Hewavitharana, S., Perera, S., Jin, X., Seneviratne, K. and Bamdad, K., 2025. A review of procurement and management of building services systems: Complexities and technology adoption. In: Waidyasekara, K.G.A.S., Jayasena, H.S., Wimalaratne, P.L.I. and Tennakoon, G.A. (eds). *Proceedings of the 13th World Construction Symposium*, 15-16 August 2025, Sri Lanka. pp. 41-55. DOI: https://doi.org/10.31705/WCS.2025.4. Available from: https://ciobwcs.com/papers/

A REVIEW OF PROCUREMENT AND MANAGEMENT OF BUILDING SERVICES SYSTEMS: COMPLEXITIES AND TECHNOLOGY ADOPTION

Sachindra Hewavitharana[1], Srinath Perera[2], Xiaohua Jin[3], Krisanthi Seneviratne[4] and Keivan Bamdad[5]

ABSTRACT

Rapid advancements in digitalisation are reshaping the global supply chains and revolutionising traditional procurement and management practices. Within the construction industry, the procurement and management of building services systems present greater complexities compared to other construction elements. This study aims to identify these complexities and explore the potential of emerging technologies to address them. A scoping literature review of 32 peer-reviewed articles was conducted to identify the complexities in the procurement and management of building services systems from different perspectives and to identify applicable digital technologies. The findings reveal that complexities span across collaboration, approvals, design requirements, technical calculations, life cycle, communication, regulatory requirements, maintenance, cost, technical skills, etc. Technologies such as Building Information Modelling (BIM), Blockchain, Data Analytics and Artificial Intelligence (AI), Digital Twin and IoT, and Building Management Systems have been widely adopted to address these complexities. This identification urges the necessity of a systematic and technology-integrated approach to the procurement and management of building services systems. The findings from this research assist construction professionals in selecting appropriate technologies aligned with the specific requirements and phases of building services procurement and management.

Keywords: *Building Services; Complexities; Procurement and Management; Technology Adoption.*

[1] PhD Candidate, Centre for Smart Modern Construction, Western Sydney University, Australia, sa.hewavitharana@westernsydney.edu.au
[2] Professor, Centre for Smart Modern Construction, Western Sydney University, Australia, srinath.perera@westernsydney.edu.au
[3] Associate Professor, Centre for Smart Modern Construction, Western Sydney University, Australia, Xiaohua.Jin@westernsydney.edu.au
[4] Doctor, Centre for Smart Modern Construction, Western Sydney University, Australia, K.Seneviratne@westernsydney.edu.au
[5] Doctor, Centre for Smart Modern Construction, Western Sydney University, Australia, K.Bamdad@westernsydney.edu.au

1. INTRODUCTION

Building Services Systems (BSS), including heating, ventilation, and air conditioning (HVAC), electrical, plumbing, fire services, and vertical transportation, play a critical role in making buildings comfortable, functional, and safe for end-users. They often contribute significantly to both the duration (up to 50%) and cost (up to 50%-60%) of construction projects, depending on project size and complexity (Chauhan et al., 2022). The installation of BSS frequently lies on the critical path of construction schedules, directly influencing project timelines and outcomes (Shoesmith, 2010). Unlike conventional building components, such as structural and non-structural components, BSS are highly specialised, requiring expert knowledge for installation, long-term lifecycle management, multidisciplinary coordination, and compliance with strict performance standards (Akhil & Das, 2019; Wan & Kumaraswamy, 2012; Wu et al., 2022). These inherent complexities are further intensified by fragmented supply chains, changing client requirements, compliance with regulatory guidelines, and frequent design changes during the initial phases of construction projects (Khan et al., 2023). Because of this nature, procurement and management (P&M) of BSS are challenging, remain inefficient and prone to errors (Hewavitharana et al., 2024). Here, procurement and management refer to operations throughout the lifecycle of BSS.

Consequently, with the advent of industry 4.0, construction companies have explored ways of utilising technologies such as Building Information Modelling (BIM), Blockchain, Internet of Things (IoT) and Building Management Systems (BMS) in the P&M of BSS (Francis & Zhou, 2025; Husin & Kristiyanto, 2024; Perera et al., 2024). The adoption of these technologies in building services systems is still emerging with varying degrees of success and acceptance. Hence, it is vital to identify the promising research directions in this domain.

This study aims to identify the complexities of P&M of BSS and drivers and limitations of adopting trending technologies in P&M of BSS. The rest of the paper is organised in the following order: The methodology adopted for the study is presented in Section 2. Section 3 presents the findings and discussion section. Lastly, the conclusion, along with the practical implications of the research and recommendations for further investigation, is presented in Section 4.

2. METHODOLOGY

In this study, a scoping review was carried out instead of a systematic review. The reason for selecting a scoping review was to focus on the breadth of the literature in this area, as it had not been explored extensively in the past. Accordingly, three research questions were formulated to guide the scoping review.

1. Why is the P&M of BSS complex than the P&M of other construction elements?
2. What are the trending technologies in P&M of BSS?
3. How can the identified technologies reduce the complexities in P&M of BSS?

