Realizing the Potential of AI in Construction Delay Analysis: An Examination of the Issues and Improvement Needs in Delay Analysis Techniques at SMDC Projects

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Abstract

This research investigates the potential of Artificial Intelligence (AI) to improve delay analysis techniques within the construction industry, specifically focusing on SM Development Corporation (SMDC) projects. The study aims to identify the limitations of traditional delay analysis methods (Balli & Güven, 2022) and explore how AI can address these shortcomings to enhance project outcomes (Egwim et al., 2021).

This likewise explores the question: ***how can SMDC project teams use artificial intelligence to prevent delays?*** This study explores three crucial aspects of project team members' work—documentation, analysis, and comprehension of delay analysis and AI potentials—by considering common delay causes, the challenges faced by project teams, and insights from delay analysis, scheduling tools, and AI tools as discussed in the literature.

The research employs a mixed-methods approach. A comprehensive literature review examines existing delay analysis techniques and the application of AI in construction (Ivanović et al., 2022). Survey regarding the understanding and insight of SMDC project team members regarding delay analysis and the potential of AI Tool for delay analysis was conducted. Further, interview to project team members of SMDC projects was conducted to assess current delay analysis practices and identify areas for improvement (Boyacioglu et al., 2022).

The study anticipates that AI-powered solutions can offer more objective, data-driven, and real-time delay analysis compared to traditional methods (Egwim et al., 2021). The research will likely reveal challenges in data quality, expertise, and integration that hinder AI implementation (Almén, 2024).

The research is limited by the availability of high-quality data from SMDC projects and the potential for bias in case study selection (SANNI-ANIBIRE et al., 2020). The generalizability of findings may be restricted to similar construction companies and project types (Ivanović et al., 2022).

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The findings will provide practical recommendations for SMDC and other construction firms on how to effectively implement AI in delay analysis (Almén, 2024). This includes strategies for data standardization, training, pilot project implementation, and fostering collaboration (Yaseen et al., 2020). The successful application of AI is expected to lead to more efficient project management, reduced cost overruns, and improved project delivery for SMDC (Arun, 2013).

Keywords: *Causes of Delay; Delay Analysis Techniques; Artificial Intelligence; Machine Learning; SM Development Corporation; Project Management*

1. Introduction

The construction industry significantly contributes to the global economy; however, it consistently faces challenges related to project delays and cost overruns (Almén, 2024). These delays can lead to a variety of negative consequences, including cost overruns, strained stakeholder relationships, and potential legal disputes (Boyacioglu et al., 2022).

The core problem lies in the limitations of traditional delay analysis methods to effectively address the complexities and data-rich environment of contemporary construction projects. These limitations include the time-consuming nature of information retrieval, confusing multiplicity of delay analysis methods, and difficulty of presenting complex evidence (Boyacioglu et al., 2022). The inability to accurately and efficiently analyze delays hinders proactive decision-making, leading to reactive mitigation strategies that are often costly and ineffective. As the construction industry is slow in change, AI is not yet efficiently used (Almén, 2024).

AI offers a promising avenue for transforming construction delay analysis (Balli & Güven, 2022). AI technologies, such as machine learning, have the potential to provide objective, data-driven insights into the causes and impacts of delays (Egwim et al., 2021). By analyzing vast amounts of project data, AI algorithms can identify patterns and predict potential delays before they occur, enabling proactive mitigation strategies (SANNI-ANIBIRE et al., 2020).

This research aims to investigate the potential of AI in enhancing delay analysis techniques, with a specific focus on projects undertaken by SM Development Corporation (SMDC). SMDC, as a major player in the real estate and construction industry, faces unique challenges in managing project timelines and costs. This study seeks to examine the limitations of current delay analysis practices within SMDC and explore how AI can be effectively implemented to address these shortcomings.

The research will explore the current state of AI adoption in the construction industry specifically in SMDC projects, focusing on its application in delay analysis. It will identify the key challenges and opportunities associated with implementing AI in this context (Balli & Güven, 2022). Furthermore, the study will provide practical recommendations for SMDC and other construction-related companies on how to leverage AI to improve project outcomes by looking at the AI-driven delay mitigation framework (Almén, 2024). By addressing these issues, this research contributes to the growing body of knowledge on AI in construction and provides valuable insights for practitioners seeking to improve project delivery and reduce the impact of delays.

The central research question guiding this study is: ***how can AI be effectively implemented to address the issues and improvement needs in current delay analysis techniques of SM Development Corporation projects, leading to improved project outcomes?***

This research is of paramount importance due to the significant impact of delays on project success. By exploring the application of AI, this research has the potential to improve the accuracy and objectivity of delay analysis (Egwim et al., 2021), enable real-time monitoring and prediction of potential delays (SANNI-ANIBIRE et al., 2020), facilitate data-driven decision-making for proactive delay mitigation (Yaseen et al., 2020), reduce cost overruns and improve project delivery for SMDC projects (Arun, 2013), and contribute to the broader adoption of AI in the construction industry (Egwim et al., 2021).

The scope of this study is focused on comprehensive review of existing delay analysis techniques and their limitations in addressing the complexities of SMDC projects (Boyacioglu et al., 2022), identification of key issues and improvement needs in current delay analysis practices, specifically regarding data management, real-time monitoring, and objective assessment (Ivanović et al., 2022), and focusing on addressing the identified issues and improvement needs (Almén, 2024)

The limitations of this study include:

- reliance on data from SMDC projects may limit the generalizability of findings to other construction contexts (Ivanović et al., 2022).
- case studies may introduce bias, and the findings may not be representative of all SMDC projects.

2. Materials & Methods

Construction delays are a pervasive issue in the industry, leading to significant cost overruns and project failures. Effective delay analysis is crucial for mitigating these problems, but traditional methods often fall short due to subjectivity and reliance on outdated data (Braimah, 2013). While the construction industry has been slow to adopt digital technologies (Abioye et al., 2021), AI offers a promising path to enhance delay analysis, providing objective, data-driven solutions (Ivanović et al., 2022). This review examines the current state of AI in construction delay analysis, its challenges and opportunities, and areas for improvement, specifically for SM Development Corporation projects.

2.1 Research Design

This research will adopt a mixed-methods approach to comprehensively assess the potential of AI in addressing issues and improvement needs in construction delay analysis at SMDC projects. The study will combine qualitative and quantitative data collection methods. In quantitative research method, the survey collects data that will analyze the respondents' capability in assessing the potential and challenges of delay analysis techniques and the use of AI. The qualitative approach will address the techniques used by the respondents to analyze delay and to provide insight of AI potentials. This combines method will gain a holistic understanding of potential of AI in addressing issues and improvement needs in construction delay analysis at SMDC projects.

