JOVES (Journal of Vocational Education Studies)
VOL 9, No. 1, 2026, pp. 249- 261
pISSN: 2614-7483 pISSN: 2614-7475 https://doi.org/10.12928/joves.v9i1.12513

Building Sustainable Futures: Enhancing Construction Workforce Competence in BIM for Blue Infrastructure

[1]Wiwi Widanengsih,[1]Yusep Sukrawan*, [2]Lilis Widaningsih, [1]Ilhamdaniah

[1]Universitas Pendidikan Indonesia, Bandung, Indonesia
[2]Center of Excellence for Science and Technology Technical and Vocational Education and Training Research Center (PUI-TVET RC)

*Coresponding Email: yusepsukrawan@upi.edu

ARTICLE INFO

Article history
Received: Jan 06, 2025
Revised: Sep 07, 2025
Accepted: Dec 08, 2025

Keywords
Blue Infrastructure
Building Information Modelling
Competence
Construction Workforce

ABSTRACT

Digital transformation in the construction industry requires a workforce with competencies to address sustainability challenges, especially in coastal blue infrastructure projects. Building Information Modeling (BIM) has become an important technology because it can integrate hydrological, ecological, and construction analysis into one collaborative model, making it highly relevant for blue infrastructure planning.This study aims to analyze workforce competency needs in utilizing BIM for blue infrastructure planning and identify its role in supporting implementation. The research used a quantitative approach through surveys of construction professionals in Indonesia, supported by literature studies. The results show that BIM mastery is the digital skill most needed by the industry, but there is still a significant competency gap among workers. The main challenges include institutions not being ready to integrate BIM into the curriculum, economic limitations related to software licensing, and weak sustainability-oriented training curriculum design.This study recommends a roadmap for BIM integration into vocational education through curriculum reform, teacher capacity building, industry collaboration, and the development of national certification standards to accelerate digital transformation in the construction sector. The findings also emphasize the importance of interdisciplinary competencies such as environmental awareness, data analysis, and collaborative problem solving to support sustainable construction practices.

Introduction

Oceans and coastal areas face increasingly complex environmental challenges due to climate change and human activities Phong et al., (2017). The problems of coastal erosion, flooding due to rising sea levels, and ecosystem degradation, including the decline in the quality of mangrove ecosystems, are serious threats to environmental sustainability and the survival of coastal communities (Deguenon et al., 2023; Ehsan et al., 2019). Indonesia, as an archipelagic country with the second-longest coastline in the world, is an area vulnerable to the impacts of climate change, such as tropical storms and seawater intrusion, which not only damage the ecosystem but also threaten the stability of its infrastructure Vinata et al., (2023).

A nature-based approach is a solution to address this problem. The implementation of Blue Infrastructure, an approach that integrates natural elements, such as mangroves, coral reefs, and seagrass beds, with artificial infrastructure, including breakwaters and green walls, can create a more resilient and adaptive coastal environment (Almaaitah et al., 2021; Perrelet et al., 2024). This approach offers natural protection against abrasion and flooding, while supporting the sustainability of marine ecosystems and enhancing the local economy Hamann et al., (2020). The successful implementation of blue infrastructure depends on the capabilities of human resources (HR), particularly construction experts (architects), who play a key role in implementing the concept. Digital technology capabilities, such as building information modeling (BIM), are crucial tools for supporting the design and management of complex infrastructure in coastal areas Zhu et al., (2021). BIM enables the modeling, analysis, and simulation of various environmental aspects in an integrated manner, facilitating effective collaboration among stakeholders (Møller and Bansler, 2017; Waqar et al., 2024). BIM's ability to visualize the interaction between artificial and natural elements can help identify potential environmental risks, such as flooding or erosion, and provide data-driven solutions to mitigate those risks Zhu et al., (2021). The integration of BIM with other technologies, such as Geographic Information Systems (GIS), also strengthens the sustainability aspect through more accurate spatial mapping Piras et al., (2024). Studies have demonstrated the effectiveness of BIM in infrastructure projects, such as the Room for the River in the Netherlands, coastal defense in Singapore, and coastal embankment development in Malaysia, as a climate change adaptation measure. These findings confirm that BIM is not simply a tool to support technical work but a strategic instrument in ensuring the sustainability of coastal infrastructure.