Scopus and Web of Science databases were used to identify relevant documents during the scoping review due to their reputation as the most appropriate and reliable sources for literature reviews. The search string; *("Procure*" OR "Tender*") AND ("Construction" OR "Built Environment" OR "Building services" OR "MEP" OR "Mechanical" OR "Electrical" OR " Plumbing" OR "Structure*" OR "Architecture*" OR "Civil*

Engineering" OR "Construction Engineering" OR "Construction Industry" OR "Construction Management" OR "Construction Engineering and Management") AND (complex OR challeng* OR difficult* OR "high uncertainty" OR inefficien*) AND ("Digital Technologies" OR "Blockchain" OR "BIM" OR "Building Information Modelling" OR "Industry 4.0" OR "AI" OR "Artificial Intelligence" OR "Digital Twin" OR "BMS" OR "Building Management System")* was used in titles, abstract or keywords of a publication. The search query resulted in a list of 407 papers from Web of Science and 421 from the Scopus database. Only journal papers written in the English language were considered as an inclusion criterion. However, the search process was not limited to the publication date, as most of the evidence in this domain is recent. After using the inclusion criteria, it resulted in 236 papers in Scopus and 188 in Web of Science. As some studies existed in both lists, duplicates were removed, and only 196 papers were retained. After careful screening of the title, abstract, only 32 remained for the in-depth review. Figure 1 illustrates the methodology followed in the scoping review.

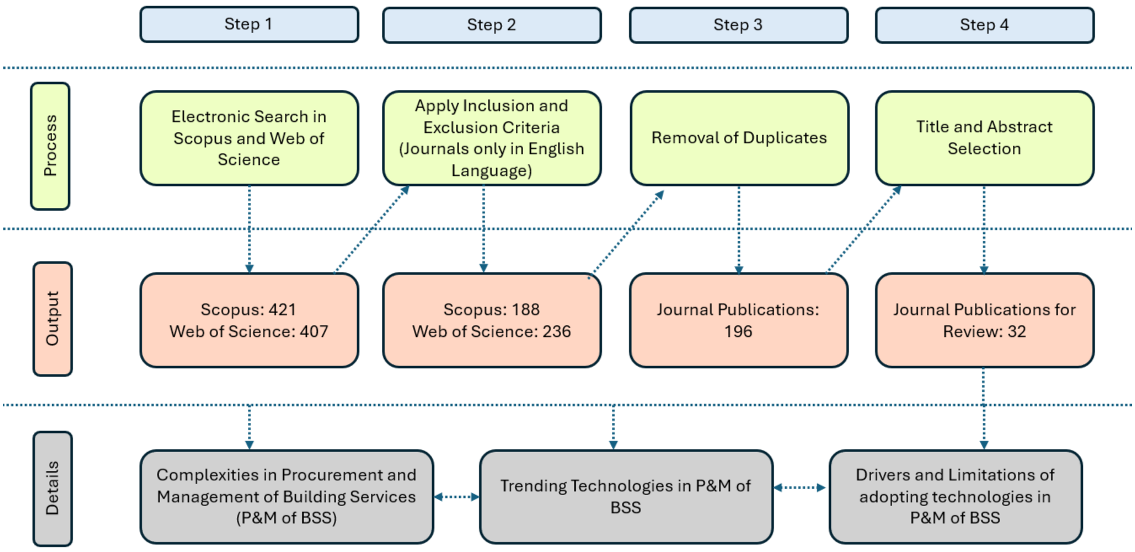

Figure 1: Research methodology adopted in the study

3. FINDINGS AND DISCUSSION

This section discusses the findings of the scoping literature review.

3.1 COMPLEXITY OF PROCUREMENT AND MANAGEMENT OF BUILDING SERVICES SYSTEMS

In general, procurement involves acquiring goods or services from external suppliers and includes activities such as requirement identification, source selection, quotation requests, and vendor evaluation (Boniface et al., 2024). However, the P&M of BSS extend beyond these conventional steps due to several factors, including the long lifecycle of systems, the involvement of multiple stakeholders, the need for specialised knowledge for installation, and strict regulatory and technical requirements. Table 1 summarises the complexities of building services from different perspectives. The areas in Table 1 were logically derived based on the literature review findings.

Table 1: Comparison of procurement and management of general building elements and building services systems

Identified Area	P&M of Building Services Systems	P&M of General Building Elements	References
(C1) Collaboration	These systems (e.g., HVAC, electrical, vertical transportation, plumbing, fire protection) are highly technical and interdependent, requiring precise integration with other building elements and subsystems. This complexity increases procurement challenges as specifications must align with performance criteria, regulatory compliance, and future adaptability.	Procurement of structural or architectural elements (e.g., concrete, steel, or finishes) has comparatively less technical integration and fewer interdependencies, making specifications and vendor selection more straightforward.	(Arora, 2023; Hassanain et al., 2019; Korman et al., 2003; Marsh, 2012; Shoesmith, 2010)
(C2) Approvals	Planning and Design require specialised knowledge, which leads to third-party consultants, builders and vendors. This process requires multiple back-and-forth approvals, which affects the schedule of the construction project.	More standardised designs and codes reduce the reliance on niche expertise.	(Abdelhameed & Saputra, 2020; Khan et al., 2023; Singh et al., 2018; Wu et al., 2022)
(C3) Design Requirements	BSS designs might include proprietary systems or vendor-specific solutions based on the intended functionalities and client requirements. Special subcontractors and manufacturers need to be selected through a tendering process for the installation.	More standardised designs and codes reduce the complexity of the designs. Subcontractor selection does not require high technical capacity.	(Akhil & Das, 2019; Rabb & Vesali, 2022; Smart Hospitals Project & Pan American Health Organization, 2020; Wan & Kumaraswamy, 2012; Wang et al., 2016)
(C4) Technical Calculations	BSS designs are more iterative, with frequent adjustments based on evolving requirements (e.g., load calculations and equipment specifications) demanding smooth collaboration.	Designs for structural and architectural components typically follow a more linear process with fewer iterations.	(Gurmu & Mudiyanselage, 2023; Smart Hospitals Project & Pan American Health Organization, 2020)

