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MAPPING CONSTRUCTION WORKFORCE COMPETENCIES FOR BLUE INFRASTRUCTURE: SCOPUS AI-BASED LITERATURE REVIEW

Wiwi Widanengsih[1,2], Isma Widiaty[1,2], Lilis Widaningsih[1,2], Ilhamdaniah[1], Yusmarwati Yusof[3]

[1]*Technical and Vocational Education Study Program, Universitas Pendidikan Indonesia, Indonesia*
[2]*Pusat Unggulan Ipteks Technical and Vocational Education and Training Research Center (PUI-TVET RC), Indonesia*
[3]*Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia, Malaysia*

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Authors email:
wiwi@upi.edu
isma@upi.edu*
liswida@upi.edu
ilhamdaniah@upi.edu
marwati@uthm.edu.my

ABSTRACT

This study identifies and maps the specific competencies required by the construction workforce for implementing blue infrastructure in coastal areas through an AI-enhanced systematic literature review. Using Scopus AI to analyze global scientific literature, this research develops a competency framework encompassing six dimensions: technical, ecological and environmental, regional planning and design, collaborative and interdisciplinary, analytical and research, and social and soft skills. The analysis reveals 25 specific competencies essential for construction experts, highlighting the shift from conventional technical skills toward integrated cross-sector capabilities. Key findings demonstrate that effective blue infrastructure implementation requires mastery of hydrological modeling, ecosystem service assessment, adaptive coastal design, and spatial data management (GIS/BIM), along with strong stakeholder collaboration and a clear understanding of environmental policy. This framework provides a strategic foundation for developing vocational education curricula, professional certification programs, and workforce development policies aligned with sustainable construction practices and nature-based solutions, particularly relevant for developing countries facing water infrastructure challenges and climate adaptation needs.

1. Introduction

The development of water-based infrastructure, known as blue infrastructure, represent a critical component of sustainable urban development, particularly in addressing cilmate change, urbanization, and water resource management challenges (Al-Humaiqani & Al-Ghamdi, 2023; Brears, 2023; Knappe et al., 2023). Within the framework of sustainable development theory, blue infrastructure integrates ecological principles with built environment practices, encompassing rainwater management systems, maintenance of aquatic ecosystems, and water-sensitive building designs (Jagadisan, 2024; O'Donnell et al., 2021). However, the successful implementation of this concept in the construction industry faces a fundamental challenges, particularly related to the workforce's readiness to understand and apply sustainability principles in construction projects (Alsharef et al., 2024; Cooper et al., 2022).

From a competency-based education perspective, the construction workforce requires multidimensional capabilities that extend beyond traditional technical skills. Construction experts must demonstrate proficiency in water system management (Poças et al., 2020; Vera-Puerto et al., 2020), wastewater management and green technology integration (Omer et al., 2024), alongside competencies in project management, cross-disciplinary collaboration, and environmental regulations (Aisheh, 2022; Maheshwari et al., 2023). This shift aligns with the evolving paradigm in technical and vocational education and training (TVET), which emphasizes the development of holistic competencies responsive to industry transformation and sustainability imperatives. The absence of systematic competency mapping in this domain creates a critical skills gap that potentially hinders effective blue infrastructure implementation, thereby undermining sustainable development goals.

Several previous studies have highlighted the importance of developing construction workforce skills in supporting sustainable practices. Studies on water system management confirm that workers involved in water-based infrastructure management require a comprehensive understanding of water distribution systems (Syed et al., 2024), wastewater treatment (Estévez et al., 2022), as well as sustainable technologies to enhance operational efficiency (Feijoo et al., 2023). In addition, several studies have investigated the implementation of green infrastructure in construction projects, revealing that workers require specialized skills in rainwater management, including the installation of rain gardens, water absorption systems, and the reuse of rainwater to alleviate the burden on urban drainage systems (Meierdiercks & McCloskey, 2022; Moscariello et al., 2021). Several studies also highlight the importance of project-based training as a practical approach to improving the skills of the construction workforce in implementing green technologies (Vranayova & Kaposztasova, 2024). In addition to technical skills, competencies in data analysis, leadership, and teamwork have also been identified as important in previous studies, particularly in ensuring the successful integration of green technology into construction projects. However, although many studies have discussed the skills and education of construction workers, a gap remains in research that specifically maps the competencies required of construction experts for implementing blue infrastructure, particularly in the context of current global challenges.