Construction practice in Indonesia still faces challenges in adopting digital technology. The BIM competency gap among construction professionals, the lack of an integrated curriculum, and the limited training models that align with industry needs are significant barriers (Anarene et al.; Moshood et al., 2024). The BIM digital education and skills gap, particularly in areas such as collaboration and sustainability, can be addressed through vertical integration within the curriculum, immersive pedagogy, and team-based learning that emphasizes multidisciplinary collaboration Ghosh et al., (2013, 2015); Herrera et al., (2019); Zhang et al., (2018). Furthermore, organizational and cultural factors, particularly in small and medium-sized enterprises, influence the rate of BIM adoption. Policy support, external networks, and a phased implementation strategy are significant drivers in developing BIM-based digital skills in the workforce.

This research aims to identify the workforce competency needs in utilizing BIM to support sustainable blue infrastructure in Indonesia's coastal areas. The novelty of this research lies in its integrative approach, which connects technological, ecological, and educational aspects to improve the competence of construction workers. The research questions posed are: 1) How can the competence of construction workers in Indonesia, particularly in the use of BIM, be improved to support the implementation of blue infrastructure in coastal areas?

Method

Data collection was conducted through a survey of construction workers across various construction industries in Indonesia. This survey aimed to determine the current conditions and demands of the workforce in the construction industry, particularly in the digital era. Questionnaires were distributed through a snowball sampling technique to workers and actors in the construction industry, who then passed them on to their colleagues. The variables in the questionnaire were determined based on current trends in skills requirements in the construction industry, then linked to the demands of sustainable development. Furthermore, this study also referred to secondary data in the form of scientific articles to validate the BIM adoption gaps identified in the survey. The research data was supplemented by a literature review on the role of digital technology in supporting the implementation of the blue infrastructure concept, providing a more comprehensive analytical framework. Thus, the analysis results are not only based on respondents' perceptions but are also strengthened by empirical data from the literature and actual practice.

Demographic data (Table 1) shows that male respondents are significantly more numerous than female respondents. This finding also indicates a male predominance in the construction sector compared to female respondents. The majority of respondents were aged between 26 and 35, indicating that most were of productive age, with sufficient work experience and competence as construction workers.

Table 1. Sample demographics

Description	*Frequency*	*Percentage (%)*
Gender		
Man	146	78.5
Woman	40	21.5
Age		
18-25	42	22.6
26-35	50	26.9
36-45	39	21
46-55	38	20.4
More than 55	17	9.1
Level of Education		
High School/ Vocational school	12	6.5
Diploma	4	2.2
Undergraduate	131	70.4
Postgraduate or higher level	39	21
Field of work		
Planning Consultant	95	51.1%
Contractor	30	16.1%
Construction Management	17	9.1%
Supervisor	15	8.1%
Interior	11	5.9%
Developer	6	3.2%
Other	12	6.5%
Work Experience in the Construction Industry		
Less than 1 year	19	10.2
1-5 years	52	28
5-10 years	32	17.2
More than 10 years	83	44.6

Source: Researcher Data, 2024

Respondent data indicate that over 70% of construction professionals had bachelor's degrees, demonstrating sufficient knowledge and understanding of technical competencies to provide valid information for the study Booth et al., (2021). The surveyed areas of expertise were predominantly in planning and consulting (Architecture), thus representing the achievement of digital capabilities in adapting sustainability concepts. Most respondents had more than ten (10) years of work experience. This indicates that the majority of respondents have substantial experience that can contribute to their level of competence and performance in the workplace Guzzo et al., (2022).

Result and Discussion

Digital Skills in the Construction Industry

Digital transformation in the construction industry requires mastery of relevant skills, particularly in the use of software that can improve the effectiveness and efficiency of work processes in the construction sector. Technical training related to digital transformation focuses on developing skills in operating various software, such as CAD, BIM, 3D modeling, 3D rendering, project management software, and post-production support applications that shown on figure 1.