Identified Area	P&M of Building Services Systems	P&M of General Building Elements	References
(C5) Lifecycle Management	Requirements evolve over the building's lifecycle, from design, installation, commissioning, operation, and maintenance to eventual upgrades or decommissioning, ensuring the service continuity after the handover phase.	These elements typically have static specifications that end after the project handover or the defect liability period.	(Chauhan et al., 2022; Hu et al., 2016; Ni et al., 2021; Tyrrell, 2023)
(C6) Communication	The integration of BSS involves multiple stakeholders, including engineers, architects, consultants, contractors, and facility managers. Misalignment or lack of communication between these stakeholders can lead to delays, cost overruns, and performance issues.	While coordination is still necessary, the roles and responsibilities are often more clearly defined, and the integration is less complex.	(Rejeb et al., 2018; Tatum & Korman, 2000; Wan & Kumaraswamy, 2012)
(C7) Regulatory Requirements	Stringent regulations related to energy efficiency, safety, and environmental impact require meticulous documentation, testing, and approvals. Non-compliance can result in significant legal and operational risks.	These typically face fewer regulatory hurdles, and compliance tends to focus on structural integrity and material standards, which are easier to validate.	(Australian Building Codes Board 2021; Gossain, 2023; Greeno & Hall, 2009; Tyrrell, 2023).
(C8) Commissioning and Handover	The commissioning and handover of the BSS are complex, involve all stakeholders and often lie in the critical path of the construction project.	The construction of conventional elements is a well-established process in the construction schedule.	(Khan et al., 2023; Schneidera et al., 2015; Xie, 2024)
(C9) Procurement Management	BSS requires specialised procurement methods, such as performance-based contracts, due to its technical component.	Traditional (design-bid-build, design-build) and modern methods (Public Private Partnership, Engineering, Procurement and Construction) can be adopted.	(Aibinu & Papadonikolaki, 2016; Akhil & Das, 2019; Heydari et al., 2024; Kim & Kim, 2024; Mosley Jr & Bubshait, 2017)
(C10) Maintenance Management	Frequent disputes over maintenance contracts, service-level agreements (SLAs), extended warranties, and system upgrades are generated.	Limited post-construction claims, mostly related to structural defects within the liability period, are created.	(Ismail, 2021; Kumar et al., 2022; Remedial, 2022)

Identified Area	P&M of Building Services Systems	P&M of General Building Elements	References
(C11) Cost	High initial costs, coupled with unpredictable operational and maintenance costs, pose challenges in estimating. Also, delays due to custom manufacturing, technological obsolescence, and specialised installation requirements create risks in deliveries and quality.	Cost estimation is generally more predictable, and risks are limited to common issues like material shortages or weather delays.	(Akhil & Das, 2019; Cai et al., 2018; Johnson & Babu, 2020; Siren & Pennanen, 2014)
(C12) Technical Skills	Maintenance is a continuous process requiring specialised skill sets and tools. Lifecycle costs often exceed initial procurement costs, necessitating robust planning and resource allocations	Maintenance requirements are generally lower and less technically demanding, with costs concentrated upfront.	(Gurmu & Mudiyanselage, 2023; Hu et al., 2018; Khana et al., 2020; Smart Hospitals Project & Pan American Health Organization, 2020)
(C13) Future Extensions	Systems often need to be scalable and adaptable to accommodate future building expansions, changing user needs, or technological upgrades, complicating P&M.	These elements rarely require scalability or adaptation after installation.	(Gunasekara et al., 2021; Howkins, 2017; Ismail, 2021; Kumar et al., 2022; Remedial, 2022)

3.2 AVAILABLE TECHNOLOGIES FOR PROCUREMENT AND MANAGEMENT OF BUILDING SERVICES SYSTEMS

In response to these complexities, an adoption of systematic procurement and management (P&M) is required in Building Services Systems (BSS) using emerging technologies. The following section discusses the potential technologies which can be used in the P&M of BSS.

3.2.1 Building Information Modelling (BIM)

Building information modelling is a significant advancement in the construction industry, which digitally presents the building or infrastructure project's physical and functional characteristics. During the pre-construction planning stage, BIM plays a vital role in visualising the project, detecting potential conflicts and optimising the design. The 3D models generated by BIM can be used for compliance checking of building services systems and spatial requirements. This clash detection highlights the potential conflicts in the design phase, preventing expensive on-site variations (Shahruddin & Zairul, 2020). Further, BIM is used to generate accurate cost estimates and is linked with budgets so that project managers can make accurate decisions on project budgets (Pérez-García et al., 2021). Additionally, BIM can be linked with project schedules and stakeholder collaborations. This transformative approach enhances visualisation, streamlines coordination, and improves communication among stakeholders, leading to improved efficiency and reduced errors in building services projects. The capability of BIM extends beyond the initial phases of the projects. It can support the facilities management of BSS and lifecycle analysis, which enhances long-term project sustainability and operational efficiency. These insights are vital for decision-making, which seeks to optimise the resources and minimise the negative environmental impact. However, BIM adaptation faces some challenges, including high initial implementation cost, the requirement of expert knowledge of using the tool, interoperability issues with data formats and drastic workflow changes. Further, the data in the BIM models is not tamperproof, so it can be subjected to manipulation without any authorisation (Husin & Kristiyanto, 2024; Li et al., 2022; Ni et al., 2021).

