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AUGMENTING PERFORMANCE OF PREFABRICATED MEP MODULAR SYSTEMS VIA BIM INTEGRATION

J.D.R. Ranathunga[1], C. Hadiwattege[2] and T.M.P.N. Thennakoon[3]

ABSTRACT

Within the Architecture, Engineering, and Construction (AEC) sectors, prefabrication is an emerging technology which concerned with the construction production process and serves as a manufacturing platform to improve productivity and safety management. Whether they are located off-site or on-site, the coordination and fabrication of Mechanical, Electrical, and Plumbing (MEP) systems have consistently presented challenges. MEP designers lack the necessary expertise to create detailed models for prefabrication, but designers proposed enhancing collaboration with fabricators to develop installation-level BIM models for design coordination, construction planning, on-site delivery planning, clash detection, and fabrication planning in Modular MEP construction. Therefore, this study aims to investigate the integration of BIM in enhancing the performance for time, cost, and quality aspects of prefabricated MEP modular systems in buildings. Accordingly, a qualitative research strategy was chosen to achieve the aim, data were collected through twelve (12) semi-structured expert interviews. Experts were selected through purposive sampling followed by snowball sampling. The data analysis was conducted through manual content analysis. Findings revealed how efficiently BIM addresses the time, cost, and quality of prefabricated MEP modular systems. Finally, as a contribution to knowledge, the study revealed the importance of BIM and how it enhances the efficiency and effectiveness of the prefabricated MEP modular system.

Keywords: *Building Information Modelling (BIM); MEP Modular System; Prefabrication.*

1. INTRODUCTION

According to Baek et al. (2023), prefabrication technology involves off-site manufacturing in a controlled environment, which enhances productivity and safety by streamlining construction. This method reduces on-site material processing and waste, leading to shorter construction periods and improved efficiency. The implementation of MEP prefabrication has already taken place in some countries, such as the United

[1] Undergraduate, Department of Building Economics, University of Moratuwa, Sri Lanka, dileesharoshane946@gmail.com.
[2] Senior Lecturer, Department of Facilities Management, University of Moratuwa, Sri Lanka, chandanieh@uom.lk.
[3] Temporary Lecturer, Department of Facilities Management, University of Moratuwa, Sri Lanka, piyumithnisansala146@gmail.com.

Kingdom (UK), the United States of America (USA), Australia, and China (Lavikka et al., 2021). Examples of prefabricated MEP modular solutions include technical rooms; prefabricated pipeline manifolds; corridor elements such as ductwork, pipework, and electrical cables in MEP racks; and bathroom pods that incorporate pipework, electrical cables, and ductwork. Throughout history, the coordination and fabrication of Mechanical, Electrical, and Plumbing (MEP) systems, whether situated on-site or within a factory as components of modular construction projects, have consistently posed difficulties (Korman & Lu, 2011).

MEP designers lack the necessary expertise to create detailed models for prefabrication, but one designer proposed enhancing collaboration with fabricators to develop installation-level BIM models and address this limitation (Pan et al., 2008). Specifically, BIM is acknowledged as a remedy for achieving seamless information integration between construction and manufacturing sites (Mostafa et al., 2020). BIM is ideal for design coordination, construction planning, on-site delivery planning, clash detection, and fabrication planning in Modular construction. Design, Construction, and Operation and maintenance are the three main aspects that are considered during MEP coordination (Korman & Lu, 2011).

A study by Glassman (2011), investigated whether the modelling of BIM at different levels of detail (LOD) had an impact on MEP design coordination. BIM permits the visualisation of virtual replicas of the structure or the creation of 3D models that aid in identifying issues and making improved decisions regarding materials, leading to a significant reduction in construction expenses. BIM facilitates the utilisation of prefabricated or modular construction methods, streamlining workflows to a greater extent compared to conventional construction approaches. According to Khanzode et al. (2008), the Prefabrication of plumbing and low-pressure ductwork enabled a general contractor to enhance construction site safety and efficiency, while the implementation of BIM improved MEP work productivity by 5 to 25% through streamlined work coordination

Despite the potential benefits of both BIM and prefabrication, there often exists a lack of synergy between these technologies and construction methods. In the context of construction projects involving prefabricated MEP modular systems, the full potential of BIM remains underutilised, leading to inefficiencies in project delivery and resource utilisation. The lack of seamless integration and effective implementation of BIM with prefabrication techniques hinders the industry's ability to achieve enhanced efficiency, cost-effectiveness, and sustainability in construction processes. Therefore, there is a gap in knowledge for “What are the project success factors (SF) that impact on time, cost and quality when integrating BIM for prefabricated MEP modular systems?” To achieve the knowledge, gap this study aims to examine how BIM can be leveraged to optimise prefabricated MEP modular systems, thus enhancing construction project outcomes and overall industry performance. This aim is supported by three objectives: identifying the BIM-enabled features for prefabricated MEP modular systems to enhance time, cost, and quality performance; determining the success factors of construction projects through a literature review; and evaluating how BIM integration affects the time, cost, and quality efficiency of prefabricated MEP modular systems through data collection.