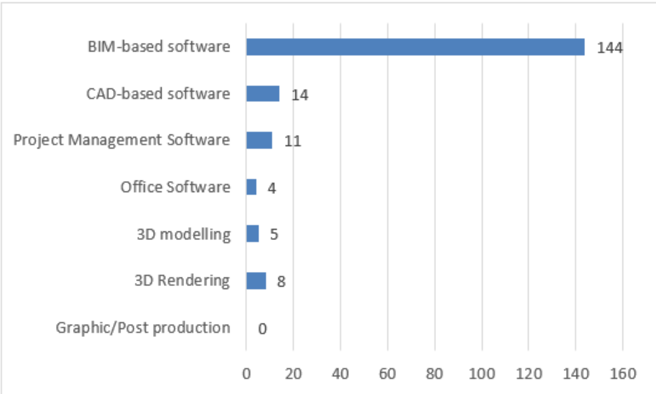

Fig 1: The most needed digital technology skills in the construction industry

A survey of 186 respondents showed that 144 identified BIM-based software as the most needed digital technology skill in the current construction industry. This finding indicates that the development paradigm of the construction industry in Indonesia is increasingly aligned with advances in digital technology. The use of BIM not only increases efficiency in project planning and management but also facilitates cross-disciplinary collaboration (Emmanuel et al., 2024; Mi and Li, 2024), making it a relevant approach for implementing the blue infrastructure concept as a multidimensional solution.

while demand for BIM systems in the construction industry continues to grow, this is not matched by the technical capabilities of human resources. The high demand for BIM systems is inversely proportional to the skill level of workers in the field of building information modeling (BIM). Surveys show that BIM operation is the skill least mastered by today's workers (Figure 2).

Email : joves@mpv.uad.ac.id
Website : http://journal2.uad.ac.id/index.php/joves

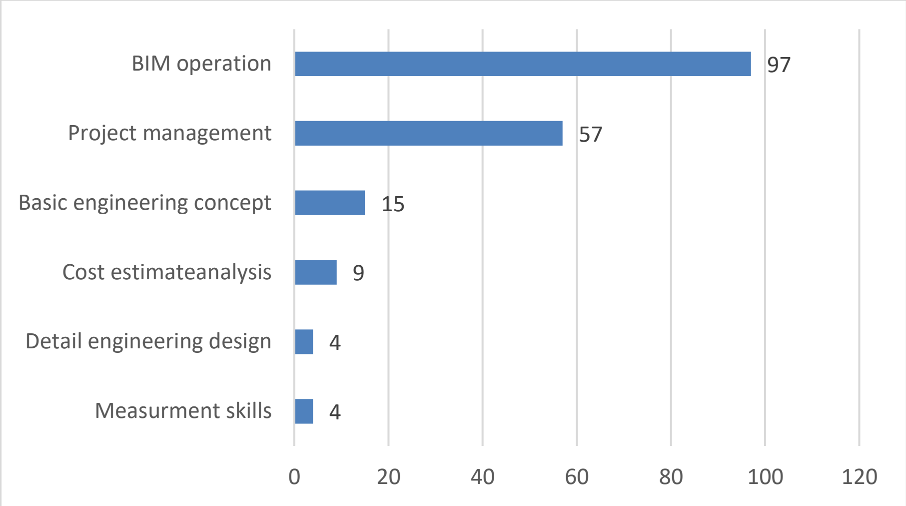

Fig 2: Technical skills that are not yet mastered and need to be improved

Building Information Modeling (BIM) is a transformative process in the construction industry that enables the creation and management of digital representations of a building's physical characteristics and functions Piras et al., (2024). In Indonesia, the implementation of BIM has a high level of urgency, especially in the context of globalization, where digital innovation continues to drive change in various sectors, including the construction industry. However, the level of digital skills among the construction workforce is a significant challenge that has the potential to hinder the optimal use of BIM.

