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5D BIM Implementation to Overcome Cost Management Issues in Upstream Oil and Gas Projects in Malaysia: A Review

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Abstract

Since the outbreak of COVID-19, the upstream oil and gas industry has faced unprecedented challenges in terms of low prices. Given the volatility and uncertainty around oil prices, it is critical for the sector to exercise capital constraints and manage costs effectively to ensure its future success. In response to the difficulties with cost overruns, oil and gas operators have implemented various strategies and measures, such as cost reduction, project prioritisation, project delays and streamlining the supply chain and contracts. However, these approaches do not provide a sustainable or cost-effective solution in the long term. Previous research on project cost overruns has shown that internal factors, particularly project data integration, are the main cause of poor project performance and cost overruns. However, no approaches or technologies have been proposed to improve cost management or control cost overruns. This paper aims to review the features and functions of 5D BIM that could improve the integration of project data throughout the lifecycle and provide a solution for cost management in Malaysia's oil and gas upstream projects. The methodology adopted in this study ensures a rigorous and systematic approach in reviewing the literature on cost management issues, cost overruns and the role of 5D BIM. Consequently, BIM streamlines cost estimating, saves time by automating data entry and producing accurate estimates, increases productivity and promotes better collaboration within the project team.

1. Introduction

Since the outbreak of COVID-19, the upstream oil and gas industry has faced notable obstacles, including historically low prices (Gaffen, 2022). The conflict between Russia and Ukraine has further exacerbated the situation and led to a sharp increase in crude oil prices, with Brent crude oil reaching $139.130 per barrel (Zhang et al., 2023). This increase is mainly due to the restrictions imposed by the US and Europe on Russian oil imports (Kolaczkawski, 2022). A similar effect was observed after the conflict between Gaza and Israel (Ferretti, 2023).

These events had a severe impact on revenues and investments in the industry. Overall, the industry has managed these challenges effectively (Camp et al., 2020). Some oil and gas producers have managed to significantly reduce their operating costs by postponing or curtailing operational tasks and rationalising their supply chain (McKinsey & Company, 2020). However, these measures were not sufficient in creating value and promoting long-term economic expansion (IEA, 2021).

Given the volatility and unpredictability of oil prices (Mubarak & Khudhuri, 2020), capital constraint and cost management will remain critical for the sector going forward. This emphasises the inadequacy of reactive cost management solutions to achieve long-term sustainability and cost efficiency. Effective working capital management, which can improve liquidity, and a longer cash conversion cycle have shown potential benefits (Bjorkman & Hillergren, 2014). There is also a significant correlation between investment decisions in capital budgeting and organisational performance (Emmanuel & Richard, 2019). When oil prices are high, costs are not a priority. However, when prices are low, the focus shifts to reducing costs by prioritising projects, halting projects and streamlining the supply chain and contracts. However, these approaches do not offer long-term sustainability and cost efficiency. It is becoming increasingly clear that revenue is not as critical to businesses as it was previously believed. In the global market, the price of Brent Crude oil has been trending upwards since the third quarter of 2021. During the pandemic, the price averaged around $50 per barrel. From January 2022 to June 2022, prices fluctuated between $80 per barrel and $122 per barrel (Trading Economics, 2022). In 2023, there was a decline in prices, ranging from $80.50 per barrel to $78.70 per barrel from January to November, with higher prices observed in September (Trading Economics, 2022). The disparity in prices between the two time periods indicates a significant decrease in oil prices following the COVID-19 pandemic.

Given the industry's reliance on volatile prices, the implementation of effective and integrated cost control solutions is crucial. Various issues and errors arise during the construction phase due to deficiencies in the design phase. The sector faces challenges such as communication, coordination, and standardization difficulties and limitations. Effectively communicating design knowledge is essential in addressing these interoperability challenges. This is where the Building Information Model (BIM) can play a significant role. In conventional approaches, project stakeholders transfer documents and drawings by creating new files each time. In BIM, the model serves as a database where data can be supplied and retrieved on demand.