This approach recognizes the complexity of construction projects and the need for both broad statistical insights and in-depth contextual understanding (Ivanović et al., 2022).

A review of existing literatures on **the delay analysis techniques and the potential to use AI,** was likewise used to establish the issues and improvement needs in delay analysis techniques, and the challenges to use AI in analyzing delays.

2.2 AI's Transformative Role in Construction

Artificial Intelligence (AI) encompasses a diverse array of technologies that empower machines to perceive, comprehend, act, and learn, as noted by Egwim et al. (2021). These advanced technologies have transformative applications in the construction industry, enhancing various aspects of project management and execution.

One significant application is **real-time activity monitoring**. AI-powered computer vision systems can continuously observe construction sites, track the progress of ongoing work, and promptly identify any potential delays, ensuring timely interventions (Abioye et al., 2021).

Another crucial application is **proactive risk management**. By analyzing historical project data, machine learning algorithms can predict potential risks, including delays, and facilitate the implementation of proactive mitigation strategies to avoid disruptions (Yaseen et al., 2020).

AI also plays a pivotal role in **optimized resource allocation**. It can efficiently allocate resources such as labor, equipment, and materials, thereby minimizing delays and enhancing overall project efficiency (Radman et al., 2022).

Furthermore, AI contributes to **predictive maintenance**. It can forecast equipment failures and schedule maintenance activities in advance, reducing downtime and preventing associated delays (Radman et al., 2022).

Lastly, AI aids in **advanced delay analysis**. By scrutinizing project data, AI algorithms can pinpoint the root causes of delays and quantify their impact on project timelines and costs, enabling better decision-making and project management (Ivanović et al., 2022).

These applications demonstrate the profound impact of AI on the construction industry, driving efficiency, reducing risks, and ensuring timely project completion.

2.3 Shortcomings of Traditional Delay Analysis Methods

Traditional delay analysis techniques, such as the impacted as-planned method, time impact analysis, and windows analysis, have several limitations. These methods often rely on expert opinions and subjective assessments, which can lead to disputes and inconsistent results. Almén (2024) notes that delay analysis can be controversial due to its nature as one party's loss and another's gain, potentially leading to legal disputes. Additionally, these techniques often struggle with incomplete, inaccurate, or outdated project data, hindering accurate analysis (Türkakın et al., 2020). Traditional methods may also be unable to handle the complexities of modern construction projects, which involve numerous stakeholders, intricate schedules, and dynamic conditions. Furthermore, analysis is often performed after a delay has already occurred, limiting the ability to take corrective action in real-time (Radman et al., 2022).

AI offers several advantages over traditional methods, addressing their limitations and providing enhanced capabilities. AI algorithms can analyze project data objectively, reducing bias and improving the accuracy of delay analysis (Ivanović et al., 2022). AI can process vast amounts of data from various sources to identify patterns and insights that would be difficult to detect manually (Radman et al., 2022). AI enables real-time delay analysis, allowing project managers to proactively identify and respond to potential delays (Radman et al., 2022). By combining machine learning with expert knowledge, AI can improve the reliability of results (Ivanović et al., 2022).

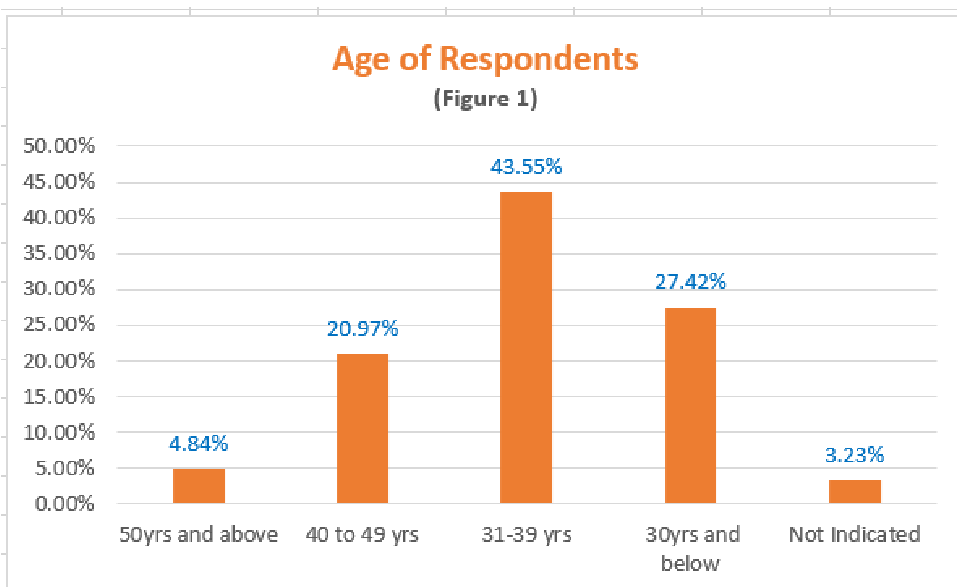
Despite the numerous benefits, implementing AI in construction faces significant challenges. AI algorithms require large amounts of high-quality data to train effectively. The construction industry often struggles with data quality issues, such as incomplete, inconsistent, and unstructured data (Egwim et al., 2021). Implementing AI requires specialized knowledge and skills, which may be lacking in many construction organizations (Almén, 2024). Integrating AI-powered delay analysis tools with existing project management systems can be complex and costly (Radman et al., 2022). The construction industry can be resistant to adopting new technologies, particularly those that require significant changes to existing processes (Balli & Güven, 2022). Ethical issues such as data privacy and algorithmic bias must be carefully considered (Abioye et al., 2021).

With the above reviews, to effectively leverage AI for delay analysis in SMDC projects, the following recommendations should be considered: Implement data standardization protocols to improve the quality and consistency of project data (Egwim et al., 2021). Develop in-house AI expertise through training programs (Almén, 2024). Evaluate AI tools on pilot projects to assess their effectiveness and identify areas for improvement (Radman et al., 2022). Encourage collaboration between researchers, technology providers, and industry professionals to share knowledge and best practices (Abioye et al., 2021). Develop user-friendly AI tools that can be easily integrated into existing workflows (Radman et al., 2022). A clearly defined objective and scope are crucial for construction projects, necessitating tailored approaches rather than standardized methods. This involves analyzing current processes, identifying areas linked to delays, and collecting delay analysis data from previous projects (Almén, 2024).