The success of BIM implementation in Indonesia can be considered a key indicator of the national construction industry's progress. Therefore, strategic efforts are necessary to enhance the digital competency of the construction workforce, ensuring more effective technology adoption. This step not only supports digital transformation in the construction industry but also has the potential to contribute to Indonesia's success in competing globally. Improving digital skills in the sector is a priority, given its crucial role in driving efficiency, productivity, and innovation in construction projects. By addressing the digital skills gap, the Indonesian construction industry can harness the full potential of BIM, thereby contributing to economic growth and sustainable development.

Barriers to BIM Training and TVET Readiness

Despite the high demand for BIM, access to training remains limited. These barriers can be categorized into three main factors. First, institutional factors: the curricula of vocational high schools (SMK) and vocational colleges in Indonesia have not yet fully incorporated BIM as a core subject, leaving graduates unprepared for industry demands. Second, economic factors: BIM software licenses are relatively expensive, and the supporting digital infrastructure (high-capacity hardware and cloud-based servers) remains out of reach for most vocational education institutions. Third, curriculum factors: available training tends to be technical and sporadic, and does not yet emphasize the integration of BIM with coastal sustainability aspects. These findings suggest the need to develop a national strategy to enhance the readiness of TVET institutions (Educational, Training, and Vocational) as the primary provider of BIM-based training. The results of this analysis align with global findings that emphasize the need for a multi-level strategy in developing BIM competencies. Integrating BIM with sustainability frameworks, such as Environmental, Social, and Governance (ESG) and Sustainable Development Goals (SDG), is becoming increasingly urgent for blue infrastructure projects, as they demand not only technical efficiency but also the achievement of long-term sustainability indicators (Chen et al., 2018; Jing and Alias, 2024; Lo et al., 2024; Sanfilippo et al., 2025). The obstacles Indonesia faces align with international findings that education and skills gaps are caused by fragmented curricula and a lack of experiential pedagogical approaches. Therefore, educational models that emphasize vertical integration, real-world project simulations, and team-based learning need to be developed (Ghosh et al., 2013, 2015; Herrera et al., 2019; Zhang et al., 2018).

BIM in support of Blue Infrastructure Implementation

Building *Information Modelling* (BIM) is increasingly used as a tool to automate and modernize manual work procedures in the construction industry (Safari and Jafari, 2021). BIM applications have advanced significantly in recent years, serving as tools for visualization and modeling that provide digital representations of a building's physical and functional characteristics Jrade and Jalaei, (2013). The main advantage of BIM is increased time efficiency and accuracy in the planning and implementation of construction projects. Compared with conventional methods, BIM can reduce project duration by up to 7% and produce cost estimates up to 80% faster. These findings demonstrate the potential of BIM to improve project productivity, efficiency, and quality, while supporting sustainability in construction projects.

The use of BIM enables the transfer of real-time data into information platforms used by decision-makers (Yan et al., 2011; Ismaeel and Mohamed, 2022). This technology is equipped with a data synchronization feature that includes information on building materials and their environmental impact Anand and Armor, (2017). This feature enables in-depth analysis of environmental impacts, providing valuable insights into selecting more environmentally friendly building materials (Ajayi et al., 2015; Wang et al., 2011). BIM enables the exchange of information among project stakeholders throughout the construction cycle Jin et al., (2019). This software also supports the decision-making process through various techniques, such as modeling, simulation, visualization, and optimization Najjar et al., (2017). In this case, the Level of Detail (LOD) is used to indicate the extent to which project information should be included in the BIM model Dupuis et al., (2017). The LOD encompasses not only the visual aspects or physical attributes of building components, but also the detailed characteristics of building components, as well as the availability of necessary data at each LOD level. This level of information depth plays a crucial role in ensuring the validity of environmental analyses, particularly for uncertainty and sensitivity analyses Safari and Jafari, (2021).