Major issue observed in oil and gas projects is cost and schedule deviation at later project stages(Ali & Kamaruzzaman, 2010). Various causative factors contribute to cost overruns at completion, poor project definition resulting to incomplete scope development, incorrect technology selection, unreliable decision making at the onset of project, unknown regarding existing facilities, and scope change (Simushi & Wium, 2020; Albtoush et al., 2020). Underestimation of project cost and project duration are the main causative factors of project slippage (Seddeeq et al., 2019). These causative factors in line with issues occurring in the upstream oil and gas projects. By mitigating cost overruns in hydrocarbon megaprojects, capital expenditures in the industry can be optimized, thereby increasing profit margins for all parties involved in these activities (Olaniranet al., 2015).

Megaprojects involving hydrocarbons (oil and gas) commonly encounter cost overruns, with 64 percent of ongoing megaprojects worldwide currently facing cost overruns. These cost overruns are a result of the intricate interplay between project characteristics, people, technology, structure, and culture (Olaniran et al., 2015).

Upstream megaprojects are susceptible to higher uncertainty and inadequate preparation, ambitious timetables, and a lack of continuity in leadership. The success rate of upstream megaprojects has declined from 50% to 22%, with the remaining 33% suffering from cost overruns due to three key factors: FEL completion, leadership change, and an unrealistic target schedule (Merrow, 2012).

The success rate in meeting the Final Investment Decision (FID) cost and schedule diminishes with the project's size; 50% of projects in the United States with a value between USD 300 million and USD 600 million are deemed successful in terms of cost variation. Consequently, it is imperative to devise a strategy that effectively integrates all functions (Merrow, 2012). Only 7% of the projects examined were completed within budget. Large urban construction projects experienced higher cost overruns and delays, while new-build projects performed better compared to renovations. Urban road projects also outperformed building projects, and cost overruns in new-build and renovation road projects exhibited no significant differences (Heravi & Mohammadian, 2021).

Although the oil and gas industry are broader and more complex when compared to other industries, it has demonstrated initiatives and capabilities in utilizing digital modelling technologies to enhance cost, time, quality, and efficiency (Lee et al., 2018), in a manner that is comparable to the innovative concept of Building Information Modelling (BIM). Moreover, projects in this industry are more well-organized, and the concept of integrated project delivery is well-understood by the primary stakeholders in the industry. However, previous studies have conclusively shown that BIM has not yet been widely implemented in the oil and gas sectors, and there continues to be a significant gap in deployment in this context. With the global decline in oil prices and the resultant impact on project performance, 5D BIM holds the potential to consolidate real-time project information throughout the project lifecycle and make it accessible to all members of the project team.

The objective of this paper is to review the features and functions of 5D BIM that could facilitate the integration of project data for the entire project lifecycle and propose solutions to the cost management challenges in Malaysia's oil and gas upstream project.

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2. Research Methodology

The research methodology used in this study is based on a systematic literature review (SLR). Its main objective is to thoroughly examine the extent of cost management issues in upstream oil and gas projects, factors that contribute to cost overruns, the concept and application of 5D Building Information Modelling (BIM), and the effectiveness of 5D BIM in addressing cost management challenges. The focus of this study is mainly on understanding these aspects within projects in Malaysia and other countries.

The literature review conducted by adopting search strategy from various technical study databases, namely Scopus, Web of Science, and Google Scholar. The main keywords "coast management," "cost overruns," "5D BIM," "oil and gas industry," "upstream projects," and "BIM adoption" are employed to encompass a wide array of relevant literature. The literature selection criteria comprehend studies that scrutinize cost management issues and the causative factors that lead to cost overruns, study that specifically focuses on 5D BIM and its advantages and challenges, and research that associated with upstream projects in the oil and gas industry and construction projects in Malaysia and other countries. The selection process only comprises peer-reviewed journal articles, conference papers, and trustworthy industry reports to guarantee the sources' authenticity and reliability. The review eliminates studies that are not relevant to research questions, articles that have not undergone peer review, and research that does not specifically focus on the specified on 5D BIM.