2. LITERATURE REVIEW

2.1 DIGITAL TRANSFORMATION: THE INTEGRATION OF BIM AND PREFABRICATION WITH A FOCUS ON MEP SYSTEMS

In the 21st century, BIM has brought a revolutionary concept to the AEC industry, allowing construction virtually before it is built on the construction field (Raut & Valunjkar, 2017). As Hurtado (2017) explained, BIM provides a more intuitive and efficient three-dimensional (3D) visual building design. As stated by Hsu and Wu (2019), the BIM approach prioritises the whole lifetime of a building, generating connections across all building aspects through information integration. This integration leads to producing a comprehensive information model for prefabricated components, successfully addressing the construction industry's widespread challenges of inefficiency and obsolete practices (Wang, 2021). BIM has significantly improved the design process of prefabricated building components.

As stated by Haggart (2020), MEP systems constitute 25%-40% of the overall project expenditure, with the exact proportion depending on the building's nature and purpose. MEP prefabrication delivers a viable substitute for conventional approaches. By producing and assessing MEP components and modules offsite, plumbers, HVAC engineers, insulators, and electricians can collaborate simultaneously during installations. This streamlined approach accelerates trade coordination and installation timelines (John, 2018). The author further explained prefabrication MEP offers numerous advantages, i.e., enhanced safety, quality, scheduling, and cost-effectiveness. Additionally, it contributes to reducing environmental impact, dust and noise pollution, and construction debris. Quality control is improved due to controlled factory settings, optimised work sequence, and improved logistical coordination.

Advances in pre-design review technologies such as BIM, as mentioned by Baek et al. (2023), have enhanced the environment in which MEP coordination may be undertaken in advance. incorporating BIM data into working drawings and the prefabrication process has opened the road for a more efficient and streamlined building system installation procedure (Glassman, 2020).

2.2 INFLUENCE OF BIM-ENABLED PREFABRICATED MEP MODULAR SYSTEMS PROJECT PERFORMANCE

Integrating BIM into prefabricated MEP modular systems is a game changer. This is expected to substantially streamline the traditionally complex construction processes and set new benchmarks in cost optimisation, time management, and overall project quality. From the feasibility and design phase of construction to the end of construction and post-operational phase includes time, cost, and quality management which are the main body of construction project management. Despite the rapid development of technology and digitalisation in this era, construction projects still face many fundamental issues, such as project delay, cost overrun, and low efficiency and performance (Linderoth, 2010).

2.2.1 Time Efficiency: Reduction in Project Timelines

BIM is also adopted for MEP module design to minimise the redesign of services, snagging, and defects (Dogan & Polat, 2016). BIM integrates different disciplines through effective communication, analyses the project systems for constructability, and estimates the cost and time of projects at any time using quantity take-offs (Iqbal et al., 2020). As a result, prefabricated MEP modules lead to reduced project duration, improved construction quality, improved site safety, and lower labour demand and costs (Korman & Lu, 2011). Time can be measured in terms of construction time, speed of construction, and time overrun (Chan & Chan, 2004).

2.2.2 Cost Efficiency: Cost Savings and Budget Management

The clients may not receive the reduced costs of MEP prefabrication in the form of a cheaper MEP subsystem. Still, the costs of the whole project will be reduced through quicker on-site installation, lower logistics costs, less material waste, and fewer worker injuries (Lavikka et al., 2021). The measure of cost can be in the forms of unit cost, and percentage of net variation over final cost (cost overrun) (Silva et al., 2016). Heravi and Ilbeigi (2012), introduce the cost performance index (CPI) which is a measure of the cost efficiency of the project.