This study addresses this gap by developing a comprehensive competency framework specifically for the blue infrastructure construction workforce, utilizing an AI-enhanced systematic literature review approach through Scopus AI. The contribution is threefold: First, it provides explicit identification of technical and non-technical competencies required for water-based infrastructure implementation, moving beyond generic construction skills to specialized blue infrastructure capabilities. Second, it employs an innovative AI-assisted methodology to systematically analyze global competency trends, ensuring comprehensive data collection and pattern recognition. Third, and most significantly for vocational education, it proposes a data-driven framework that can guide the development of TVET curricula, professional certification standards, and competency-based training programs aligned with industry needs and sustainable development objectives. By establishing precise competency mapping, this study provides a foundation for educational institutions, industry stakeholders, and policymakers to collaboratively develop workforce preparation strategies that bridge the current skills gap in sustainable water infrastructure development. Therefore, this study attempts to answer the following research questions:

(a) What are the specific competencies required by construction experts in implementing blue infrastructure based on existing literature?
(b) How does the concept of blue infrastructure competency illustrate the interrelationships between the required dimensions of skills?
(c) Who are the key research experts in the field of blue infrastructure, and how have they contributed to the development of the competency framework?

(d) What further research questions emerge from the blue infrastructure literature review, and how do these reflect the direction of development of the field?

2. Method

This study employs an exploratory literature review approach, utilizing the Scopus AI tool, an innovative artificial intelligence (AI)-based tool developed by Elsevier on the Scopus database platform. The selection of Scopus AI is justified by three key advantages: (1) comprehensive access to high-quality peer-reviewed literature from the Scopus database, ensuring data reliability and academic rigor; (2) advanced natural language processing capabilities that facilitate pattern recognition across large volumes of literature; and (3) automated generation of conceptual relationships and thematic clusters that support competency framework development. This AI-enhanced approach enables more systematic and efficient literature synthesis than traditional manual reviews, particularly valuable for mapping emerging interdisciplinary fields such as blue infrastructure competencies.

2.1 Search and Data Processing

The research process commenced with a comprehensive search of scientific publications using primary query: "What is blue infrastructure and what skills are needed to work in this field?" This natural language query was translated into a structured Boolean search formula to ensure systematic coverage:

Query 1. Keyword search: ("blue infrastructure" OR "green infrastructure" OR "water management" OR "sustainable design") AND ("skills" OR "competencies" OR "capabilities" OR "expertise") AND ("urban planning" OR "land use" OR "environmental management" OR "ecosystem services") AND ("construction" OR "engineering" OR "design" OR "maintenance") AND ("climate adaptation" OR "resilience" OR "biodiversity" OR "restoration").

The search results consist of various information elements, including publication summaries, keyword concept maps, lists of relevant field figures, and follow-up research questions generated automatically by the system.

2.2 Validation and Critical Analysis

To ensure methodological rigor and avoid algorithmic bias, all Scopus AI outputs underwent systematic validation and critical analysis. This process involved three stages: (1) cross-referencing automated findings with established literature and theoretical frameworks in sustainable construction and TVET; (2) manual verification of competency classifications against multiple independent sources to ensure accuracy and relevance; and (3) expert judgment to synthesize AI-generated patterns with contextual understanding of blue infrastructure implementation challenges. This human-in-the-loop approach maintains academic quality control while leveraging AI efficiency, ensuring that the final competency framework reflects both data-driven patterns and contextual validity.

2.3 Literature Synthesis

The synthesis process used a keyword dependency framework, analyzing keyword relationships to identify dominant thematic structures. Concept maps generated by Scopus AI were systematically analyzed to develop a thematic understanding and identify relevant competency elements in the context of blue infrastructure construction. The competency framework development followed an iterative process: initial categories emerged from keyword clustering, which were then refined through manual literature review and validation against competency-based education principles. This mixed approach—combining automated pattern recognition with critical scholarly interpretation—enabled the development of a comprehensive, theoretically grounded competency framework applicable to the design of vocational education curricula. Figure 1 presents the detailed research methodology employed in this study.