Data extraction is conducted utilising a standardised form to methodically collect vital information from each study, including the author, year, title, publication source, research objectives, methodology, and significant findings pertaining to cost management concerns, cost overruns, and 5D BIM. Thematic analysis is performed to detect patterns, trends, and gaps in the literature. The analysis specifically scrutinises typical cost management issues in projects, causative factors leading to cost overruns, and overview and main features of 5D BIM, and the benefits and potential challenges of 5D BIM deployment in projects. The analysis include assessment of 5D BIM efficiency in addressing cost management issues in projects.

The quality of the selected studies is evaluated based on their relevance to the research questions, clarity of research design and methodology, validity and reliability of findings, and their contribution towards cost management issues and 5D BIM. The results are structured to address each research question and findings' comparison against the existing literature. The discussion emphasizes on the implications for implementation and future research, specifically underlining the cost management issues within the upstream of oil and gas projects, the unknown factors contributing cost overruns and the features of 5D BIM in enhancing cost management and reducing overruns.

In summary, the research methodology adopted in this study assures a thorough and methodical strategy in performing literature review on cost management issues, project cost overruns, and the feature of 5D BIM. The result provides valuable insights specifically to the upstream oil and gas projects and suggest opportunities for future research in enhancing the efficiency of 5D BIM as solutions to cost management issues.

3. Cost Management in Projects

3.1 Cost Management Issues in Upstream Oil and Gas Projects

Projects in upstream oil and gas face many challenges, encompassing project complexity, cost estimation, budgeting, control tools, reporting reliability, communication, and stakeholder management. These issues if not addressed can lead to cost management issues throughout the project life cycle, requiring vigilant cost control measures from the project teams (Tanaka, 2014).

Complexity type of a project significantly contribute to cost overruns and delays. Large scale projects with high complexity face challenges in data entry persists in high complexity and large-scale projects which require a specific cost management approach (Kujala et al., 2014; Azmat & Siddiqui, 2023). Dynamic budgeting, inaccurate cost estimates, and inefficient cost controlling tools are hindering the cost management effectiveness resulted to failure in supporting inter-organisational cost management and portray budgeting limitation (Mohd Nor et al., 2022; Monyane et al., 2019). The insertion of unnecessary budget components in project expenses further complicates cost management (Hanid et al., 2011).

Accurate cost estimates and thorough risk analysis are important in recognising potential risk to develop proper risk management plan indirectly reduce or eliminate any probability of cost overruns and delays (Kwoyigah et al., 2021). Nonetheless, project monitoring remains as the main challenges due to unavailability of integrated cost control digital tools to manage huge volume of project data (Sloninsky, 2012; Adjei et al., 2017).

The absence of effective and robust support system requires by Integrated Project Delivery (IPD) leads to poor project performance. Project issues such as information quality, incompetence, organisational structure, and holding of information to present positive project success are identified as ineffective communication hinders for success project management (Pozin et al., 2018; (Nalewaik et al., 2009). Additionally, communication with long distance stakeholders jeopardise due to poor communication technologies (Hussain et al., 2018).

Managing project conflict demands, eliminating communication issues such as information distortion, delays, miscommunication, conflicts of information, and trust issues are among the task in managing stakeholder relations (Rajhans, 2018). Complex projects require an effective team collaboration and enhanced management proficiency to foster confidence among stakeholders, effective decision making and minimize resource wastage (Al Nahyan et al., 2019).

In conclusion, effective cost management in upstream oil and gas projects require focus in managing the complexity, refining estimation and effective budgeting process, deployment of efficient cost control tools, improved communication, and effective stakeholder management through robust support systems and team collaboration.

3.2 Causative Factors of Cost Overruns

Cost overruns are defined as scenario when the actual cost of a project exceeds the sanctioned budget. The cost variance denoted as a positive variance between the actual cost at completion and the budget (Derakhshanalavijeh & Teixeira, 2017), additional actual costs incurred compared to the awarded contract cost during the bid proposal (Endut et al., 2005), or when the actual amount spent surpasses the planned amount (Gupta, 2019). The Cambridge Dictionary (2005) also defines cost overruns as extra actual costs expended on a project (Cambridge Dictionary, 2005).