3.2.2 Data Analytics and Artificial Intelligence (AI)

Data analytics and AI can be used for data-driven insights that guide strategic procurement and management of building services systems. Data analytics not only evaluate suppliers' performance but also uncover market trends, offering a holistic view of the procurement landscape. This understanding allows professionals to make better decisions on procurement strategies (Ibem & Laryea, 2014). On the other hand, AI improve the decision-making capabilities by predicting purchasing trends and optimising clients' requirements. Further, AI can automate repetitive tasks by reducing the number of intermediaries. AI can be used to analyse the contract documents and identify variations with dynamic changes in site operations (Alaloul et al., 2020). Moreover, in the post-installation phase, AI-powered systems are enabled to monitor predictive and preventive maintenance measures without human involvement. However, the adoption of AI presents several limitations. One major challenge is the requirement for large, high-quality datasets to support predictive decision-making. In practice, data within the construction sector is often fragmented across multiple software platforms, making it difficult to consolidate, trace, and extract the necessary information for effective AI model training. Additionally, many AI models, particularly deep learning algorithms, operate as "black boxes," offering limited interpretability of the underlying decision-making processes. This lack of transparency reduces stakeholder trust and confidence in AI-generated outcomes. Furthermore, ethical concerns arise regarding the use of sensitive or confidential data, particularly in relation to data security, ownership, and privacy protection (Francis & Zhou, 2025; Perera et al., 2024).

3.2.3 Digital Tools for Communication and Collaboration (DTC)

Before Procurement 4.0, construction project teams were challenged with coordinating and collaborating with diverse stakeholders such as architects, contractors, subcontractors, manufacturers and installers, especially in the planning and design phase of the building services systems (Chopra, 2018). The invention of numerous software with cloud-based systems has significantly improved stakeholder integration and promoted teamwork. Cloud-based platforms, such as file-sharing software and email communication software, facilitate real-time access to essential project data, thereby reducing the likelihood of miscommunication and ensuring everyone is aligned with project objectives and requirements (Puolitaival et al., 2018). Especially in the planning and design phase, numerous documenters are transferring among stakeholders, which is difficult to handle without a real-time update mechanism. Further to above, advanced functionalities such as version control, document tracking and permission-based access ensure data accuracy, support traceability and maintain consistency, which helps project teams to maintain a clear audit trail and ensure that everyone is working with the most updated document. A key challenge of using DTC is the fragmentation and lack of interoperability across platforms. This fragmentation makes it difficult for users to trace data origins, leading to frustration and a lack of accountability, as it becomes unclear who generated or modified specific information. In building services systems (BSS), data manipulation is a recurring issue, particularly during the maintenance phase, further undermining data integrity. If a system does not effectively prevent data manipulation, users are unlikely to have confidence in its reliability and integrity. Additionally, data security concerns and inconsistencies in stakeholder adoption of different software platforms exacerbate these limitations.

3.2.4 Blockchain (BT)

Blockchain technology represents a new era of security and transparency within procurement processes. Its integration into construction procurement workflows ensures secure, transparent, and tamper-proof execution of transactions (Jeoung et al., 2022). Moreover, the transactions recorded in the blockchain are immutable thus, the data in the blockchain is secure. The use of smart contracts in blockchain further automates procurement activities, reducing reliance on intermediaries and lowering associated costs and delays. This automation not only streamlines operations but also accelerates transaction timelines, contributing to improved project efficiency. Additionally, the distributed ledger in blockchain architecture provides real-time visibility into procurement actions, ensuring traceability and accountability while mitigating the risk of fraudulent activities (Mahmudnia et al., 2022). Blockchain support in building services systems in the maintenance period as well. Inspection data can be securely recorded on the blockchain, ensuring tamper-proof documentation that is free from manipulation or human bias. This immutable record-keeping mechanism serves as a reliable audit trail, supporting the development of asset condition reports at the end of the system's lifecycle.

This transparent approach supports data-driven decision-making, allowing construction organisations to shift smoothly throughout the procurement lifecycle. Despite the benefits of blockchain, the practical implementation of it in P&M of BSS is not without challenges. Integration of blockchain with existing legacy systems is complex and requires substantial architectural changes, as it operates as an underlying technology. Moreover, P&M of BSS generate huge data, leading to scalability and performance limitations, particularly in balancing on-chain storage with off-chain data processing. The deployment of smart contracts also raises regulatory and legal uncertainties, especially concerning contract enforceability, liability attribution, and compliance with regulations (Hijazi et al., 2021).