BIM dimensions encompass 2D, 3D, 4D, 5D, 6D, and even 7D, each with distinct functions and varying levels of complexity Tirunagari and Kone, (2019). A 2D model is the simplest form, consisting of X and Y sources. In contrast, a 3D model has an additional Z dimension that describes the geometry, location, and orientation of elements and components required for the design development stage, including conceptual designs and structural details Elakkad and Ismail, (2021). The 4D dimension includes the time dimension required for resource scheduling, work volume, and project stages. The 5D dimension extends functionality by incorporating the cost dimension, enabling budget allocation analysis: cash flow plans, and integrated project cost estimates Xu, (2017). The 6D concept focuses on energy efficiency and long-term sustainability aspects of development, supporting green development goals. Meanwhile, the 7D covers project management, including monitoring, maintenance, and infrastructure management.

It is also important to consider regional disparities in digital infrastructure readiness. Java, with its relatively advanced technological infrastructure, has a greater opportunity to adopt BIM compared to regions outside Java, which face limitations in internet connectivity, hardware, and access to training. This disparity can create a competency gap between the national and regional workforces, so national policy should emphasize the equitable distribution of BIM training across Indonesia.

Despite having great potential, the application of BIM in construction projects in Indonesia remains minimal, particularly in the implementation of blue infrastructure projects in coastal areas. This highlights the necessity for strategies to enhance BIM adoption in the construction sector, including workforce competency development and technology integration to promote sustainable development.

Beyond technical excellence, the effectiveness of BIM in coastal projects is also influenced by the perceptions of project owners and construction contractors. They believe BIM can provide practical value in the form of cost efficiency, accelerated decision-making, and increased accuracy in coastal disaster risk mitigation. However, to maximize these benefits, workers' non-technical skills must also be strengthened. Soft skills such as cross-disciplinary collaboration, visual communication, and data interpretation are key factors in the success of BIM implementation in blue infrastructure projects. Without these skills, BIM's potential will remain at the technical level and will not fully deliver its transformational impact.

The Need for Digital Skills Training to Support Blue Infrastructure

Advances in digital technology have become a key driver of transformation in the construction industry. However, the transition to the digital era faces several challenges, one of which is the low level of digital skills among construction workers. This condition is primarily caused by limited access to relevant training and educational curricula that do not support the development of digital competencies. In an effort to identify training needs that align with industry demands, this survey asked construction workers to determine the types of training they consider most important in the construction industry today. The survey aims to provide relevant recommendations based on factual conditions in the field. The analysis results indicate that technical training is the top priority that must be implemented, followed by soft skills training, occupational safety training, and quality assurance training. These findings underscore the importance of providing comprehensive and sustainable training programs to enhance workforce competency and support the construction industry's competitiveness in the face of the digital era's challenges. Explain in Figure 3.

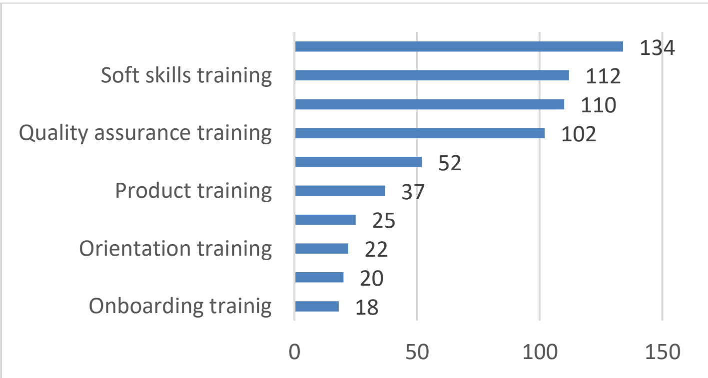

Fig 3: The most important training in the construction industry

Based on the literature analysis, best practices for BIM workforce development involve project- and team-based learning that simulates real-world collaboration, as well as industry-academia collaboration to bridge theory and practice (Hermoso-Orzáez et al., 2023; Nordin et al., 2025; Obi et al., 2024). In addition, policy mechanisms and incentives from the government and professional associations are crucial to strengthening BIM adoption in the Indonesian construction sector, particularly in expanding access to training in areas lacking digital infrastructure (Bui et al., 2016; Nguyen, 2021; Tanoli, 2025).