2.2.3 Quality Improvement: Enhanced System Performance

Some studies estimated that 10% of rework on the construction site is related to quality defects (Safa et al., 2015; Akinci et al., 2006), and the rework rate during the installation of the MEP system approaches 20% (Khanzode et al., 2008). Chan and Chan (2004) stress that quality, technical performance, and functionality are closely related and are considered important to the owner, designer, and contractor. Heravi and Ilbeigi (2012) use product quality and process quality separately. Elattar (2009) also refers to quality and technical performance as two distinctive criteria. However, the quality of a project was commonly defined as meeting technical specifications (Khosravi & Afshari, 2011).

2.3 CONSTRUCTION PROJECT SUCCESS FACTORS

According to Han et al. (2011) define success factors as those factors that influence, constitute as well as determine the success of a project. According to De Wit (1988) and Cooke-Davies (2002), success factors are those inputs to the management system that lead directly or indirectly to the success of the project. According to De Wit (1988), measuring success is complex because it depends on the stakeholders' points of view, and it is time dependent. The concept of success in a construction project, according to some researchers, corresponds to efficiency and effectiveness measures (Atkinson, 1999; Belout, 1998; Brudney & England, 1982; Crawford & Bryce, 2003; De Wit, 1988; Pinto & Slevin, 1988). Table 1 presents the factors with the most influence on a construction project's success as indicated by some previous studies.

Table 1: Project success factors

Code	Success Factors	References
SF01	Risk Management - Weather conditions	[11]
SF02	Risk Management - Government regulatory changes	[11], [15]
SF03	Risk Management - Site conditions	[27]
SF04	Project team competency - Skilled and experienced professionals	[1], [4], [7], [8], [9], [10], [20]
SF05	Stakeholder communication - Transparency	[5], [6]
SF06	Resource Management - Labour, material, and equipment	[3], [26]
SF07	Technological Integration - Construction related Software integration	[12], [13], [14], [25]

Code	Success Factors	References
SF08	Adaptability and Flexibility - Ability for modifications and customisation	[18], [20], [22]
SF09	Environmental management - Construction-related noise, dust, and other environmental impacts	[18], [19]
SF10	Logistics and Transportation planning - Logistics challenges	[20], [21], [23]
SF11	Maintenance consideration - Future maintenance and ease of access to components	[24]
SF12	Clash detection and resolution - Identify and resolve issues during the design phase	[16], [17]
SF13	Public Amenities and infrastructure improvements - Improvement of local public amenities and infrastructure	[2]
SF14	Inflation and currency risks - Risks associated with inflation and currency fluctuations	[11]
SF15	Local economic instability - Risk associated with interest rate changes, labour market changes, supply chain disruptions, and market demand fluctuations	[11]

[1] Belassi & Tukel (1996); [2] Sadeh et al. (2000); [3] Patanakul & Milosevic (2009); [4] Ihuah et al. (2014); [5] Osei-Kyei & Chan (2017); [6] Molwus et al. (2017); [7] Banihashemi et al. (2017); [8] Tripathi & Jha (2018a); [9] Tripathi & Jha (2018b); [10] Maghsoodi & Khalilzadeh (2018); [11] Gudienė et al. (2014); [12] Lam et al. (2010); [13] Hwang et al. (2017); [14] Sang & Yao (2019); [15] Unegbu et al. (2020); [16] Jiang (2021); [17] Korman & Lu (2011); [18] Gunawardena et al. (2014); [19] Schnell (2022); [20] Wuni & Shen (2020a); [21] O'Connor et al. (2014); [22] Choi et al. (2016); [23] Li et al. (2016); [24] Wuni & Shen (2020b); [25] Belay et al. (2021); [26] Esmaeili et al. (2014); [27] Salminen (2005)

Efficiency measures deal with time, budget, and specifications, whereas effectiveness measures refer to the achievement of project objectives, user satisfaction, and the use of the project (Takim & Adnan, 2009). Therefore, construction project success could be viewed as the degree of achievement of efficiency (short-term perspective) and effectiveness (long-term perspective) objectives of execution of a project (Baccarini, 1999). The construction sector still faces challenges due to time delays, excessive costs, poor quality and safety. It is important to understand a project's performance and the relationship between results and initial objectives to overcome these challenges. As a result, there is a continuing need to identify and determine the factors that influence the success of construction projects (El Touny et al., 2021).