3. Data Collection

The researcher conducted an online survey distributed through emails of SMDC project team members (including internal project management team, external Construction Management and contractors) to ensure that the respondents would be working or presently engaged at SMDC projects. At the beginning of the survey, the respondents will provide their age, number of years of experience, prior to joining SMDC, their role in the project, and their tenure as project team member. After that, respondents will answer another set of questions. These questions include the following:

1. *How do you assess your level of knowledge to the different Delay Analysis Techniques (DAT's)?*
2. *Among the tools mentioned, which one do you typically use when preparing or managing a construction schedule, including delay analysis?*
3. *What are most common causes of delays?*
4. *What techniques did you use in analyzing the delay analysis in your SMDC Construction project?*
5. *What challenges do you encounter in your current delay analysis techniques?*
6. *Do you have knowledge or understanding of any **AI Tools** that is being used for schedule management or delay analysis?*
7. *Have you ever used that **AI Tool**?*

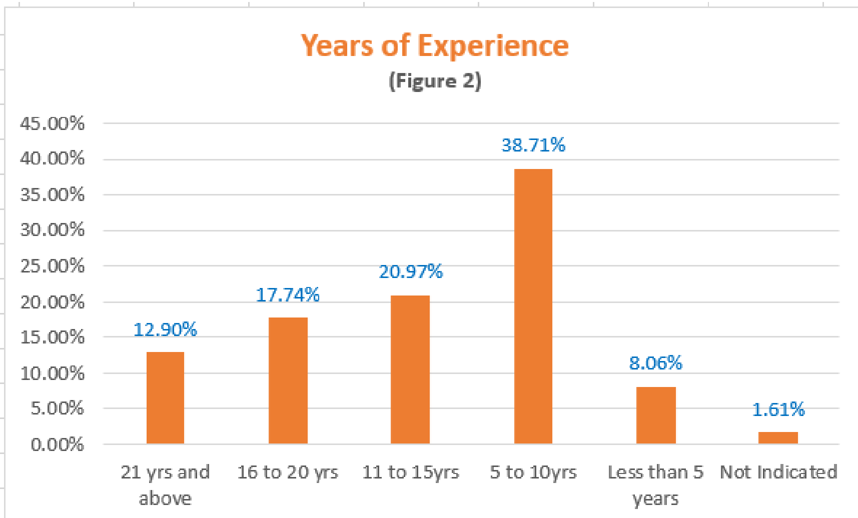


With this approach, collecting data will facilitate the analysis and identification of the study's objectives, providing valuable insights into the experiences and performance of project team members in SMDC projects regarding potential of AI in delay analysis, including its issues and needs.

4. Results

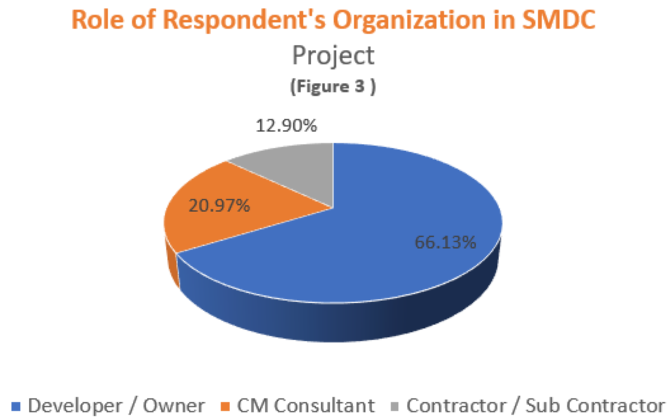
4.1 Demographic of respondents:

Based on the age and experience distribution as provided in Figures 1 and 2 respectively, the 31-39 age group (43.55%) with 5-10 years of experience (38.71%), which is referred as the **experienced core**, signifies that the survey captured the views of professionals who are actively involved in project execution and have firsthand knowledge of the challenges related to delays. This group's insights into the practical aspects of delay analysis would be particularly valuable for identifying areas where AI could provide the most benefit.



Likewise, the **seasoned expertise** which is combining the 40-49 age group (20.97%) with those having 11-20+ years of experience (12.90% + 17.74% + 20.97% = 51.61%) indicates a substantial representation of seasoned professionals. These individuals likely hold managerial or supervisory roles, and possess a deep understanding of project management principles, delay analysis techniques, and the overall construction process. Their perspectives on the limitations of traditional methods and the potential of AI to overcome these limitations would be highly insightful.

Furthermore, the **emerging professionals,** which refers to the less than 5 years' experience bracket (8.06%) coupled with the dominant 31-39 age range may suggest a later entry into the construction industry or a career change. Their familiarity with newer technologies may make them more receptive to AI solutions, but their limited experience might temper their perspectives on the intricacies of delay analysis.



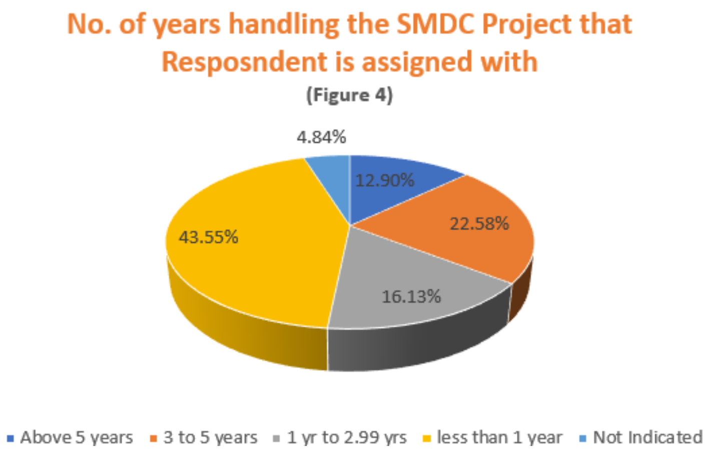
Finally, the **mature leadership,** which is a small segment of respondents (4.84%) are 50 years and above. These individuals, with potentially decades of experience, likely hold leadership positions or act as consultants. While their direct involvement in day-to-day project activities may be limited, their strategic overview and understanding of long-term project outcomes make their input valuable for assessing the broader impact of AI adoption. Keep in mind that with an aging workforce, experience can become a key factor.