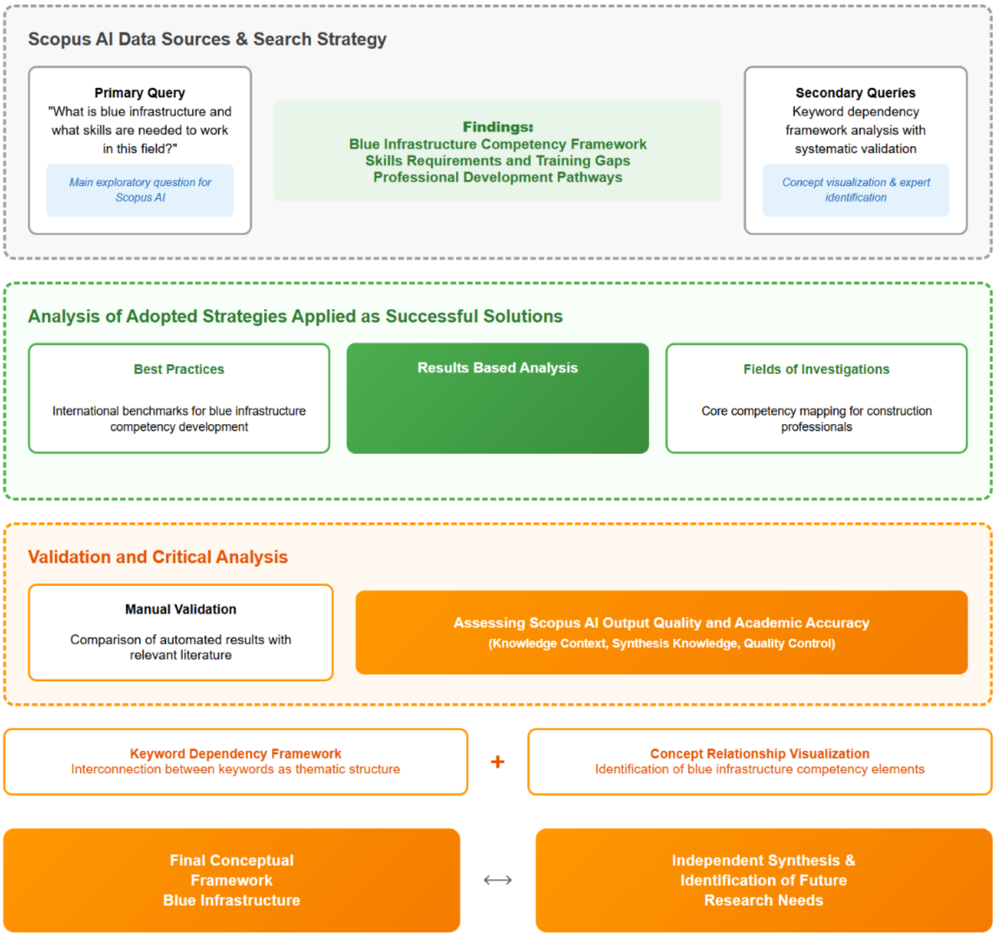

Figure 1. Research Methodology for Blue Infrastructure Competency Mapping using Scopus AI

3. Result and Discussion

3.1 Specific Competencies of Construction Experts in Blue Infrastructure

The systematic literature analysis identified six primary competency dimensions essential for construction experts in blue infrastructure implementation: (1) technical competence, (2) ecological and environmental competence, (3) regional planning and design competence, (4) collaborative and interdisciplinary competence, (5) analytical and research competence, and (6) social and soft skills competence. These dimensions emerged from dominant themes in the literature, including stormwater management, ecosystem-based adaptation, urban resilience, and nature-based solutions (Hohmann et al., 2025; O'Donnell et al., 2021; Wang & Foley, 2023; Well & Ludwig, 2020). Table 1 presents the comprehensive competency matrix encompassing 25 specific competencies across these six dimensions.