3. RESEARCH METHODOLOGY

According to Creswell (2016), the research approach is a collection of plans and procedures for conducting research, ranging from general hypotheses to specific techniques for gathering, analysing, and interpreting data. Given the specific characteristics of the data required for this study, a qualitative approach was chosen instead of opting for quantitative or mixed approaches. Since this study required the experiences of experts and specialists and observation-based solutions to investigate how BIM enhances the efficiency of prefabricated MEP modular systems, the study followed a qualitative approach. Accordingly, in line with the qualitative research approach adopted, expert interviews with open-ended, and -semi-ended questions were deemed appropriate for gathering data in this study. The questions become more structured in successive phases to verify previous consensus, examine assumptions, and finalise decision-making frameworks (Birdsall, 2004). The semi-structured interview guide is chosen because it offers a clear set of instructions to interviewers, ensuring reliability and comparability in acquiring qualitative data (Salminen, 2005). Further, this method offers significant advantages, including the ability to gather more information, overcome resistance through interviewer skills, greater flexibility, and facilitated observation. Therefore, this data collection method can successfully achieve the third research objective by evaluating which project success factors are achieved through BIM features and how these factors contribute to improvements in cost, time, or quality efficiency of the project.

Therefore, through the expert's interviews success factors (SF) that impact on time, cost, and quality `of a construction project and the factors impacting the efficiency of prefabricated MEP modular systems when integrated with BIM were identified. Accordingly, success factors (SF) that impact on Time, Cost, and Quality were determined. Therefore, this paper addressed the research problem "What are the project success factors (SF) that impact time, cost, and quality when integrating BIM for prefabricated MEP modular systems".

Twelve semi-structured interviews which were saturated after the ninth interview, were conducted with industry professionals from diverse countries who were keenly interested in the subject matter and demonstrated curiosity about the BIM concept. These interviews were designed to produce insights aligned with the literature findings. Comprehensive interview guidelines were prepared to ensure the acquisition of relevant information. Details of the interviewees were summarised in Table 2.

Table 2: Profiles of interviewees

Code	Designation	Experiences with the construction industry (Including BIM, MEP, and prefabricated modular systems)	Country
E1	Senior Quantity Surveyor	16	Sri Lanka
E2	MEP & Infrastructure Construction Manager	25	Egypt
E3	Senior BIM Manager	17	USA
E4	Senior MEP Quantity Surveyor	10	Sri Lanka
E5	Project Manager- Modular Building Construction	21	UAE
E6	Commercial Manager	26	UAE
E7	Senior MEP Quantity Surveyor	13	Saudi Arabia
E8	MEP Prefabricator	11	UAE
E9	Senior Quantity Surveyor | Contracts Administrator	12	Qatar
E10	BIM Coordinator	18	Saudi Arabia
E11	MEP Industrialised Construction Consultant	15	Australia
E12	General Manager- Manufacturing	23	UAE

4. RESEARCH FINDINGS AND DISCUSSION

Based on the generic factors which are identified related to construction project success factors were analysed according to the opinions of the experts. Time, cost, and quality influence of that success factors when implementing BIM for prefabricated MEP projects. The collected data were analysed through manual content analysis. Consequently, findings through the conducted expert interviews have been discussed as follows.

4.1 TIME EFFICIENCY: HOW DOES BIM INTEGRATION AFFECT THE TIME EFFICIENCY OF PREFABRICATED MEP MODULAR SYSTEMS?

All the experts identified that integrating BIM within the prefabricated MEP modular systems will extensively enhance efficiency in terms of time. According to the experts analyse, most of them identified SFs have a positive impact on the time factor whereas a minority of them remained neutral considering BIM integration within the prefabricated MEP modular systems. Considering SF 03 and SF 04, all the experts agreed that integrating BIM will be time efficient. For the SF 03, most of the experts pointed out that off-site prefabrication reduces workload on-site, decreasing time spent at the construction site. Moreover, E3 and E4 insisted that BIM considerably reduces the time spent on-site to install prefabricate MEP modular systems. Considering SF 04, E7 highlighted that with BIM, the project team can collaborate more effectively, allowing MEP designers, engineers, and prefabrication specialists to work closely together.

All the experts except E1 agree that BIM can save time when integrating into Prefabricated MEP modular systems when considering SF 05. E1 conveyed that "*it only sometimes saves time, as expected. For example, coordinating stakeholders can lead to misunderstandings, causing delays in software installation".* When considering SF06 most of the experts expressed that project managers optimise resource allocation by incorporating prefabricated MEP modules into the BIM model, ensuring that labour, materials, and equipment are available at the right time and in the right quantities. This eliminates delays caused by resource shortages or overstocking, increasing time efficiency throughout construction. Considering SF 07, E4 remained neutral regarding time efficiency and E1, E7, E8, and E12 experts emphasised that digitally modelling the assembly process allows construction teams to determine the most effective order for positioning MEP modular components on-site. This optimises the construction schedule with minimal disruptions and interruptions, saving time.