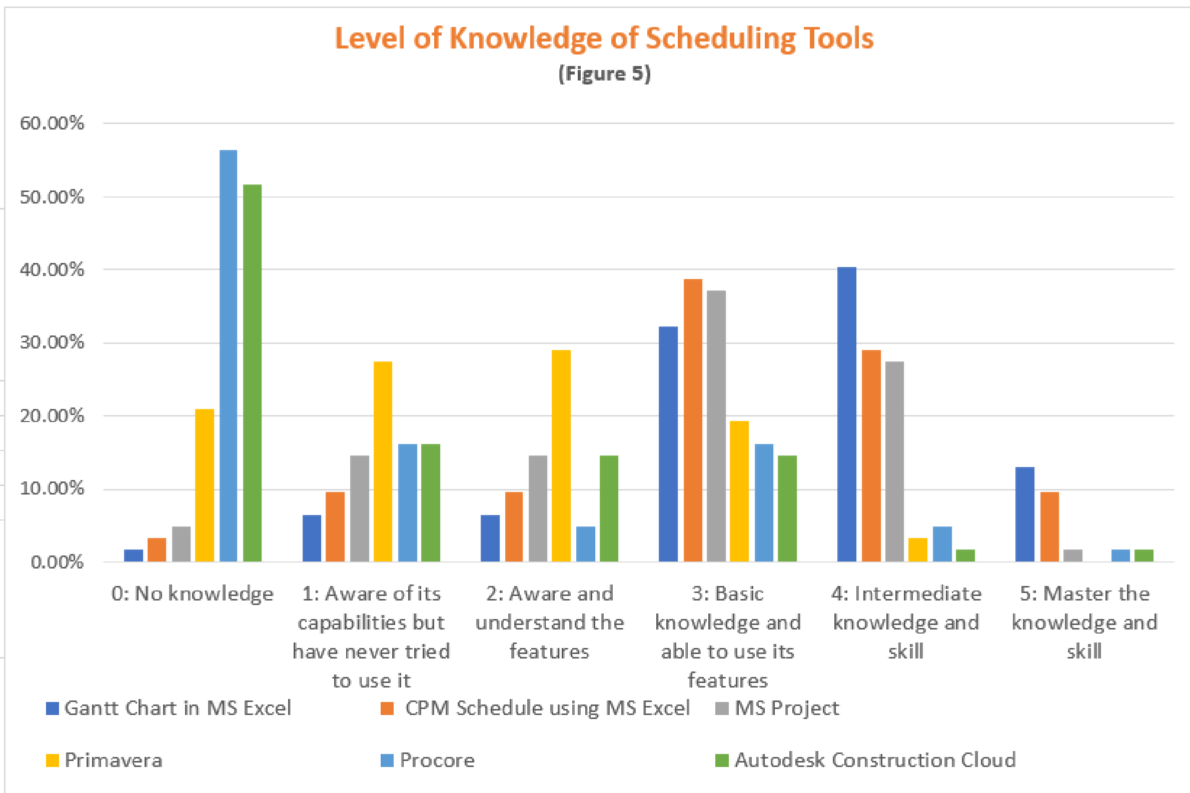
4.2 SMDC Landscape on role and familiarity of the project

The results at Figures 3 and 4 paint a detailed picture of the SMDC project landscape. In Figure 3, a significant presence of **Developers/Owners** (66.13%) is shown, indicating their strong interest in project outcomes. However, a striking 43.55% of respondents have less than a year of experience on their current SMDC project as shown in Figure 4, suggesting either high turnover or a rapid influx of new initiatives. This presents a challenge: while Developers/Owners are invested, many may lack deep project-specific knowledge. AI solutions, as highlighted in our literature review, offer a way to bridge this gap by providing rapid access to insights gleaned from historical data. AI can help new project team members quickly understand potential risks and optimize decision-making.

Construction Management Consultants (20.97%) bring expertise, but their experience levels likely vary. AI tools can augment their abilities by providing advanced analytical capabilities. For instance, AI can process large datasets to identify delay patterns that might be missed by traditional methods.

Contractors/Subcontractors (12.90%) need AI for resource optimization and real-time monitoring, but their adoption may be hindered by a 'Resistance to Change' or a 'Lack of Expertise and Resources'. Success here hinges on user-friendly AI that integrates seamlessly with existing workflows, delivering tangible benefits on the ground. Pilot projects and case studies are essential to demonstrate AI's value and build confidence.





4.3 Level of knowledge and preferred scheduling tool

Based on Figures 5 & 6, the survey data reveals a significant disconnect between the preferred scheduling tools and the level of knowledge in scheduling tools. While a majority (50%) prefer using Gantt charts in MS Excel, only 12.90% have mastered it, and a large proportion have only intermediate knowledge (40.32%).

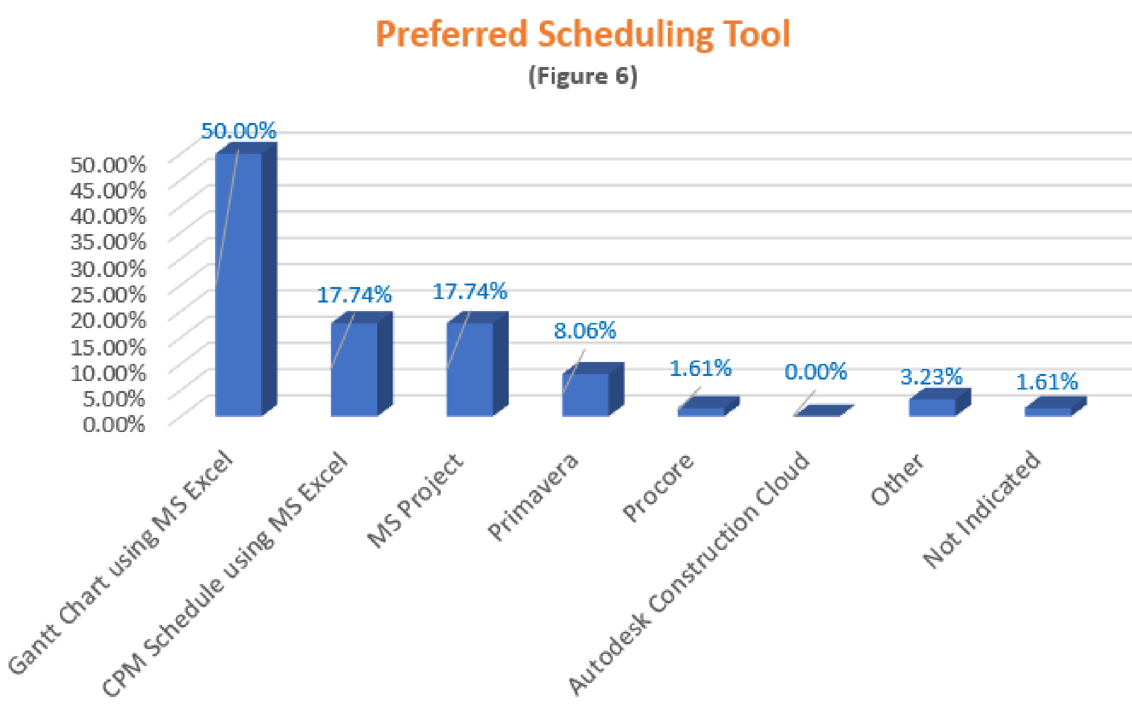
This suggests a reliance on a familiar but potentially limited tool, even if its capabilities are not fully utilized. The reliance on manual data collection and analysis, can be time-consuming and prone to errors.