Factors contributing to cost overruns vary based on project scale, complexity, and geographic location (Memon et al., 2011). Major causes include flawed design, excessive contract duration, imposed requirements, insufficient expertise, delayed supply deliveries, poor management-worker relationships, tardy completion and acceptance of drawings, inadequate planning and scheduling, and ineffective site management. Errors during the construction phase are particularly impactful (Memon et al., 2011).

Internal risks, such as project risk and government support, as well as unethical behavior by stakeholders, also contribute to cost overruns (Adeleke et al., 2022; (Gomarn & Pongpeng, 2022). Specifically, in Saudi Arabian oil and gas construction, the primary factors are client-driven design changes, poor planning and scheduling, design errors, misunderstanding of the work scope during bidding, and cost/schedule underestimation (Seddeeq et al., 2019). Technical, economic, financial, political, regulatory, management, resource, and environmental factors are also significant contributors ((Abdel Hafeez et al., 2016)).

Change orders, which involve client-contractor negotiations, are a common cause of cost overruns and delays (Dahlin & Pesämaa, 2021) In building construction, primary risk factors include contractor financial instability, owner delays in progress payments, lowest-bidder contract awards, inadequate planning and scheduling, manpower shortages, and insufficient contractor experience (Alshihri et al., 2022). Other factors include variation orders, inadequate supervision, delays between procurement and design phases, force majeure events, limited design team experience, work suspension, inaccurate cost estimation, volatile currency exchange rates, and ineffective coordination among contracting parties (Daoud et al., 2023).

Design issues, such as errors, changes, and inconsistencies, significantly increase project costs (Berihu et al., 2023). Deviations in design specifications and discrepancies between quantity take-off and project drawings are also problematic (Abdulraheem & Gbenga, 2023). In summary, change orders are identified as most frequent causative factors of project cost overruns, followed by the requirement of well-defined project scope and sufficient budget allocation.

4. 5D Building Information Model

5D Building Information Modeling (5D BIM) emphasise on developing accurate cost information namely capital expenses, maintenance costs, and future replacement cost. This model-based costing enables visualising expenses in 3D, triggers notification upon any changes, and automatically quantifying components related to the project (Cheng et al., 2017).

Adding the cost dimensions to BIM process enables a reliable cost monitoring and planning throughout the project lifecycle and generate value creation to projects. 5D BIM safeguards efficiency and adherence to sanctioned budget by utilizing 4D progress data and contract value. Precise cost estimates rely on data from various sources shared on a single platform. Cost managers to define and understand common features across different models prior to developing model for 2D project components (Alrashed & Kantamaneni, 2018).

An information model typically includes quantities from real model components, invisible model components, and non-modeled quantities like temporary works and construction joints. Design models reveal design quantities, but construction quantities are only apparent during the construction phase. Cost managers must consider quantities not solely dependent on model components. As BIM technology advances, it will be better utilized in engineering cost management (Wen, 2019).

One significant advantage of extracting cost from the information model is the ability to access and update data throughout a project. Cost managers can provide faster and more accurate cost reporting from the project's inception, requiring them to work faster and more iteratively. BIM technology should be applied to the entire

construction project process for effective cost management, contributing to overall project control and economic benefits (Ha, 2021).

Previous studies confirm that BIM technology allows for precise cost information extraction, benefiting all project teams by ensuring accurate and efficient cost management throughout the construction process.

4.1 Benefits of 5D BIM

Existing research highlights numerous advantages and benefits of adopting BIM in the construction industry. BIM deployment generates significant competitive advantages through enhanced collaboration, increased productivity, precise model representations, reduce changes, early problem detection, and enhanced data management in an organisation (Jesline, 2018). Key benefits include increased efficiency, cost-effectiveness, and sustainability, as demonstrated by a successful BIM implementation study in Malaysia, which noted improved project monitoring, enhanced safety, and greater stakeholder collaboration (Al-Ashmori et al., 2020).