Conclusion

Building a sustainable blue infrastructure future requires developing BIM competencies through a multi-level approach. First, sustainability frameworks must be integrated into BIM workflows, addressing ESG and SDG objectives. Second, vocational education reform must be implemented through vertical integration, immersive technology, and team-based learning. Third, organizational culture and strategic networks must be leveraged, particularly for small and medium-sized enterprises (SMEs), to overcome cost and technology barriers. Fourth, the development of specialized BIM software focused on interoperability and sustainability is an urgent need. These recommendations align with global best practices and address Indonesia's regional challenges in developing a competent construction workforce.

Future research should conduct longitudinal studies to evaluate the effectiveness and long-term sustainability of immersive pedagogical models in vocational education. Furthermore, the development and validation of BIM software specifically for blue infrastructure, as well as the integration of digital twin platforms with real-time ESG metrics, are promising directions for innovation..

References

Ajayi, S. O., Oyedele, L. O., Ceranic, B., Gallanagh, M., & Kadiri, K. O. (2015). Life cycle environmental performance of material specifications: A BIM-enhanced comparative assessment. *International Journal of Sustainable Building Technology and Urban Development, 6*(1), 14–24. https://doi.org/10.1080/2093761X.2015.1006708

Almaaitah, T., Appleby, M., Rosenblat, H., Drake, J., & Joksimovic, D. (2021). The potential of blue-green infrastructure as a climate change adaptation strategy: A systematic literature review. *Blue-Green Systems, 3*(1), 223–248. https://doi.org/10.2166/bgs.2021.016

Bui, N., Merschbrock, C., & Munkvold, B. E. (2016). A review of building information modeling for construction in developing countries. *Procedia Engineering, 164*, 487–494.

https://doi.org/10.1016/j.proeng.2016.11.649

Chen, S., Jin, R., & Alam, M. (2018). Investigation of interoperability between Building Information Modeling (BIM) and Building Energy Simulation (BES). *International Review of Applied Sciences and Engineering, 9*(2), 137–144. https://doi.org/10.1556/1848.2018.9.2.9

Deguenon, S. D. D. M., Hounmenou, C. G., Adade, R., Teka, O., Toko, I. I., Aheto, D. W., & Sinsin, B. (2023). Simulation of the impacts of sea-level rise on coastal ecosystems in Benin using a combined approach of machine learning and the Sea Level Affecting Marshes Model. *Sustainability, 15*(22). https://doi.org/10.3390/su152216001

Ehsan, S., Ara Begum, R., Ghani Md Nor, N., & Nizam Abdul Maulud, K. (2019). Current and potential impacts of sea level rise in Malaysia's coastal areas. *IOP Conference Series: Earth and Environmental Science, 228*(1). https://doi.org/10.1088/1755-1315/228/1/012023

Ghosh, A., Parrish, K., & Chasey, A. D. (2013). From BIM to collaboration: A proposed integrated construction curriculum. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Ghosh, A., Parrish, K., & Chasey, A. D. (2015). Implementing a vertically integrated BIM curriculum in an undergraduate construction management program. *International Journal of Construction Education and Research, 11*(2), 121–139. https://doi.org/10.1080/15578771.2014.965396

Hamann, F., Blecken, G.-T., Ashley, R. M., & Viklander, M. (2020). Valuing the multiple benefits of blue-green infrastructure for a Swedish case study: Contrasting the economic assessment tools B£ST and TEEB. *Journal of Sustainable Water in the Built Environment, 6*(4). https://doi.org/10.1061/JSWBAY.0000919

Hermoso-Orzáez, M. J., Carazo Alvarez, D., Amezcua Ogáyar, J. M., Montiel Santiago, F. J., & Terrados Cepeda, J. (2023). The teaching innovation project project-based education-EBP with BIM methodology within the master's degree in industrial engineering UJAEN. *Proceedings of the International Congress on Project Management and Engineering*, 2093–2105.

Herrera, R. F., Rivera, F.-L., Vielma, J. C., & Atencio, E. (2019). Impact on team performance of interaction with BIM. *World Transactions on Engineering and Technology Education, 17*(3), 260–265.