Table 1. Competency Matrix of Construction Experts in the Implementation of Blue Infrastructure

Dimensions	Code	Competencies	Reference
Technical competence	T1	Analyze hydrological and drainage systems to design effective blue infrastructure for stormwater management.	(Hohmann et al., 2025; Wang & Foley, 2023)
	T2	Design artificial wetlands and infiltration channels based on eco-hydrological principles adapted to site-specific conditions.	(Hohmann et al., 2025; Well & Ludwig, 2020)

Dimensions	Code	Competencies	Reference
	T3	Operate GIS-based spatial tools and remote sensors to collect environmental data supporting water infrastructure planning.	(De Vito et al., 2022; Wilczyńska et al., 2023)
	T4	Select corrosion-resistant and sustainable building materials suitable for saline or tidal environments.	(Deely et al., 2020; Wang & Foley, 2023)
	T5	Implement sustainable drainage systems (SuDS) that integrate ecological, engineering, and urban design considerations.	(Hohmann et al., 2025; Well & Ludwig, 2020)
Ecological and Environmental Competence	E1	Interpret ecosystem interactions in coastal zones to enhance biodiversity through blue infrastructure integration.	(Chowdhury et al., 2025; Wang & Foley, 2023)
	E2	Conduct environmental impact assessments (EIA) to ensure ecological compatibility of construction interventions.	(O'Donnell et al., 2021; Wang & Foley, 2023)
	E3	Apply eco-engineering approaches using native vegetation to stabilize shorelines and manage flood risks.	(Hohmann et al., 2025; Wilczyńska et al., 2023)
	E4	Manage construction waste and material flows according to low-carbon and circular economy strategies.	(Deely et al., 2020; Wang & Foley, 2023)
Competence in Planning and Design of Areas	P1	Integrate blue-green infrastructure components into urban master plans to enhance spatial resilience and ecological function.	(Hohmann et al., 2025; Well & Ludwig, 2020)
	P2	Adjust infrastructure designs according to site topography, geomorphological conditions, and coastal dynamics.	(O'Donnell et al., 2021; Wilczyńska et al., 2023)
	P3	Apply climate-adaptive planning principles to ensure the long-term viability of water-based infrastructure systems.	(Wang & Foley, 2023; Well & Ludwig, 2020)
	P4	Design multifunctional public spaces that harmonize aesthetic values and environmental services.	(Chowdhury et al., 2025)
Collaborative and Interdisciplinary Competence	K1	Facilitate collaboration between stakeholders, including government, community, and private sector, during project implementation.	(Hohmann et al., 2025; O'Donnell et al., 2021)
	K2	Interpret legal and policy frameworks governing water management, land use, and environmental protection.	(O'Donnell et al., 2021; Wang & Foley, 2023)
	K3	Participate in interdisciplinary design teams to co-develop nature-based solutions across technical and social domains.	(O'Donnell et al., 2021; Wilczyńska et al., 2023)
	K4	Negotiate technical decisions in public forums by articulating project benefits and trade-offs to non-expert stakeholders.	(Hohmann et al., 2025; O'Donnell et al., 2021)

Dimensions	Code	Competencies	Reference
Analytical and Research Competence	A1	Analyze climatological information based on statistical data to verify the relevance of the technological implementation of NBS.	(O'Donnell et al., 2021; Wilczyńska et al., 2023)
	A2	Simulate hydrological behavior under extreme weather scenarios to inform flood mitigation design.	(De Vito et al., 2022)
	A3	Develop innovative, site-specific, nature-based solutions through applied research and case study analysis.	(Wang & Foley, 2023; Wilczyńska et al., 2023)
	A4	Integrate BIM, GIS, and IoT platforms to monitor, document, and evaluate infrastructure performance.	(Deely et al., 2020; Wilczyńska et al., 2023)
Social Competence and Soft Skills	S1	Communicate the ecological and social value of blue infrastructure to diverse audiences and stakeholders.	(Hohmann et al., 2025; O'Donnell et al., 2021)
	S2	Solve context-specific challenges creatively by adapting technical approaches to local needs and constraints.	(De Vito et al., 2022; O'Donnell et al., 2021)
	S3	Uphold sustainability ethics and environmental responsibility in all stages of infrastructure project delivery.	(Hohmann et al., 2025; Wang & Foley, 2023)
	S4	Lead interdisciplinary project teams with an emphasis on inclusive decision-making and collaborative implementation.	(Chowdhury et al., 2025; Wilczyńska et al., 2023)

From a TVET perspective, the technical competency dimension represents a fundamental shift from traditional construction skills toward water-sensitive design capabilities. Blue and digital skills emerge as critical elements for the sustainability of the blue economy, integrating mastery of digital technology with blue infrastructure-specific expertise (Ferreira et al., 2024). Particularly significant is the requirement for proficiency in Geographical Information Systems (GIS), which enables data-driven planning and management of Blue-Green Infrastructure (BGI) (Sörensen et al., 2021).