3.2.5 Digital Twin (DT)

A digital twin, also called a data twin, is a dynamic digital representation of a physical asset created by gathering real-world data through technologies such as 3D laser scanning, drones, IoT-enabled sensors, cameras, and other smart devices. When combined with Artificial Intelligence (AI) and the Internet of Things (IoT), digital twins can learn and autonomously update to mirror changes occurring in their physical counterparts. These models capture a wide range of asset properties, including spatial orientation, operational status, and environmental interactions. Synchronisation between the digital and physical environments is affirmed with BIM, 3D modelling software, point cloud data, and real-time sensor feedback. Digital twins significantly enhance the analytical power of BIM by transforming static models into intelligent, "living" systems capable of real-time monitoring and decision support. They enable construction teams to gain granular insight into each building service system, facilitating proactive maintenance, performance optimisation, and lifecycle assessment. This arrangement of physical and virtual environments allows stakeholders to visualise real-time asset conditions and simulate operational scenarios before implementation. For facility owners and managers, digital twins are useful for comprehensive asset monitoring, enabling the digital reconstruction of physical environments and supporting data-driven decision-making throughout the asset lifecycle. However, DT application involves high set-up and maintenance costs with many resources. Further, it requires real-time data inputs, which is challenging with IoT sensors in a construction environment. Additionally, modelling the dynamic behaviour of complex building systems remains technically demanding due to limited standardisation across platforms (Opoku et al., 2021).

3.2.6 Building Management Systems (BMS)

Building Management Systems (BMS), also called Building Automation Systems (BAS), are centralised, computer-based control systems designed to monitor and manage a building service infrastructure. Acting as the central control point for all facilities within the building, the BMS enables facility managers to remotely control and adjust equipment performance through desktop or mobile interfaces, without physically walking to each building floor and room to shut down, switch on or manually adjust the systems.

BMS enhances building performance by real-time data acquisition and automated control algorithms while reducing energy consumption and operational costs. The system plays a critical role in sustainable facility management by optimising resource usage and maintaining predefined environmental conditions. Additionally, modern BMS platforms often incorporate data analytics, fault detection, and predictive maintenance capabilities, further supporting strategic decision-making and extending asset lifespan. The key challenges associated with Building Management Systems (BMS) include limited flexibility for custom integration and reliance on expensive proprietary platforms. These systems often involve complex setup and configuration processes, and they require ongoing technical support for effective operation and maintenance.

Table 2 illustrates the summary of the potential technologies in addressing the identified complexities in P&M of BSS.

Table 2: Technological solutions to identified complexities

Complexities in P&M	Features of the technology to address the complexity in P&M	BIM	AI	DTC	BT	DT	BMS
(C1) Collaboration	BIM enables centralised design data, Digital collaboration tools improve real-time coordination, and Blockchain ensures transparency and traceability of design changes.	√		√	√		
(C2) Approvals	Blockchain ensures immutable approval logs and digital signatures, BIM helps visualise compliance for approvals, AI assists in document classification and automated review workflows.	√	√		√		
(C3) Design Requirements	BIM allows for coordination of proprietary systems and data-rich object representation; AI supports selecting optimal systems, Digital Twins simulate performance and refine requirements early in the design phase.	√	√			√	
(C4) Technical Calculations	AI automates load and energy calculations; BIM integrates technical data in design, IoT provides real-time performance data that informs calculation accuracy.	√	√			√	
(C5) Lifecycle Management	Digital Twins enable ongoing monitoring, BMS manages and adjusts systems with real time data with IoT and manages lifecycle.					√	√
(C6) Communication	Cloud-based tools facilitate cross-stakeholder collaboration, BIM provides a visual single source of truth for technical and functional data. Blockchain enhances the trust among parties.	√		√	√		
(C7) Regulatory Requirements	BIM tracks compliance throughout the design; Blockchain secures compliance records, AI detects non-conformities automatically.	√	√		√		
(C8) Commissioning and Handover	BIM and Digital Twins support accurate as-built records and operational handovers, Blockchain secures commissioning documentation and responsibilities.	√			√	√	
(C9) Procurement Management	Blockchain supports smart contracts and procurement transparency, AI assists in supplier selection and tender evaluation	√	√		√		

Complexities in P&M	Features of the technology to address the complexity in P&M	BIM	AI	DTC	BT	DT	BMS
	(Predictive analytics). BIM provides clear designs and specifications for procurement.						
(C10) Maintenance Management	BMS automates monitoring, fault detection and energy analytics. IoT provides real-time fault data with remote monitoring, Digital Twins simulate maintenance needs and optimise schedules (Performance forecasting), Blockchain maintains accountable and immutable maintenance records.	√				√	√
(C11) Cost	AI predicts cost overruns, BIM improves cost estimation through model-based quantity take-offs, Digital Twins help simulate long-term operational costs.	√	√			√	
(C12) Technical Skills	AI and digital platforms reduce dependency on manual skills, Digital Twins support remote diagnostics, IoT simplifies complex data gathering for technicians. Further Digital twin supports scenario testing.		√			√	
(C13) Future Extensions	BIM allows scalable modular designs, Digital Twins forecast performance under future changes, IoT provides feedback for reconfiguration. Blockchain provides all historical records for knowledge management.	√			√	√	

BIM: Building Information Modelling, AI: Artificial Intelligence, DTC: Digital tools for Communication and Collaboration, BT: Blockchain, DT: Digital Twin, BMS: Building Management System

4. CONCLUSION AND RECOMMENDATIONS

This study highlights the complexities involved in the Procurement and Management of Building Services Systems (P&M of BSS) due to their lengthier lifecycles, the engagement of multiple stakeholders, and the requirement of specialised technical knowledge. A scoping literature review was conducted with 32 journal papers and identified complexities in P&M of BSS in terms of collaboration, approval process, design requirements, technical calculations, lifecycle, communication, regulatory requirements, etc. The findings highlighted the importance of systematic, technology-driven approaches to address these complexities.