Regarding the SF 11 E2, E4, E5, E7, E8, E10, and E12 experts elaborated that Engineers, designers, and fabricators can guarantee that components within prefabricated MEP systems are structured; thus, that maintenance tasks are easily accessible by incorporating future maintenance considerations into the design process utilising BIM. E2 explained the impact on time from SF 12, *"When considering prefabricated MEP modular systems, precision is key. BIM allows us to precisely coordinate these MEP modules, ensuring a flawless fit when assembled on-site. This precision saves time modifying or adjusting components due to clashes, providing faster installation".* E6 identified that SF15 positively impacts time integrating BIM whereas other experts remained neutral, elaborating that local economic instability and associated risks like interest rate changes, supply chain disruptions, labour market fluctuations, and market demand fluctuations can significantly affect construction project timelines. This helps optimise project efficiency and stability, assuring timely delivery despite economic challenges.

<u>Discussion</u>

MEP modular systems with BIM for improving time efficiency reveal a consensus among experts on several success factors. Experts unanimously agree that BIM integration significantly reduces on-site workload, enhances coordination, and minimises risks, thus reducing construction duration. This is attributed to real-time data exchange and seamless collaboration among stakeholders. Additionally, BIM facilitates effective communication, value engineering, regulatory compliance, resource planning, and clash detection during the design phase, all of which contribute to streamlined workflows and accelerated project timelines.

4.2 COST INFLUENCE: WHAT ARE THE COST IMPLICATIONS OF IMPLEMENTING BIM IN PREFABRICATED MEP MODULAR SYSTEMS? HOW DOES IT AFFECT SAVINGS OR OVERRUN?

The SF03, E1, and E5 mentioned that prefabrication helps mitigate on-site construction risks, such as weather delays, accidents, and material wastage, which can incur unexpected costs. E3 and E10 identified that SF 04 positively impacts cost by elaborating that a skilled professional can use BIM to facilitate the prefabrication process of MEP modules. These experts can automatically generate fabrication drawings and details directly from the model, enabling the manufacturers to understand the MEP module design and specification. Moreover, E3 clarified that SF 05 positively impacts utilising BIM and that the project team can view the same digital platform simultaneously.

For SF 06, most of the experts identified that merging BIM with prefabricated MEP modular systems positively explained their insights, while E7 stayed unbiased. E1, E3, E4, E6, and E8 clarified that prefabricated MEP modules are assembled off-site in controlled environments by skilled labourers, reducing the need for on-site labour and associated costs. Furthermore, minimises the cost with BIM, allowing for detailed planning and scheduling of labour tasks. When considering SF08 regarding the cost characteristic. E2, E7, E10, E11, and E12 Highlighted that incorporating MEP modular systems into the BIM model allows for precise coordination between off-site fabrication and on-site installation activities. As an outcome, the chance of errors and discrepancies is minimised, leading to fewer costly modifications during fabrication.

Most of the respondents insisted that integrating BIM reduces the overall transportation costs related to the project. Further, E5 specified that it reduces the need for overtime or rush deliveries, reducing labour costs and saving the project's overall cost. All experts agreed that while E1 stayed unbiased, SF11 saves costs when utilising BIM within prefabricated MEP modular systems. E12 explained that owners can make more informed decisions about system design, material selection, and maintenance strategies by modelling alternative maintenance scenarios and analysing the financial implications throughout the building's lifecycle. This proactive strategy minimises maintenance expenses while increasing system reliability and performance. Considering the SF12, all the experts highlighted that by addressing clashes early with BIM, these costly rework scenarios are avoided.

Discussion

The incorporation of BIM with prefabricated MEP modular systems is crucial for optimising cost-effectiveness in construction projects. Experts agreed that harnessing BIM incorporates several positive impacts. Automatically generating fabrication drawings and details (prefabrication model), accessibility to the project team for the same digital platform simultaneously, reducing site labour requirement due to BIM cooperated off-site work and minimising errors, and discrepancies by leading to fewer costly modifications during fabrication are the main positive impacts that extracted from experts' opinion. Additionally harnessing BIM for prefabricated MEP construction is a proactive strategy that minimises maintenance expenses while increasing system reliability and performance.

