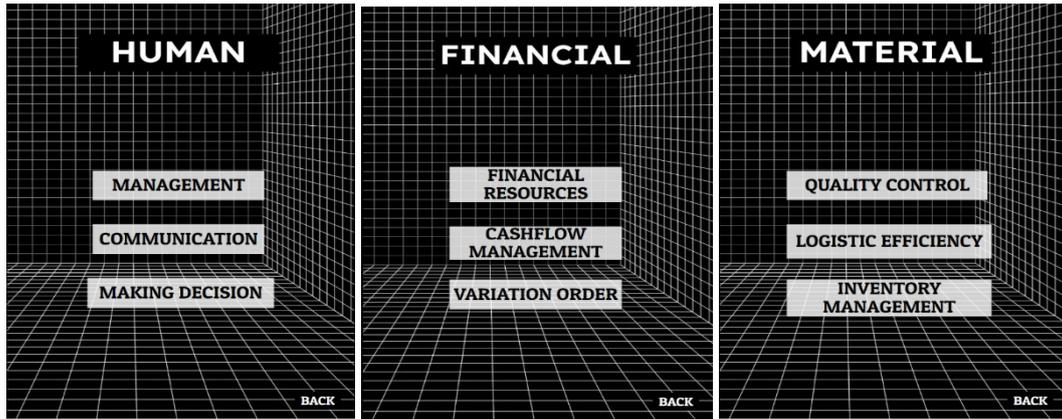


Fig. 3 Categories of Decision Support System

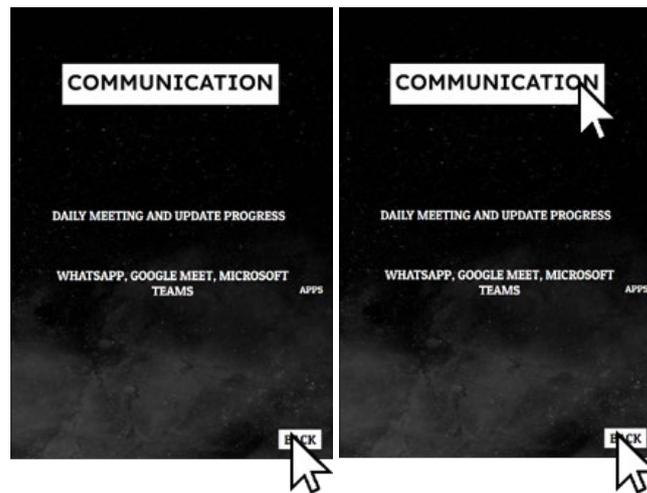


(a)

(b)

(c)

Fig. 4 Type of problems (a) Human category; (b) Financial category; (c) Material category



(a)

(b)

Fig. 5 Solution of the problems (a) User; (b) Authorized

DAILY MEETING AND UPDATE PROGRESS	
AGREE	DISAGREE
<input type="checkbox"/>	<input type="checkbox"/>
0	0

Fig. 6 Spreadsheet Interface

## 5. Conclusion

This research was conducted to give the construction stakeholders involved in the construction project the tool to mitigate project delays. To achieve the first objective which is to identify critical factors of project delays and the second objective which is the decision support requirement which has three categories (Human, Financial, and Material), and each category has a problem, the qualitative method was used for this study on G7 Contractor who were registered and authorized by CIDB, with data acquired through interview sessions that were handled via online session and offline session. Five out of ten companies responded and gave feedback during the interview session. The acquired data from the respondents was analyzed by the researcher using Microsoft Word software and was then input into the system to achieve the third objective, which is to develop a DSS. This system uses Google Slides and Google Spreadsheets software as the interfaces. In conclusion, this research was successfully conducted, and all the research objectives were accomplished and achieved, which can be acknowledged as identifying critical factors of project delay affecting the improvement of project performance in construction projects and analyzing the decision support requirement in mitigating project delays for project performance improvement in construction projects. Despite certain limits and difficulties in carrying out this research, such as postponing the interview session because of the hectic schedule of the respondents, the data collected and obtained by using the mixed approach that includes offline and online interview sessions is sufficient to be analyzed and fulfills the research objectives. Ideally, the acquired data would make the construction industry more interested in the need for a DSS for project delay to improve project performance in construction projects.

## Acknowledgement

The author would like to thank the Faculty of Technology Management and Business and Universiti Tun Hussein Onn Malaysia for their support.

## Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

## Author Contribution

The authors confirm their contribution to the paper as follows: **study conception and design:** Faizal N.F., Kasim, N. **data collection:** Faizal N.F.; **analysis and interpretation of results:** Faizal N.F., Kasim, N., **draft manuscript preparation:** Faizal N.F., Kasim, N., Ern, P. A. S., Ismail, Z.A., Namara, I. All authors reviewed the results and approved the final version of the manuscript.

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