Green skills are also a key factor, where a deep understanding of the ecological impacts and benefits of blue infrastructure, including ecosystem services and nature-based solutions, is essential (Lafortezza et al., 2018; Wang & Foley, 2023). Additionally, skills in water management, such as hydrological planning and water-sensitive urban design (WSUD), are essential in addressing the challenges of stormwater management and water quality (Himanujahn et al., 2024).

Furthermore, interdisciplinary skills have become an inseparable aspect of BGI planning and implementation, where cross-disciplinary collaboration, such as urban planning, civil engineering, sociology, and environmental science, is essential to create a comprehensive approach (O'Donnell et al., 2020; Sörensen et al., 2021). Active engagement across disciplines through ongoing interactions is also essential in integrating expertise and addressing biophysical and sociopolitical barriers. Additionally, effective data management is necessary to support BGI planning and maintenance, including the collection, organization, and accessibility of data across various sectors and disciplines. Skills in performance-based monitoring are also essential to evaluate the effectiveness of urban green spaces in reducing urban heat island stress (Mukherjee & Takara, 2018).

Advocacy and community engagement aspects also have a strategic role in strengthening the implementation of blue infrastructure. Empowering the younger generation, especially those from marginalized communities, is crucial for increasing advocacy for green stormwater infrastructure solutions and encouraging participation in the planning process (Reckner et al., 2024). Participatory action research approaches are also essential for enhancing environmental resilience and promoting ecological justice through collaborative learning and community-based data collection (Meyer et al., 2018). Ultimately, leadership in interdisciplinary projects is crucial for integrating diverse methods and perspectives to facilitate the effective implementation of BGI. Alignment between data management and political-strategic objectives is also an important factor in ensuring sustainable and efficient BGI planning and governance.

From a TVET perspective, the technical competency dimension represents a fundamental shift from traditional construction skills toward water-sensitive design capabilities. Blue and digital skills emerge as critical elements for the sustainability of the blue economy, integrating mastery of digital technology with blue infrastructure-specific expertise (Ferreira et al., 2024). Particularly significant is the requirement for proficiency in Geographical Information Systems (GIS), which enables data-driven planning and management of Blue-Green Infrastructure (BGI) (Sörensen et al., 2021). This technological integration reflects a broader trend in vocational education toward digitalization and data literacy as core competencies across technical trades.

The ecological and environmental competency dimension reveals a paradigm shift in construction education, where understanding of ecosystem services and nature-based solutions becomes as essential as structural engineering knowledge (Lafortezza et al., 2018; Wang & Foley, 2023). This dimension challenges traditional vocational training models that compartmentalize technical and environmental knowledge. For educational institutions, this necessitates a curriculum redesign that integrates ecological literacy with construction techniques, exemplified by competencies in water-sensitive urban design (WSUD) and hydrological planning for stormwater management (Himanujahn et al., 2024). The implication for workforce development is profound: construction professionals must now function as environmental stewards, requiring interdisciplinary training that bridges civil engineering and environmental science.

The prominence of collaborative and interdisciplinary competencies underscores a critical transformation in construction practice. BGI planning inherently requires cross-disciplinary collaboration spanning urban planning, civil engineering, sociology, and environmental science (O'Donnell et al., 2020; Sörensen et al., 2021). This collaborative imperative poses significant challenges for TVET systems traditionally organized around discipline-specific training silos. Adequate workforce preparation must therefore incorporate collaborative learning experiences that simulate real-world interdisciplinary project environments. Key competencies include stakeholder engagement across sectors, effective data management supporting cross-disciplinary planning, and performance-based monitoring to evaluate BGI effectiveness in reducing urban heat island effects (Mukherjee & Takara, 2018). These competencies cannot be effectively developed through traditional classroom instruction alone; they require experiential learning through project-based and problem-based pedagogies.