4.3 QUALITY ENHANCEMENT: IN WHAT WAYS DOES BIM CONTRIBUTE TO ENHANCING THE QUALITY OF PREFABRICATED MEP MODULAR SYSTEMS

Most of the experts identified SF 04 enhances quality when integrating BIM within the prefabricated MEP modular systems. E2 emphasised the importance of training a BIM-competent team to continuously improve and elevate quality standards. Likewise, E3, E4, E6, and E12 supported streamlined collaboration and error reduction during the fabrication and installation stages as key aspects of augmenting quality levels. For the SF 07, all the experts excluding E1 and E4 have recognised BIM enhances the Quality when integrating with the prefabricated MEP modular systems. E5, E9, and E11 explained that BIM can harmoniously integrate with modern construction techniques, such as off-site prefabrication and modular construction.

Considering SF 05, only E1, E4, and E7 remained neutral while other experts stressed that BIM integration influence positively quality in prefabricated MEP modular systems. E2, E3, and E9 stated that in organisations with a transparent culture, there is a greater emphasis on open communication and cooperation among stakeholders participating in BIM-integrated projects. For SF 08, E4 and E9 highlighted that BIM software supports parametric models, in which components are specified by their parameters and connections to other elements in the model. This parametric modelling technique allows for more freedom in design adjustments and customisations. Engineers update factors inside the BIM model, such as size, materials, or connection types, to adapt to changes without requiring extensive redesign work. Regarding SF 13, E4 and E8 explained that enhanced public amenities usually include updated building codes and regulations. Thus, incorporating BIM with local regulatory conditions ensures that prefabricated MEP systems are developed and installed in adherence with these standards, improving safety and efficiency.

Only three experts (E2, E4, and E9) expressed that incorporating BIM into prefabricated MEP modular systems positively impacted SF 03. E4 and E9 emphasised that by considering site conditions such as transportation restrictions and assembly requirements, manufacturers can reduce production workflows and ensure that the modular systems are fabricated to the highest quality standards, including implementing quality control measures to detect and rectify defects or variations before the modules are delivered to the construction site. Three experts (E2, E8, and E10) described their opinions on SF 09. E8 and E10 noted that by utilising BIM, construction teams can simulate the assembly of prefabricated MEP modules and determine the optimal sequence to minimise noise and dust generation, enhancing the quality of overall site environmental management.

Discussion

The integration of Building Information Modeling (BIM) into prefabricated modular systems has been identified as a significant factor in enhancing quality. Experts emphasise the importance of training a BIM-competent team, streamlined collaboration, and error reduction during fabrication and installation stages. BIM can harmoniously integrate with modern construction techniques, such as off-site prefabrication and modular construction. BIM integration positively influences quality in prefabricated MEP modular systems, as it allows for more freedom in design adjustments and customisations. BIM software supports parametric models, allowing for more freedom in design adjustments and customisations. By considering site conditions, manufacturers can reduce production workflows and ensure high-quality systems. BIM also allows construction teams to simulate assembly and minimise noise and dust generation, enhancing overall site environmental management.

5. CONCLUSIONS

The construction sector confronts various challenges tied to project efficiency, coordination, and resource management. One specific issue pertains to the suboptimal utilisation of BIM technology alongside prefabricated MEP modular systems. Despite the potential benefits of both BIM and prefabrication, there often exists a lack of synergy between these technologies and construction methods. This research aims to tackle this issue by examining how BIM can be leveraged to optimise prefabricated MEP modular systems, thus enhancing construction project outcomes and overall industry performance. A qualitative research strategy was chosen to achieve the aim. A multi-faceted approach to comprehensively investigate the potential of BIM in enhancing building performance within prefabricated MEP-integrated modular service systems.

The scope of this study is to identify the advantages of prefabricated MEP modular systems to traditional MEP installation within the context of BIM. Further, this research narrowed to the benefits of prefabricated MEP modular systems in terms of time, cost, and quality. The study contributed knowledge by identifying construction projects' CSFs that impact the BIM-enabled prefabricated MEP modular systems. Further, the study revealed the importance of BIM and how it enhances the efficiency and effectiveness of the prefabricated MEP modular system to achieve the time, cost, and quality efficiency of a project. Future research and exploration can further enhance the understanding, implementation, and optimisation of this integration. Future research should delve into comprehensive lifecycle analyses to understand the long-term implications of BIM-integrated prefabricated MEP systems on maintenance strategies, system performance, and sustainability.

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