BIM's ability to replicate buildings within an informative environment, contributing detail visualization capabilities that accelerate design development. This technology features enable designers manage informative environments, stimulate models swiftly, assess design options, analyse various building scenarios without any manual drawn sketches, and expediating the extraction of building plans, details and sections (Fakhimi et al., 2021).

Thru the design phase BIM plays significant role, project team able to visualize construction sequences which incorporated in construction deliverables, significant input for constructability review and feasibility of designs. 4D models provide a clear visualisation of construction overview which enables effective construction planning (Stanley & Thurnell, 2015).

Quantity Take Off (QTO) is automatically generated from the models, enables BIM in generating precise quantity, indirectly reducing the inaccuracies and errors captured with manual cost estimation, and improve cost estimation process by adopting standardised measurement methods (Fakhimi et al., 2017).

BIM technology features major benefits such as improved collaboration among stakeholders, provide digital representation, visualisation of project scope, efficient QTO tools resulted to reduction of change orders (Hasan & Rasheed, 2019). 5D BIM plays vital role during the initial design stages to facilitate collaboration among stakeholders and integrates value engineering as a 5D BIM technique for maximizing value improvement (Lee et al., 2018).

4.2 Challenges of 5D BIM

Existing research highlights on several significant challenges arise during 5D BIM deployment, such as negative attitudes towards data sharing, resistance to change, uncertain organisational benefits, a limited number of 5D BIM experts, the absence of well-established BIM workflows, and increased investment costs (Yao et al., 2020). Struggle in adapting existing workflow to lean-oriented processes and inculcate understanding of BIM's potential advancements compared to conventional methods are common challenges in the UK construction industry (Khosrowshahi & Arayici, 2012).

Most organisations are yet to discover the benefits and efficiency in using BIM process. Nevertheless, industry demands for faster, highly efficient, and more precise billing is expected to expedite the BIM deployment (Mesároš et al., 2019). Slow BIM acceptance in Malaysia is mainly due to lack of awareness on the technology to potential users (Al-Ashmori et al., 2020). Limited 5D BIM specialist is due to the extensive training required and high investments associated with the capability development hinders opportunities to explore this technology (Hasan & Rasheed, 2019). Research conducted in UK shows that getting an expert in BIM remain a challenge (Khosrowshahi & Arayici, 2012).

A well-structured deployment plan is crucial to mitigate these challenges and ensure successful implementation of the technology in Malaysia. Key success factors include strong commitment and knowledge of BIM among industry stakeholders, capacity-building initiatives, organisational support, and collaborative synergy among industry professionals. Comprehensive education and training programs for practitioners are necessary, especially in the ICT sector, to facilitate BIM adoption. Organisational support through employee training and investments is essential, as is fostering collaboration to overcome industry fragmentation (Amuda-Yusuf, 2018).

5. How Cost Management Problems in Upstream Oil and Gas Could Be Solved with 5D BIM

Based on the SLR conducted, it can be concluded that 5D BIM possesses the necessary features and functionality to effectively address the prevailing cost management challenges encountered in Upstream Oil and Gas projects. The subsequent paragraph will expound upon how BIM can mitigate these cost management issues, namely through accelerated data entry and automated calculations, consolidation of project data within a single platform, generation of highly precise cost estimations, and facilitation of efficient project information flow.

Cost management of upstream oil and gas projects are challenging due to the project scale and complexity (Tanaka, 2014) resulted to delay in data entry of project report. 5D BIM able to save time in managing cost (Usman et al, 2019), improves productivity (Al-Ashmori et al., 2020) with its ability to automatically generate quantities from a model which could be utilize for updating physical and cost progress. The integration of project data into a unified platform has the potential to streamline the data entry process, minimize errors in data input, automate progress calculations based on predefined formulas, and ultimately generate accurate and reliable reports. Consequently, this integration can greatly enhance productivity.