The social and soft skills dimension highlights often-overlooked competencies in technical education, yet these prove critical for blue infrastructure success. Community engagement and advocacy are essential, particularly in empowering marginalized communities to participate in green stormwater infrastructure planning and advocacy (Reckner et al., 2024). This reflects a broader movement toward environmental justice in infrastructure development, where technical expertise must be complemented by cultural competence and community partnership skills. Participatory action research approaches enhance environmental resilience through collaborative learning and community-based data collection (Meyer et al., 2018). For TVET institutions, this dimension challenges the traditional focus on technical skills, requiring curricula to expand to include communication, cultural sensitivity, and ethical leadership. The integration of these "soft" competencies with technical expertise defines the modern construction professional as a facilitator of sustainable community development rather than merely a technical implementer.

3.2 The Relationship between Skill Dimensions in Blue Infrastructure

The concept map generated through Scopus AI literature exploration (Figure 2) reveals three interconnected skill clusters that illustrate the multidimensional nature of blue infrastructure competencies: environmental awareness, technological competencies, and skills development. This clustering is not merely descriptive but reveals fundamental pedagogical implications for competency development.

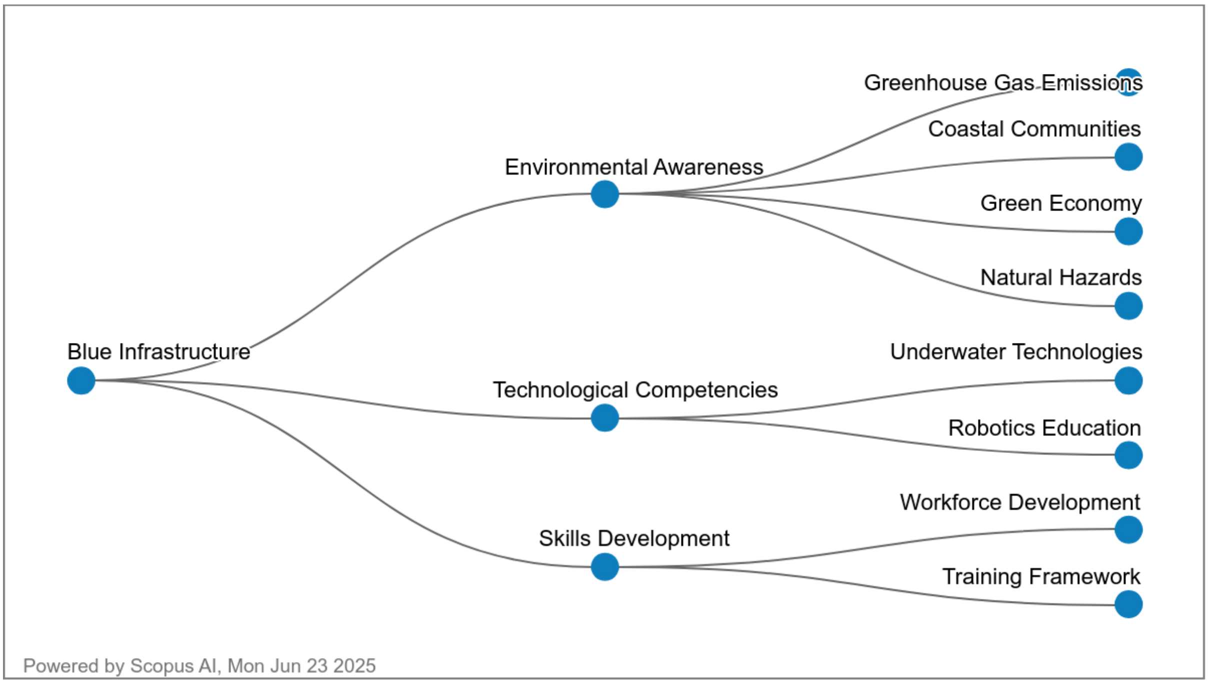

Figure 2. Blue Infrastructure Competency Dimension Concept Map

The environmental awareness cluster encompasses understanding of greenhouse gas emissions, coastal community impacts, and green economy principles, directly supporting ecological, regional planning, and social awareness competencies. This cluster represents the cognitive foundation upon which other competencies build—without fundamental environmental literacy, technical skills remain disconnected from sustainability objectives. For curriculum design, this suggests that environmental awareness should serve as a foundational learning module rather than an isolated supplementary topic.