Similarly, while 17.74% prefer CPM schedules in MS Excel, only 9.68% have mastered it, and a substantial portion only have basic knowledge (38.71%). This indicates that while CPM scheduling is appreciated, the actual expertise to implement it effectively within Excel is lacking. This further emphasizes the point from the literature review about the limitations of traditional methods.

The preference for MS Project aligns with the knowledge level, with 17.74% preferring it and a moderate level of basic knowledge (37.10%), but very few having mastered it (1.61%). The more specialized tools like Primavera and Autodesk Construction Cloud show a stark contrast. Despite their potential for advanced delay analysis and real-time monitoring, preference and knowledge levels are very low. 8.06% prefer Primavera, but a significant portion of 20.97% has no knowledge and 27.42% are aware but have never tried it. Autodesk Construction Cloud has zero preference and 51.61% have no knowledge, and only 14.52% have basic knowledge.

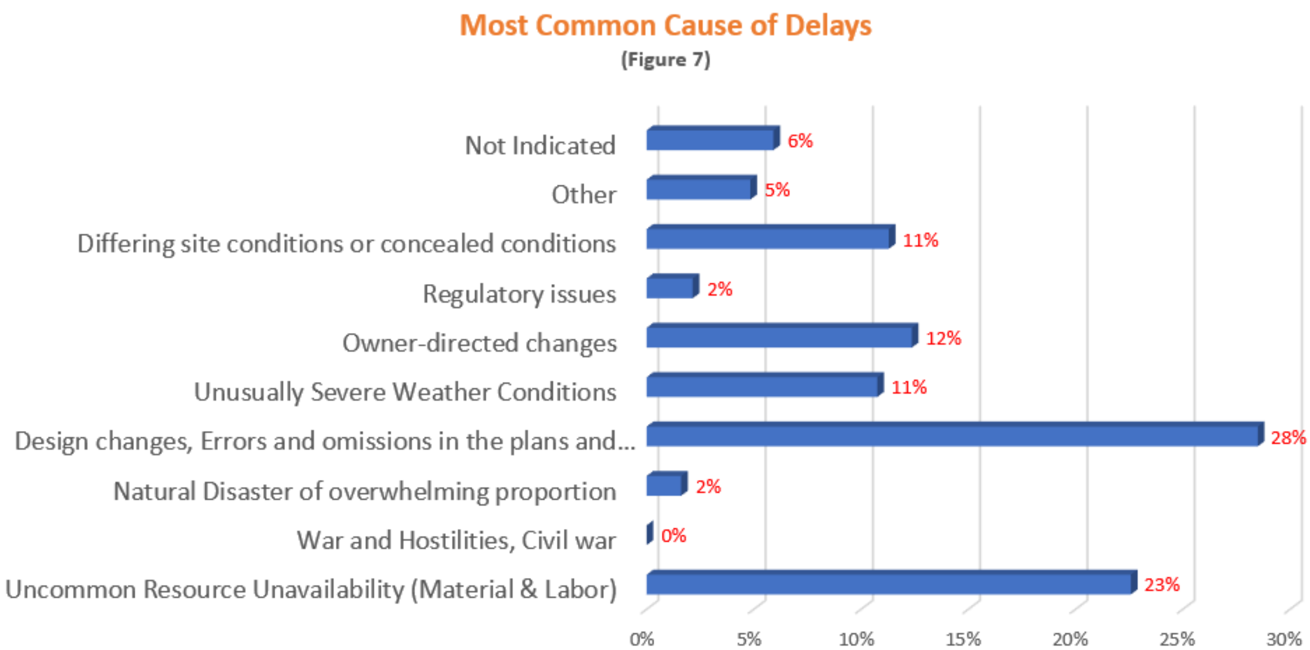
This correlation highlights a key challenge in realizing the potential of AI in construction delay analysis in SMDC projects. As AI-powered solutions often require data inputs from sophisticated scheduling platforms (Radman et al., 2022), the limited adoption and expertise in these platforms may hinder the effective implementation of AI. The construction industry can be resistant to adopting new technologies.

4.4 Perceived causes of delays



As per Figure 7, the survey data reveals that **design changes, errors, and omissions in plans** are considered the most common cause of delays in SMDC projects (28%). This is an emphasis on thorough design and the importance of minimizing design-related issues. This can also include misunderstanding of owner's requirement by designers and engineers.

Resource unavailability (material & labor) is another significant factor (23%), which the literature review also identifies as a major contributor to delays (Almén, 2024). Shortage of materials is a critical factor (Meena. & Babu, 2015).



Owner-directed changes and differing site conditions also contribute substantially (12% each). These factors can disrupt project flow and require adjustments. Change orders, as highlighted in several sources, are a frequent cause of delay (Assaf & Al-Hejji, 2006; Meena. & Babu, 2015).

Severe weather conditions account for 11% of the perceived causes. Proactive planning and risk management can mitigate this impact.

Factors like **contractor's poor workmanship, inefficiency, mismanagement, and delayed procurement (5%)** highlight the importance of contractor-related performance. The literature review further supports this, mentioning poor site management and ineffective planning as major contributors (Meena. & Babu, 2015).