Another challenge is to consolidate different parts of different projects into a whole report. Consolidating data from different systems can also make it hard to report accurately and on time (Nalewaik et al., 2009). Previous studies concluded that 5D BIM established connection between the BIM model and project information (Agostinelli et al., 2019) which eliminates the hassle of consolidation project reports from various stakeholders. By incorporating this feature, the process of report consolidation will be expedited, leading to a significant reduction in the time required for report generation.

Insufficient cost contingencies to cater the project uncertainties such as materials, fabrication work and rigs could lead to cost overrun. 5D BIM able to generate high accuracy cost estimates thru better collaboration within project team, provide clear project information such as scope, clear visualization of the project, clash detection, limitation of project design, assumptions made, integration of 3D model, time, and cost (Hasan & Rasheed, 2019). Highly accurate cost estimates, derived from a comprehensive analysis of the scope of work and the prevailing competitive market rates, significantly minimize the likelihood of cost overruns.

Another common issue in a project is the project information flow. Issue arises when stakeholders unable to deliver precise information timely to the right person which mainly caused by information distortion, information delays, miscommunication between critical stakeholders, conflicts between the client and contractors or internal conflicts within the project team, a lack of a single point of contact, and a lack of trust among stakeholders (Rajhans, 2018). (Maliha et al., 2021) proofed BIM able to integrate project information and ensure distribution of correct information to identified stakeholders thru a systematic document management. Integration of project data is crucial to ensure the same information reach all levels (Ernst & Young, 2017).

Overall, research on cost overruns describes in depth the underlying causes(Bergli & Falk, 2017; Kamaruddeen et al., 2020; Karami & Olatunji, 2020; Kayrbekova et al., 2012; Manuel & Teixeira, n.d.; Niazi & Painting, 2017), mitigating actions (Asiedu et al., 2017; Ullah et al., 2018), and suggested improvements (Olawale & Sun, 2015; Wardhan, 2021). Project information under Building Information Modeling (BIM) can be effectively disseminated to all stakeholders, thereby facilitating the elimination of issues related to miscommunication, information distortion, and non-delivery of information. However, certain sensitive data pertaining to project estimation, tender price, and award value necessitates the implementation of robust security measures, ensuring that access is restricted solely to authorized personnel.

6. Conclusion

The current project system lacks integration in processes, people, and technologies, which renders it incapable of addressing cost overrun issues. Therefore, it is necessary to adopt a supplementary project management strategy to rectify this deficiency and effectively manage the deployment of BIM in the industry. By integrating project data into a unified platform, BIM can streamline data entry, automate progress calculations, and generate precise cost estimates. Consequently, this can significantly reduce the time required for report generation and enhance overall productivity. Additionally, BIM facilitates improved collaboration within the project team, enabling the production of highly accurate cost estimates. However, it is crucial to ensure that project information is properly disseminated to all stakeholders to mitigate issues such as miscommunication, distortion of information, and failure to deliver information. Consequently, it is crucial to implement robust security measures to safeguard sensitive data. This paper provides a significant new foundation for the oil and gas industry to make informed decisions about BIM deployment by highlighting its features that effectively address the prevailing cost management challenges in the industry.

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Conflict of Interest

We declare that there is no conflict of interest regarding the research work presented in the manuscript titled "5D BIM Implementation to Overcome Cost Management Issues in Upstream Oil and Gas Projects in Malaysia: A Review." We affirm that neither of us has any financial or personal relationships with individuals or organisations that could inappropriately influence or bias the content of this work. This research has been conducted impartially

and without any external influence. We disclose any potential conflicts of interest that could be perceived as having an impact on the integrity or objectivity of the research process and its outcomes.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design***: Azura, Mohamad Syazli; ***data collection***: Azura; ***analysis and interpretation of results***: Azura, Mohamad Syazli; ***draft manuscript preparation***: Azura. All authors reviewed the results and approved the final version of the manuscript.

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