The technological competencies cluster emphasizes advanced technical skills, including underwater technologies and robotics education, which are critical for automation and monitoring in nature-based projects. This cluster reflects the digitalization imperative in modern construction, where traditional manual skills increasingly integrate with digital tools and automated systems. The analytical dimension strengthened by this cluster positions construction professionals as data-informed decision-makers rather than traditional craft workers. This transformation necessitates significant investment in TVET infrastructure and instructor development to bridge the digital divide in vocational education.

The skills development cluster demonstrates the foundational role of workforce capacity strengthening through systematic training and competency development. This cluster underpins the collaborative and soft skills essential to multidimensional project implementation. The prominence of this cluster validates the competency-based education approach, emphasizing that blue infrastructure capabilities cannot be acquired through isolated technical training but require systematic, progressive skill development. The interconnections among these three clusters suggest that effective TVET programs must adopt an integrated curriculum rather than teach competencies in isolation. For instance, teaching GIS skills (technological cluster) without environmental context (awareness cluster) or communication abilities (skills development cluster) produces technically capable but strategically limited professionals.

3.3 Topic Expert Contribution in Competency Framework Development

Topic expert identification through Scopus AI analysis provides scholarly validation for the competency framework. Three experts with significant citation impact and h-index values (Table 2) demonstrate distinct but complementary contributions to blue infrastructure knowledge domains, collectively supporting the multidimensional competency framework proposed in this study.

Table 2. Topic Expert

Expert	Citation	h-index	Most Contributed topics
Sharifi, Ayyoob A.	10,497	58	Smart City Frameworks for Sustainable Urban Development, Urban Resilience and Adaptive Management Frameworks, Climate Change and Its Impact on Global Security
Jackson, Bethanna MBM	2,465	28	Ecosystem Services and Land Use Dynamics, Integrating Ecosystem Services and Natural Capital, Resilient Urban Water Management Strategies
Benavidez, Rubianca R.	525	7	Ecosystem Services and Land Use Dynamics, Resilient Urban Water Management Strategies, Urban Biodiversity and Species Adaptation Dynamics

Sharifi's work on smart city and urban resilience frameworks establishes the theoretical foundation for technology integration, adaptive planning, and data-driven environmental monitoring competencies (Dang et al., 2021; Nguyen et al., 2021). His emphasis on resilience thinking provides a conceptual lens through which construction professionals must view blue infrastructure—not as static systems but as adaptive mechanisms responding to dynamic environmental conditions. This perspective fundamentally shapes the analytical and research competency dimension, emphasizing scenario planning and adaptive management capabilities.

Jackson's research strengthens the ecological and collaborative dimensions through systematic investigation of ecosystem services, natural capital, and resilient urban water management strategies (Fang et al., 2021). His work bridges ecological science and urban planning, providing empirical evidence for the importance of ecosystem-based approaches in infrastructure design. This body of work validates integrating ecological literacy into technical training, demonstrating that ecosystem understanding is not supplementary but central to effective blue infrastructure implementation.

Benavidez's focus on biodiversity dynamics and species adaptation provides critical insights into ecological landscape design and the Utilization of native vegetation (Fang et al., 2021). This specialized knowledge area underscores the depth of ecological expertise required for competent blue infrastructure practice, extending beyond general environmental awareness to species-level understanding. The collective contributions of these experts validate the multidisciplinary nature of blue infrastructure competencies and provide a research-informed foundation for curriculum development. TVET institutions can leverage these scholarly contributions to ensure that vocational training reflects current scientific understanding and best practices in blue infrastructure implementation.