Technologies such as BIM, blockchain, digital communication platforms, digital twins, and building management systems have been identified as trending technologies which have the potential to streamline workflows, enhance transparency, and support informed decision-making across different phases of the building services systems lifecycle. It is important to emphasise that these technologies should go hand in hand with each other for better performance. Further, there are limitations of each technology which need attention before the adaptation, including technical, environmental, and people considerations.

Given the limited research focused specifically on building services systems procurement and management, this study contributes to bridging that gap by identifying the complexities and proposing potential technological solutions. The findings are intended to assist project stakeholders, specifically decision-makers, in selecting appropriate digital tools to manage complexity more effectively. By promoting technology adoption, the research underscores the potential for improving efficiency, collaboration, and overall project success in the construction industry, leading to the achievement of sustainable development goals. Future research can focus integration of these technologies for systematic P&M of BSS.

5. ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the Centre for Smart Modern Construction of Western Sydney University, Australia and the facilitators of the Centre.

6. REFERENCES

Abdelhameed, W., & Saputra, W. (2020). Integration of building service systems in architectural design. *Journal of Information Technology in Construction*, *25*, 109-122. https://doi.org/10.36680/j.itcon.2020.007

Aibinu, A., & Papadonikolaki, E. (2016). BIM implementation and project coordination in design-build procurement. *Proceedings of the 32nd annual ARCOM conference* (pp. 15-24) ARCOM 2016, Manchester. https://discovery.ucl.ac.uk/id/eprint/10048671/

Akhil, R. P., & Das, B. B. (2019). Cost reduction techniques on MEP projects. *Sustainable construction and building materials* (pp. 495 - 517) ICSCBM 2018, Kandy, Sri Lanka. https://link.springer.com/chapter/10.1007/978-981-13-3317-0_44

Alaloul, W. S., Liew, M. S., Zawawi, N. A. W. A., & Kennedy, I. B. (2020). Industrial revolution 4.0 in the construction industry: Challenges and opportunities for stakeholders. *Ain Shams Engineering Journal*, *11*(1), 225-230. https://doi.org/10.1016/j.asej.2019.08.010

Arora, S. K. (2023). Project failure: A bad communication (Case Study). *International Journal of Management and Humanities (IJMH)*, *9*(5), 5-7. https://www.doi.org/10.35940/ijmh.E1553.019523

Australian Building Codes Board (2021). Fire safety systems-Model guidance on BCR recommendation 19 2021. https://www.abcb.gov.au/sites/default/files/resources/2021/BCR-rec19-Fire-safety-systems.pdf

Boniface, N. A., Nnadi, E., & Eze, V. H. U. (2024). Evaluating public procurement's challenges in Nigeria's construction industry. *International Journal of Recent Technology and Applied Science (IJORTAS)*, *6*(1), 25-36. https://doi.org/10.36079/lamintang.ijortas-0601.621

Cai, K., He, S., & He, Z. (2018). Information sharing under different warranty policies with cost sharing in supply chains. *International Transactions in Operational Research*, *27*(3), 1550-1572. https://doi.org/10.1111/itor.12597

Chauhan, K., Peltokorpi, A., Abou-Ibrahim, H., & Seppänen, O. (2022). Mechanical, electrical and plumbing coordination practices: Case finnish construction market. *Annual conference of the international group for lean construction, 2022*, Canada. International Group for Lean Construction (IGLC) https://research.aalto.fi/en/publications/mechanical-electrical-and-plumbing-coordination-practices-case-fi

Chopra, A. (2018). Technology in procurement and supply as prevalent today and scope for future. *International conference on automation and computational engineering (ICACE)*, Greater Noida, India. IEEE. https://doi.org/10.1109/ICACE.2018.8686928

Francis, M., Perera, S., Zhou, W. & Nanayakkara, S. (2025). Artificial intelligence applications for proactive dispute management in the construction industry: A systematic literature review. *Journal of Information Technology in Construction (ITcon)*, *30*(29), 711-730. https://10.36680/j.itcon.2025.029

Gossain, A. (2023). *Blockchain and AI in elevators: Ensuring secure and smart vertical mobility*. Kone. Retrieved 23 of February 2025 from https://www.financialexpress.com/business/digital-transformation-blockchain-and-ai-in-elevators-ensuring-secure-and-smart-vertical-mobility-3282584/

Greeno, R., & Hall, F. (2009). *Building services handbook* (4th ed.). Butterworth-Heinemann. https://doi.org/10.1201/9781003434894

Gunasekara, H. G., Sridarran, P., & Rajaratnam, D. (2021). Effective use of blockchain technology for facilities management procurement process. *Journal of Facilities Management*, *20*(3), 452-468. https://doi.org/10.1108/jfm-10-2020-0077

Gurmu, A., & Mudiyanselage, P. W. (2023). Plumbing defects in residential buildings: Analysis of anomalies and their causes. *Facilities*, *41*(13/14), 927-956. https://doi.org/10.1108/F-10-2022-0130

Hassanain, M. A., Adewale, B. O., Al-Hammad, A.-M., & Sanni-Anibire, M. O. (2019). Modeling knowledge for MEP coordination in building projects in Saudi Arabia. *Journal of Architectural Engineering*, *25*(2), 04019011. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000357

Hewavitharana, S., Perera, S., Jin, X., Seneviratne, K. & Bamdad, K. 2024, Application of blockchain in procurement and management of building services: A critical and systematic review, *Journal of Information Technology in Construction*, *29,* 635-661 https://doi.org/10.36680/j.itcon.2024.029.