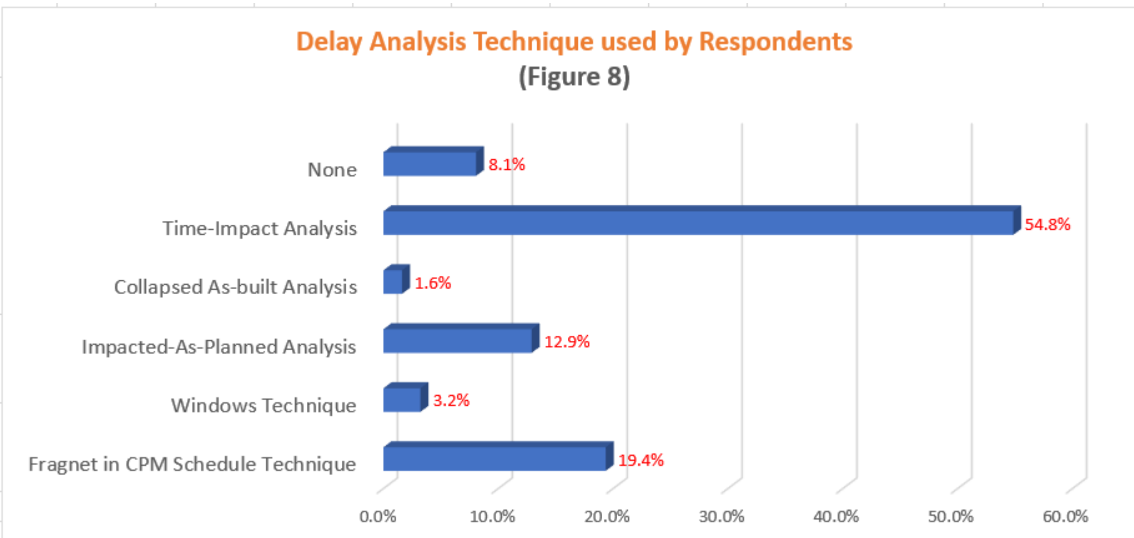
These survey responses directly relate to several key areas in the literature review outline. For instance, **data quality and availability** become crucial when analyzing design errors and resource constraints. **The complexity of construction projects** further exacerbates the issues of design changes and differing site conditions. The industry's potential **resistance to change** also plays a role, making it harder to implement better design processes or resource management strategies.

4.5 Preferred Delay Analysis Techniques (DAT's)

As per Figure 8, the survey indicates that **Time-Impact Analysis** is the most prevalent delay analysis technique in SMDC projects, utilized by 55% of respondents. This suggests a preference for a prospective approach that assesses the impact of delays as they unfold, enabling real-time evaluation and potential mitigation (Hegazy, 2012). It is used to isolate schedule slippage (Hegazy, 2012).

Fragnet in CPM Schedule Technique (19%) and **Impacted-As-Planned Analysis (13%)** are also employed to a considerable extent. These techniques involve integrating delay events into the project schedule to ascertain their cumulative effect on project completion (Dinakar, 2014).

The relatively infrequent use of **Windows Technique (3%)** and **Collapsed As-built Analysis (2%)** implies that these methods may be perceived as less suitable for SMDC projects, potentially due to their complexity or data requirements. It is one of the realistic and reasonably accurate techniques (Arun, 2013).



The fact that **8%** of respondents reported using **none** of the listed delay analysis techniques raises concerns. This may stem from a lack of awareness, resources, or expertise in formal delay analysis methods, potentially leading to disputes and inaccurate delay assessments. It also shows an area where AI could be used in firms where formal techniques aren't used because of limited resources. The selection of the proper analysis method depends upon a variety of factors including information available, time of analysis, capabilities of the methodology and time, funds and effort allocated to the analysis (Ghaithi et al., 2017).

4.6 Challenges encountered in current delay analysis techniques in SMDC Projects.

Based on Figure 9, one of the biggest challenges encountered in current delay analysis techniques is **data or information quality issues (lack of supporting documents, 66%)**. This highlights the critical importance of comprehensive record-keeping and documentation practices in construction projects. Without accurate and readily available data, any delay analysis technique will be severely hampered.

Lack of skilled personnel to perform the techniques (11%) is another notable challenge. This suggests a need for training and development programs to equip construction professionals with the necessary expertise in delay analysis methodologies. This could also indicate that the available techniques are complex (Alnaas et al., 2014). A related paper identified that the main obstacles to the use of delay analysis methods relates to deficiencies in project records and scheduling practice (Ndekugri et al., 2008).

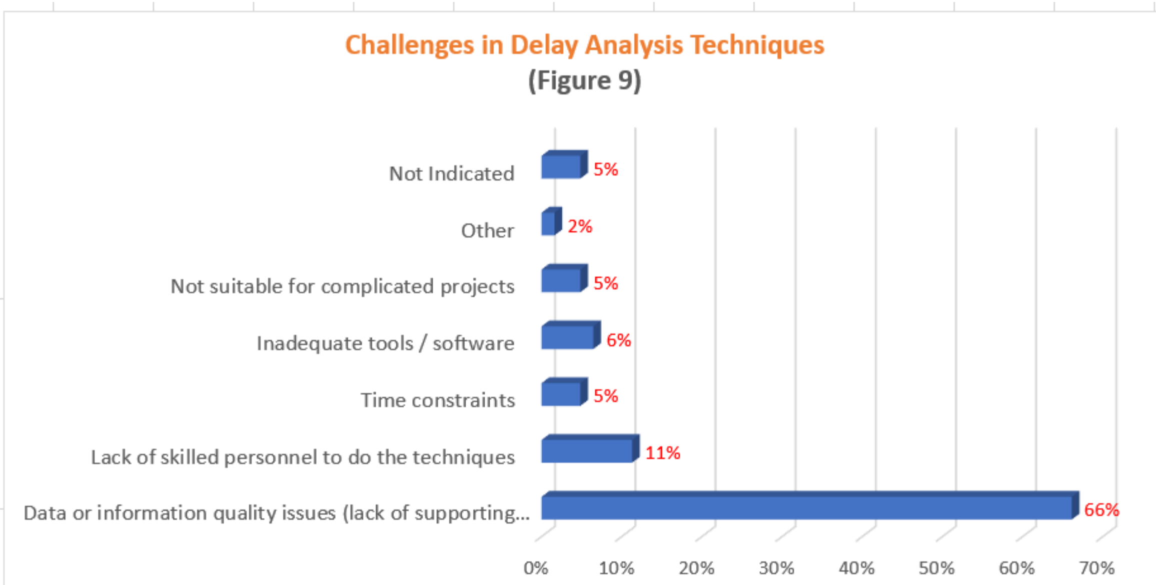
Time constraints (5%) and **inadequate tools/software (6%)** also contribute to the challenges faced in delay analysis. These factors highlight the need for efficient and user-friendly tools that can streamline the delay analysis process and reduce the time required to perform it.

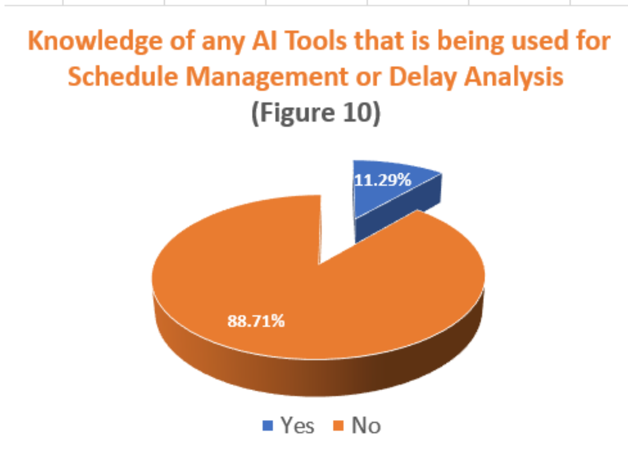
The fact that **5%** of respondents find the current techniques **not suitable for complicated projects** suggests a need for more sophisticated and adaptable delay analysis methods that can handle the complexities of large-scale construction projects (Alnaas et al., 2014). As projects become more complex, the interfaces increase and the number of causes for delay rises (Alnaas et al., 2014).