3.4 Direction of Blue Infrastructure Research Development

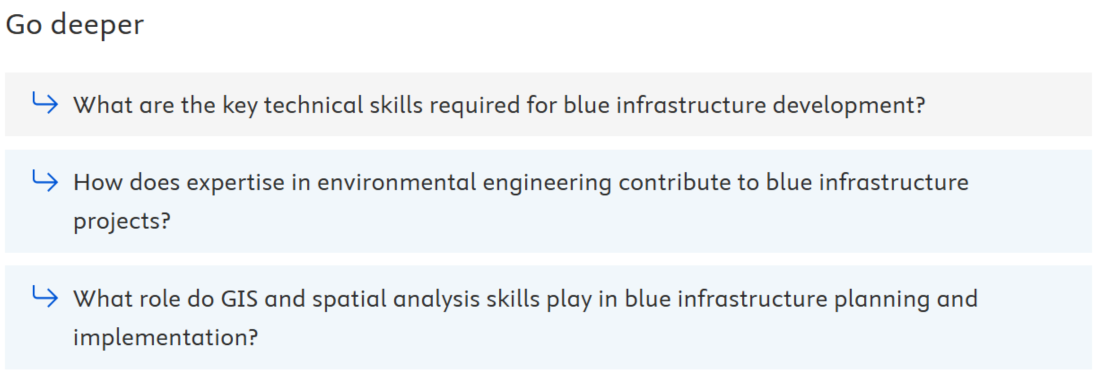

Figure 3. Emerging Research Questions on Workforce Competencies for Blue Infrastructure Implementation

The research synthesis reveals three critical directions for advancing blue infrastructure competency development, each with distinct implications for vocational education research and practice. First, an in-depth investigation of primary technical skills—including applied hydrology, sustainable drainage system design, and environmental mapping technology—is needed to establish detailed learning outcomes for TVET programs. Current competency descriptions remain relatively broad; granular specification of required knowledge, skills, and attitudes would enable more precise curriculum design and competency assessment. This research direction aligns with outcomes-based education principles, requiring collaboration between industry practitioners, environmental scientists, and educational researchers to define observable, measurable competency indicators.Second, exploring environmental engineering's role in blue infrastructure project success—particularly in rainwater treatment, waste management, and the application of nature-based solutions—requires investigating practical pedagogical approaches for developing these specialized competencies. Traditional engineering education emphasizes theoretical understanding; blue infrastructure demands applied problem-solving in complex, context-specific scenarios. Research should examine how problem-based learning, design thinking, and experiential education can effectively develop these competencies, including optimal sequencing of theoretical and practical learning experiences.

Third, a deeper investigation of the Utilization of spatial technologies—particularly GIS and location analysis—for blue infrastructure planning and monitoring effectiveness is essential. Beyond technical skill development, research should examine how spatial thinking and data literacy can be cultivated in vocational learners from diverse educational backgrounds. This direction raises important questions about digital equity in TVET: how can programs ensure all learners develop spatial technology competencies despite varying levels of digital access and prior experience?

These research directions collectively demonstrate that blue infrastructure competency development requires an interdisciplinary, technology-enhanced approach oriented toward climate change challenges and sustainable development imperatives. For TVET systems, this necessitates not only curriculum revision but fundamental reconsideration of pedagogical models, assessment strategies, and industry-education partnerships. The path forward involves collaborative research that bridges the domains of vocational education, environmental science, urban planning, and construction technology.

4. Conclusion

This study successfully developed a comprehensive competency framework identifying 25 specific competencies across six dimensions essential for construction workforce engagement in blue infrastructure implementation. The framework, grounded in systematic literature analysis enhanced by Scopus AI and validated through expert contributions, advances beyond conventional construction skills to encompass integrated capabilities spanning technical expertise, ecological literacy, spatial planning, interdisciplinary collaboration, analytical thinking, and social competencies. The findings reveal that effective blue infrastructure practice requires transformation of traditional construction workforce preparation. Technical proficiency must integrate with environmental understanding, data literacy must complement manual skills, and community engagement must accompany technical implementation. Critical competencies include hydrological modeling, ecosystem service assessment, adaptive coastal design, and spatial data management (GIS/BIM)—capabilities demanding systematic integration into TVET curricula rather than supplementary add-ons.

For vocational education institutions, this framework provides actionable guidance for curriculum development, professional certification design, and training program structure. Educational institutions should prioritize: (1) integrating environmental and technical content rather than teaching in silos; (2) developing experiential learning opportunities emphasizing interdisciplinary collaboration; (3) incorporating digital tools and spatial technologies throughout the curriculum; and (4) partnering with industry to ensure competency relevance and currency. For policymakers, the framework informs workforce development strategies to address gaps in blue infrastructure implementation, particularly critical for developing countries like Indonesia, which face coastal water infrastructure challenges and climate adaptation needs. The framework ultimately positions competency-based TVET as a strategic mechanism for advancing sustainable construction practices and nature-based solutions, contributing to broader sustainable development goals while ensuring workforce readiness for evolving industry demands.

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Conflicts of Interest

The author declares no conflict of interest regarding the publication of this paper. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

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