Heydari, M. H., Naderi, H., & Shojaei, A. (2024). BIM and Blockchain integration in construction procurement planning. *Construction research congress 2024*, https://doi.org/10.1061/9780784485262.080

Hijazi, A. A., Perera, S., Calheiros, R. N., & Alashwal, A. (2021). Rationale for the integration of BIM and blockchain for the construction supply chain data delivery: A systematic literature review and validation through focus group. *Journal of Construction Engineering and Management*, *147*(10), 03121005. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002142

Howkins, R. (2017). Lift modernisation challenges. *7th Symposium on lift and escalator technologies, Northampton, UK*. https://liftescalatorlibrary.org/paper_indexing/papers/00000139.pdf

Hu, Z.Z., Tian, P.L., Li, S.W., & Zhang, J.P. (2018). BIM-based integrated delivery technologies for intelligent MEP management in the operation and maintenance phase. *Advances in Engineering Software*, *115*, 1-16. https://doi.org/10.1016/j.advengsoft.2017.08.007

Hu, Z.Z., Zhang, J.P., Yu, F.Q., Tian, P.L., & Xiang, X.-S. (2016). Construction and facility management of large MEP projects using a multi-Scale building information model. *Advances in Engineering Software*, *100*, 215-230. https://doi.org/10.1016/j.advengsoft.2016.07.006

Husin, A. E., & Kristiyanto, B. D. K. (2024, October 2). Blockchain-BIM: reducing cost in green retrofitting for sustainable construction development. *Sinergi, 28*(3) 521-534, http://doi.org/10.22441/sinergi.2024.3.009

Ibem, E. O., & Laryea, S. (2014). Survey of digital technologies in procurement of construction projects. *Automation in Construction*, *46*, 11-21. https://doi.org/10.1016/j.autcon.2014.07.003

Ismail, Z.-A. B. (2021). Towards a BIM-based approach for improving maintenance performance in IBS building projects. *Engineering, Construction and Architectural Management*, *28*(5), 1468-1490. https://doi.org/10.1108/ECAM-07-2020-0508

Jeoung, J., Jung, S., Hong, T., & Choi, J.K. (2022). Blockchain-based IoT system for personalized indoor temperature control. *Automation in Construction*, *140*, 104339. https://doi.org/10.1016/j.autcon.2022.104339

Johnson, R. M., & Babu, R. I. I. (2020). Time and cost overruns in the UAE construction industry: A critical analysis. *International Journal of Construction Management*, *20*(5), 402-411. https://doi.org/10.1080/15623599.2018.1484864

Khan, M. W., Shaari, M. F., & Hussain, S. (2023). *MEP system installation related rework causes and impact on project performance; A case study of Riyadh metro project Saudi Arabian.* https://doi.org/10.31838/ecb/2023.12.s2.400

Khana, N., Leea, D., Alia, A. K., & Park, C. (2020). Artificial intelligence and blockchain-based inspection data recording system for portable firefighting equipment. *Proceedings of the international symposium on automation and robotics in construction, Kitakyushu, Japan*. https://doi.org/10.22260/ISARC2020/0130

Kim, M., & Kim, Y.W. (2024). Applications of blockchain for construction project procurement. *Automation in Construction*, *165*, 105550. https://doi.org/10.1016/j.autcon.2024.105550

Korman, T. M., Fischer, M. A., & Tatum, C. (2003). Knowledge and reasoning for MEP coordination. *Journal of Construction Engineering and Management*, *129*(6), 627-634. https://doi.org/10.1061/(ASCE)0733-9364(2003)129:6(627)

Kumar, S., Dohare, U., & Kaiwartya, O. (2022). FLAME: Trusted fire brigade service and insurance claim system using blockchain for enterprises. *IEEE Transactions on Industrial Informatics*, *19*(6), 7517-7527. https://doi.org/10.1109/TII.2022.3212172

Li, X., Lu, W., Xue, F., Wu, L., Zhao, R., Lou, J., & Xu, J. (2022). Blockchain-enabled IoT-BIM platform for supply chain management in modular construction. *Journal of Construction Engineering and Management*, *148*(2), 04021195. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002229

Mahmudnia, D., Arashpour, M., & Yang, R. (2022). Blockchain in construction management: Applications, advantages and limitations. *Automation in Construction*, *140*, 104379. https://doi.org/10.3390/buildings11120594

Marsh, C. (2012). *Building Services Procurement* (Vol. 2). Routledge. https://doi.org/10.4324/9780203301531

Mosley Jr, J. C., & Bubshait, A. A. (2017). Project procurement systems for mechanical, electrical and piping projects in Saudi Arabia: an empirical assessment. *Journal of Engineering, Construction and Architectural Management*, *24*(6), 1004-1017. https://doi.org/10.1108/ECAM-02-2016-0055