4.7 Knowledge or Understanding of AI Tools in Delay Analysis

As per Figure 10, the survey data reveals a significant disparity: while construction professionals within SMDC projects likely possess knowledge of traditional scheduling tools, a staggering **88.71% lack knowledge or understanding of AI tools** used for schedule management or delay analysis. This chasm in AI awareness, juxtaposed with the challenges already plaguing delay analysis – data quality, personnel skills, time constraints, and project – forms a substantial impediment to leveraging AI's transformative potential within SMDC. This is further reinforced by studies that point out difficulties of analyzing process due to the nature of delay (Almén, 2024).

The lack of understanding of AI in the construction industry is not an isolated issue; it is compounded by several factors. Many construction professionals have limited exposure to AI tools in their current roles or training, which restricts their familiarity with these technologies. AI is often perceived as complex and difficult to grasp, deterring exploration and adoption. Additionally, there is a general lack of awareness regarding the specific AI tools available for schedule management and delay analysis, along with their potential to address current challenges.





The construction industry is known for its conservative nature, which can lead to resistance in embracing new technologies. High operational costs and a lack of knowledge further complicate the implementation of new applications in traditional projects (Almén, 2024). These factors collectively contribute to the slow adoption of AI in the construction sector.

5. Discussion

5.1 Summary of Findings

Construction projects, especially those at SMDC, frequently grapple with delays that lead to significant cost overruns and impact overall project performance. Traditional delay analysis techniques often fall short because they rely heavily on manual data collection, are subjective, and struggle to process large volumes of data effectively. This is where Artificial Intelligence steps in, offering a transformative potential to revolutionize how delays are managed and mitigated.

AI's ability to analyze historical project data, identify patterns, and predict potential delays with greater accuracy makes it a powerful tool. AI applications in this context range from delay forecasting and risk management to resource optimization and real-time monitoring. Techniques like machine learning, neural networks, and fuzzy theory are particularly relevant. For instance, machine learning algorithms can be used to forecast construction delay times, which can enhance risk management (SANNI-ANIBIRE et al., 2020). Hybrid AI models, such as the integrative Random Forest classifier with Genetic Algorithm optimization, can also offer robust and reliable techniques for project delay prediction (Yaseen et al., 2020).

The adoption of AI in construction faces several challenges. A significant obstacle is the lack of high-quality, structured data. Although construction projects generate vast amounts of data, it is often unstructured, incomplete, and inconsistent. This issue is evident in interviews with project teams from SMDC projects in Laguna and Cagayan de Oro, where teams struggled to extract accurate and complete information related to delay events. Initially, these teams attributed delays solely to the contractor's lack of manpower. However, further review and analysis uncovered that the primary causes of delays were site conditions, delays in owner-supplied materials and nominated sub-contractor procurement by the owner, design deficiencies, and owner-initiated changes.

The complexity of construction projects, involving numerous stakeholders and dynamic conditions, further complicates AI implementation. Additionally, many construction companies, particularly smaller enterprises, may lack the expertise and resources to implement AI solutions. The industry also tends to resist adopting new technologies.

By addressing these challenges and implementing these recommendations, SMDC can leverage AI to enhance project performance, reduce costs, and increase stakeholder satisfaction. Future research should focus on specific AI applications tailored to SMDC projects and the development of AI-powered decision support systems. Frameworks such as the AI-driven delay mitigation framework, which includes planning, development, and evaluation phases, can also guide managers in strategically implementing AI technologies to improve project outcomes (Almén, 2024).

5.2 Comparison of Results

5.2.1 Current Landscape

The construction industry, particularly in the context of SMDC projects, faces significant delays that adversely affect project performance and financial outcomes. Traditional delay analysis methods rely heavily on manual processes and subjective evaluations, struggling to manage the vast amounts of data generated by modern projects. Given the current landscape of SMDC projects, as reflected in the survey results shown in Figures 1 to 4, AI offers several implications to address these challenges.

a. **Targeted Solutions:**
Survey data suggests that AI solutions should be customized to meet the needs of both experienced professionals managing complex projects and those newer to the field who require more intuitive and user-friendly tools.
b. **Knowledge Integration:**
AI implementation should leverage the expertise of seasoned professionals by incorporating their knowledge and insights into algorithms and decision-making processes. This could involve using machine learning techniques to capture and codify the expertise of experienced project managers.
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AI implementation should leverage the expertise of seasoned professionals by incorporating their knowledge and insights into algorithms and decision-making processes. This could involve using machine learning techniques to capture and codify the expertise of experienced project managers.
d. **Training and Education:**
Comprehensive training and education programs are essential to overcome resistance to change and ensure successful AI adoption. These programs should target professionals at all experience levels, addressing their specific needs and concerns (Almén, 2024).
e. **Data Standardization:**
The lack of high-quality, structured data is a major obstacle to AI adoption in construction. Emphasizing data standardization and management practices is critical for ensuring that AI algorithms can effectively analyze project data and generate accurate predictions.

As indicated in Figure 6, the preference for simpler tools like MS Excel, despite their limitations, likely stems from factors such as ease of use, familiarity, and cost considerations. To address the skills gap in using advanced scheduling tools, a multi-pronged approach is recommended. First, to effectively upskill project teams on advanced scheduling tools, it is essential to first identify specific areas for improvement. Then, develop targeted training programs tailored to the varying proficiency levels and needs of the staff. This approach will facilitate their adaptation to digital transformation initiatives within the organization, particularly in scheduling and delay analysis (Espiritu et al., 2023)

Second, AI solutions should be designed to be compatible with a range of data inputs, including those from simpler tools like Excel. This will allow teams with varying levels of expertise to benefit from AI-powered insights (Almén, 2024).

Furthermore, pilot projects and case studies are crucial to demonstrate the value of AI and build confidence in its application. By showcasing how AI can improve project outcomes and reduce delays, resistance to change can be overcome, encouraging wider adoption (Almén, 2024).

Finally, promoting collaboration and knowledge sharing between researchers, industry practitioners, and technology providers can accelerate the development and deployment of AI solutions tailored to the unique challenges of SMDC projects.