Jing, W., & Alias, A. H. (2024). Key factors for Building Information Modeling implementation in the context of environmental, social, and governance and sustainable development goals integration: A systematic literature review. *Sustainability, 16*(21). https://doi.org/10.3390/su16219504

Lo, T., Au, I., Liu, P., Ng, R. C. W., Ho, M., & Chin, M. (2024). Putting Green BIM in practice—Optimizing the application of building information models for green building assessments. *IOP Conference Series: Earth and Environmental Science, 1363*(1). https://doi.org/10.1088/1755-1315/1363/1/012022

Møller, N. L. H., & Bansler, J. P. (2017). Building information modeling: The dream of perfect information. *Proceedings of the 15th European Conference on Computer Supported Cooperative Work*. https://doi.org/10.18420/ecscw2017-24

Nguyen, T. A. (2021). Competence-targeted education for BIM professionals: A case example of the Vietnamese construction industry. *Engineering Journal, 25*(7), 147–156. https://doi.org/10.4186/ej.2021.25.7.147

Nordin, R. M., Jafri, N. S., Brahim, J., & Fajarianto, O. (2025). Implementation of Building Information Modeling (BIM) education for construction management students: The case of Malaysia. *Journal of Design and Built Environment, 2025*(Special Issue V), 1–10.

Obi, L. I., Omotayo, T., Ekundayo, D., & Oyetunji, A. K. (2024). Enhancing BIM competencies of built environment undergraduate students using a problem-based learning and network analysis approach. *Smart and Sustainable Built Environment, 13*(1), 217–238. https://doi.org/10.1108/SASBE-05-2022-0085

Perrelet, K., Moretti, M., Dietzel, A., Altermatt, F., & Cook, L. M. (2024). Engineering blue-green infrastructure for and with biodiversity in cities. *npj Urban Sustainability, 4*(1). https://doi.org/10.1038/s42949-024-00163-y

Phong, N. T., Parnell, K. E., & Cottrell, A. (2017). Human activities and coastal erosion on the Kien Giang coast, Vietnam. *Journal of Coastal Conservation, 21*(6), 967–979. https://doi.org/10.1007/s11852-017-0566-9

Piras, G., Muzi, F., & Zylka, C. (2024). Integration of BIM and GIS for the digitization of the built environment. *Applied Sciences, 14*(23). https://doi.org/10.3390/app142311171

Sanfilippo, R., Esfandiari, M., Foria, F., Garbutt, D., Glab, K., Karlovšek, J., Menozzi, A., Paskaleva, G., & Robert, F. (2025). ITA–AITES tunneling information modeling—A BIM approach for sustainable life cycle management. *Tunnelling and Underground Space Technology, 165*. https://doi.org/10.1016/j.tust.2025.106711

Tanoli, W. A. (2025). Assessing drivers, barriers, and policy interventions for implementing digitalization in the construction industry of Pakistan. *Buildings, 15*(15). https://doi.org/10.3390/buildings15152798

Vinata, R. T., Kumala, M. T., & Yustisia Serfiyani, C. (2023). Climate change and reconstruction of Indonesia's geographic baselines: Reconfiguration of baselines and Indonesian archipelagic sea lanes. *Marine Policy, 148*. https://doi.org/10.1016/j.marpol.2022.105443

Waqar, A., Othman, I., Almujibah, H., & Hayat, S. (2024). Implementing Building Information Modeling (BIM) for the success of geotechnical offshore construction projects in the Malaysian construction industry. *Quality & Quantity, 58*(2), 1945–1970. https://doi.org/10.1007/s11135-023-01730-8

Zhang, J., Wu, W., & Li, H. (2018). Enhancing Building Information Modeling competency among civil engineering and management students with team-based learning. *Journal of Professional Issues in Engineering Education and Practice, 144*(2). https://doi.org/10.1061/(ASCE)EI.1943-5541.0000356

Zhu, D., Li, Y., & Dong, Y. (2021). Reliability-based retrofit assessment of coastal bridges subjected to wave forces using 3D CFD simulation and metamodeling. *Civil Engineering and Environmental Systems, 38*(1), 59–83. https://doi.org/10.1080/10286608.2021.1895126