Ni, Y., Sun, B., & Wang, Y. (2021). Blockchain-based BIM digital project management mechanism research. *IEEE Access*, *9*, 161342-161351. https://doi.org/10.1109/ACCESS.2021.3130270

Opoku, D.G. J., Perera, S., Osei-Kyei, R., & Rashidi, M. (2021). Digital twin application in the construction industry: A literature review. *Journal of Building Engineering*, *40*, 102726. https://doi.org/10.1016/j.jobe.2021.102726

Perera, P., Perera, S., Jin, X., Rashidi, M., Nanayakkara, S., Yazbek, G., & Yazbek, A. (2024). Application of visual computing and deep learning in the construction industry. *Creating capacity and capability: embracing advanced technologies and innovations for sustainable future in building education and practice AUBEA 2023*, (vol 564, pp 297-308). Springer,. https://doi.org/10.1007/978-981-96-2802-5_23

Pérez-García, A., Martín-Dorta, N., & Aranda, J. Á. (2021). BIM requirements in the Spanish public tender—Analysis of adoption in construction contracts. *Buildings*, *11*(12), 594. https://doi.org/10.3390/buildings11120594

Puolitaival, T., Kestle, L., & Kähkönen, K. (2018). What's the real story around digital technologies in construction management? *42nd Australasian universities building education association (AUBEA) conference: Educating building professionals for the future in the globalised world* , (vol. 2, pp. 251-260) Technology. https://hdl.handle.net/10652/4399

Rabb, R., & Vesali, N. (2022). Design of a mechanical, electrical, and plumbing (MEP) course to enhance a new construction engineering program. *2022 ASEE Annual conference & exposition, Minneapolis, Minnesota.* American Society for Engineering Education https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Design+of+a+Mechanical%2C+Electrical%2C+and+Plumbing+%28MEP%29+Course+to+Enhance+a+New+Construction+Engineering+Program&btnG=

Rejeb, A., Sűle, E., & G Keogh, J. (2018). Exploring new technologies in procurement. *Transport & Logistics*, *18*(45). https://ssrn.com/abstract=3319424

Remedial. (2022, February 3). *The strata manager's role in building maintainance*. Retrieved July 7, 2025 from https://remedial.com.au/blogs/strata-managers-role-building-maintenance/

Schneidera, K., Lædrea, O., & Lohnea, J. (2015). Challenges found in handover of commercial buildings. *Procedia -Social and Behavioral Sciences*, *226,* 310-317. https://doi.org/10.1016/j.sbspro.2016.06.193

Shahruddin, S., & Zairul, M. (2020). BIM requirements across a construction project lifecycle: A PRISMA-compliant systematic review and meta-analysis. *International Journal of Innovation, Creativity and Change*, *12*(5), 569-590. https://www.researchgate.net/profile/Syafizal-Shahruddin/publication/341566334

Shoesmith, D. R. (2010). A study of the management and procurement of building services work. *Construction Management & Economics*, *14*(2), 93-101. https://doi.org/10.1080/014461996373548

Singh, J., Deng, M., & Cheng, J. C. (2018). Implementation of mass customization for MEP layout design to reduce manufacturing cost in one-off projects. *26th Annual conference of the international group for lean construction (IGLC), India*. pp. 625–635. https://doi.org/10.24928/2018/0519

Siren, K., & Pennanen, A. (2014). Electrical systems procurement by means of target costing. *Annual conference of the international group for lean construction, Brazil.* https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=45a2a23159af4dcfa8f473ee5f4537 3931347fc1

Smart Hospitals Project, & Pan American Health Organization. (2020, October 8). *PAHO Smart Hospitals Projects: MEP Design Issues*. UK aid. https://www.paho.org/en/documents/paho-smart-hospital-project-mep-design-issues-lessons-identified

Tatum, C. B., & Korman, T. (2000). Coordinating building systems: process and knowledge. *Journal of Architectural Engineering*, *6*(4), 116-121. https://doi.org/10.1061/(ASCE)1076-0431(2000)6:4(116)

Tyrrell, P. (2023). *Navigating the Complexities of HVAC procurement: Best Practices for 2023*. Retrieved February 23, 2025 from https://www.fieldinsight.com/blog/hvac-procurement-guide/#:~:text=One%20of%20the%20most%20fundamental,of%20issues%20down%20the%20road.

Wan, S. K., & Kumaraswamy, M. M. (2012). Improving building services coordination at the pre-installation stage. *Engineering, Construction and Architectural Management*, *19*(3), 235-252. https://doi.org/10.1108/09699981211219580

Wang, J., Wang, X., Shou, W., Chong, H.-Y., & Guo, J. (2016). Building information modeling-based integration of MEP layout designs and constructability. *Automation in Construction*, *61*, 134-146. https://doi.org/10.1016/j.autcon.2015.10.003

Wu, Q., Chen, L., Shi, P., Wang, W., & Xu, S. (2022). Identifying impact factors of MEP installation productivity: An Empirical Study. *Buildings*, *12*(5), 565. https://doi.org/10.3390/buildings12050565

Xie, Y. (2024). *Automatic as-built BIM reconstruction for MEP systems from point cloud*. Nanyang Technological University, Singapore https://dr.ntu.edu.sg/entities/publication/935ef17f-0296-41f7-936e-c8984e1b8ec8