5.2.2 AI as a Transformative Force

Artificial Intelligence presents a paradigm shift, offering the potential to revolutionize delay analysis through data-driven insights and predictive capabilities (Almén, 2024). AI algorithms can sift through vast datasets, identify patterns, forecast potential delays, and optimize resource allocation. Specific applications include:

a. **Delay Forecasting:**
   AI can learn from historical data to predict potential delays, enabling proactive risk management and more realistic project planning (SANNI-ANIBIRE et al., 2020).

b. **Risk Management:**
   AI identifies and assesses potential risks, assisting in the development of mitigation strategies.
c. **Resource Optimization:**
   AI optimizes resource allocation, improves site safety, and enhances project planning.
d. **Real-time Monitoring:**
   AI monitors project execution, identifies deviations from the schedule, and triggers timely interventions, using data from sources like drones and sensors.

Techniques such as machine learning, neural networks, probabilistic models, and fuzzy theory are relevant (Yaseen et al., 2020).

5.2.3 Challenges to AI Adoption

Despite its promise, AI adoption faces significant hurdles:

a. **Data Quality and Availability:**
   A primary obstacle is the lack of high-quality, structured data. Data is often unstructured, incomplete, and inconsistent.
b. **Project Complexity:**
   Construction projects involve numerous stakeholders, complex dependencies, and dynamic conditions.
c. **Lack of Expertise and Resources:** Many construction companies, particularly smaller ones, lack the skills and resources to implement AI solutions.
d. **Resistance to Change:**
   The construction industry can be resistant to adopting new technologies.
e. **Ethical Considerations:**
   AI bias and data privacy must be addressed.

5.2.4. Addressing the Challenges and Tailoring AI for SMDC Projects

To fully realize the potential of AI in SMDC projects, several needs must be addressed:

a. **Data Standardization and Management:**
Standardized data collection and management practices are crucial
b. **Collaboration and Knowledge Sharing:** Collaboration between researchers, industry practitioners, and technology providers should be promoted
c. **Education and Training:** Investment in education and training programs is needed to develop the skills to implement and manage AI solutions
d. **Pilot Projects and Case Studies:** These can demonstrate the benefits of AI and build confidence in the technology
e. **Management Support and Incentives:** Support can encourage AI adoption
f. **Focus on SMDC Project Needs:** Recommendations must be tailored to SMDC projects' specific characteristics

5.3 Limitations

The study's narrow focus on SMDC projects restricts the generalizability of findings to other construction contexts. Data quality and availability pose significant challenges, as construction projects often generate unstructured and inconsistent data, which may hinder the application of AI algorithms. The complexity of construction projects, involving numerous stakeholders and dynamic conditions, adds another layer of difficulty to AI implementation. Limited AI expertise and resources within construction companies, especially smaller enterprises, can impede the successful adoption of AI solutions. Moreover, the industry's resistance to change and ethical considerations related to AI bias and data privacy must be addressed. The research should also acknowledge the rapid pace of technological advancements in AI, which could render findings outdated quickly, and provide a comprehensive cost-benefit analysis to justify AI investments. Finally, external factors like government regulations and economic conditions can influence AI adoption in construction. By addressing these limitations, the research can provide a more realistic assessment of AI's potential in construction delay analysis for SMDC projects, while also considering the need for tailored solutions and the controversial nature of delays (Almén, 2024). Future research should focus on real-life project data to validate findings (Braimah, 2013).

6. Conclusion

AI has the potential to revolutionize construction delay analysis and improve project performance. Proactive measures are needed to address the challenges and realize this potential. Future research should focus on specific AI applications tailored to SMDC projects, and the development of AI-powered decision support systems for delay mitigation. By addressing these challenges and implementing the recommendations, SMDC can leverage AI to enhance project performance, reduce costs, and increase stakeholder satisfaction. Furthermore, digital technologies and real-time data acquisition systems can be used for delay mitigation (Radman et al., 2022).

The literature review outline highlights limitations of traditional delay analysis methods, such as reliance on manual data collection, subjectivity, and the inability to process large data volumes effectively. The fragmented nature of the construction industry in the Philippines and the complexities of SMDC projects exacerbate these challenges. AI can address these limitations by:

- Automating data collection and analysis using technologies like drones and sensors.
- Reducing subjectivity through data-driven insights and predictive modeling.

- Processing large volumes of data to identify patterns and forecast potential delays.

Considering the survey results and the literature review, there is an opportunity to promote AI-powered delay analysis tools in SMDC projects. These tools can streamline the delay analysis process, improve accuracy, and enable more informed decision-making.

AI can address these challenges by:

- Automating data collection and analysis, reducing reliance on manual data collection.
- Improving data quality by identifying inconsistencies and errors in project data.
- Simplifying the delay analysis process, making it easier for construction professionals to perform these tasks.
- Providing decision support, offering insights and recommendations for delay mitigation.

Realizing the potential of AI in construction delay analysis for SMDC projects necessitates a comprehensive approach that addresses key issues and fosters continuous improvement. AI offers innovative solutions, particularly in data analysis and prediction, but its successful implementation depends on overcoming challenges related to data quality, project complexity, and limited expertise. The need for standardized data practices, collaboration, education, pilot projects, and government support is paramount.

Specific for SMDC projects, tailoring recommendations to their unique characteristics and context is crucial. This involves considering factors such as project size, type, location, and stakeholder involvement. Additionally, the dynamic and controversial nature of construction delays must be acknowledged when developing AI-driven solutions (Almén, 2024). The difficulty of the analyzing process also lies in the controversial nature of delay because it constantly forms one party's loss and another's gain and might even lead to legal disputes (Almén, 2024).

Ultimately, by proactively addressing these issues, the construction industry can unlock AI's full potential to revolutionize delay analysis, enhance project performance, and gain a competitive edge (Almén, 2024). As future research, real-life project data should be used to validate case study findings and focus on specific AI techniques applicable to SMDC projects (Braimah, 2013).

In short, the way forward to unlocking the full potential of AI in construction delay analysis is a multifaceted approach that is tailored to the specific context of the project, with consideration of the nature of construction delays (Almén, 2024).

In summary, a commitment to adaptability and innovation is essential for developing a project management strategy that is both digitally resilient and proactive (Espiritu et al., 2023). Similarly, harnessing the potential of AI in SMDC projects necessitates a concerted effort to bridge the skills gap, standardize data, and cultivate a culture of innovation and collaboration. By investing in education, creating user-friendly AI solutions, and demonstrating tangible benefits, we can empower project teams to utilize AI for proactive delay management and enhanced project performance.

7. Conflict of Interest

The authors declare that they have no conflict of interest.

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