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Transition to Sustainable Infrastructure Competency Framework for Engineers

Overview

This document outlines the **Transition to Sustainable Infrastructure (TSI) Competency Framework** developed by The University of Queensland Sustainable Infrastructure Research Hub (SIRH).

Competencies provide an overarching framework for the integration of knowledge, skills and attitudes that are required to perform specific tasks [1, 2,]. The Framework provides a structure for identifying, developing, and assessing the skills and knowledge needed to integrate sustainability practices, supported by digitalisation, into infrastructure projects across their full lifecycle.

It can serve as a guide for employee selection, job design and professional development to ensure that engineers are equipped to meet emerging tasks associated with the sustainability transition. While the TSI Competency Framework was designed specifically for engineers in the Australian infrastructure industry, its relevance for other built environment professionals has also been noted.

Industry Context for a Transition to Sustainable Infrastructure

In 2024, the UQ Sustainable Infrastructure Research Hub identified emerging skills and knowledge requirements required to support the transition to sustainable infrastructure in Australia. The need to upskill the industry is driven by a number of challenges facing the Australian Infrastructure industry in 2025 including:

- Ongoing engineering workforce shortages and limited availability of the required knowledge, skills, and abilities to rapidly advance sustainability goals;
- An increasing requirement for cross-disciplinary skills to integrate new technologies, such as Building Information Modelling (BIM), Digital Twins and other Industry 4.0 tools with sustainability practices;
- The speed and intensity of change associated with the application of new technologies; and
- Increasing requirements from large asset owners, such as government, for specific attention to sustainability, driven by societal expectations, legislative changes, and national and international industry standards.

Why do we need the TSI?

The TSI Competency Framework was developed to provide a comprehensive and integrated set of competencies to support the transition to sustainable infrastructure.

In doing so, the framework provides a structured approach for the industry to consistently define the key skills and behaviours needed to achieve sustainability outcomes.

Integrating the TSI Framework into workforce development, operations, and decision-making allows industry standardisation of skill requirements, a point of particular importance given the “ecosystem” environment of large infrastructure asset delivery.

Development Process

The TSI Competency Framework was developed by an interdisciplinary team of researchers with expertise in engineering, organisational psychology, organisational change, sustainability and digitalisation. They drew on current research and practice, including the following:

- **Academic literature.** Recent reviews of current and future sustainability skills;
- **Grey literature.** Industry reports such as Engineers Australia’s *Implementing Sustainability: Principles and Practice* (2017)[3];
- **Reference to existing competencies and competency frameworks.** Engineers Australia’s (EA) Stage 1 Professional Engineer[4] and Stage 2 Experienced Professional Engineer Competency Standards[5], the International Engineering Alliance’s Graduate attributes and professional competencies[6], and Australian BIM Academic Forum (ABAF) BIM Competency Framework for Australian Universities[7];
- **Stakeholder consultation**, including academic and industry experts, Infrastructure CoLab organisational partners and other subject matter experts. These stakeholders also reviewed and refined competencies and definition wording.

The Framework was then tested in practice using illustrative employee profiles. See Page 5 for an example.

Framework Structure

SIRH identified that an accelerated transition to sustainable infrastructure will require an interdisciplinary approach where practitioners bring both their deep disciplinary knowledge, skills, together with practical understandings of other disciplines, particularly sustainability and digital engineering. Therefore, a "shield shaped" competency profile was used to develop the TSI Competency Framework. This "shield shaped" model has been applied in other fields[8, 9] where there is need to innovate by integrating knowledge across two or more discipline areas in a way that would be unlikely to occur if approached from a single disciplinary perspective.

TSI Competency Framework is presented in Figure 1 with descriptions and sources of each competency detailed in Table 1. Competencies have been grouped into four sub-groups within the "shield"; Core Sustainability, Technical Sustainability, Digital and Disciplinary Competencies as explained below.

Core Sustainability Competencies

This set of interlinked and interdependent competencies are discipline neutral and are needed to develop and implement sustainability action plans in collaboration with others and ensure success over time through resilience. These are taken directly from Redman & Weik's[10] eight key competencies for advancing sustainability transformations and are based on the UN's Education for Sustainable Development Goals: Learning Objectives[11]. During development, significant positive stakeholder feedback confirmed these were essential competencies for engineers to possess to advance the transition.

Technical Sustainability Competencies

This set of competencies focuses on the field of sustainability as relevant to infrastructure projects. These are comprised of a combination of future "green skills" and competencies described in the literature [12, 13], as well as key design skills required to implement sustainability engineering principles and practices in Australia[3]. Stakeholder feedback also led to the inclusion of four additional competencies as shown in Table 1.

Digital Competencies

This set of competencies addresses enabling sustainable infrastructure outcomes through the application of digital engineering. Competencies were developed from current and future engineering skills identified in the literature[12] including for roles in the renewable energy sector[13] as well as the BIM Competency Framework for Australian Universities[7]. Stakeholder feedback also led to the inclusion of three additional competencies (see Table 1) and grouping of competencies into a Data Use, Management & Governance sub-category.

Disciplinary Competencies

The shield-shaped framework builds around the central spine of the engineering professional domains associated with the design and delivery of infrastructure, such as civil, geotechnical, mechanical, structural and chemical engineering.

Applications

A selection of examples of the potential application of the TSI Competency Framework to support the transition to sustainable infrastructure include:

Industry Training

Guiding the design of targeted learning programs to build expertise in areas like energy efficiency, lifecycle assessment, and nature-based solutions.

Talent Acquisition and Management

Supporting recruitment and selection processes by identifying and evaluating candidates with relevant skills for best practice projects.

Development Planning

Individuals can self-assess skills and knowledge to plan professional development needs to achieve the requirements of a current or aspirational role.

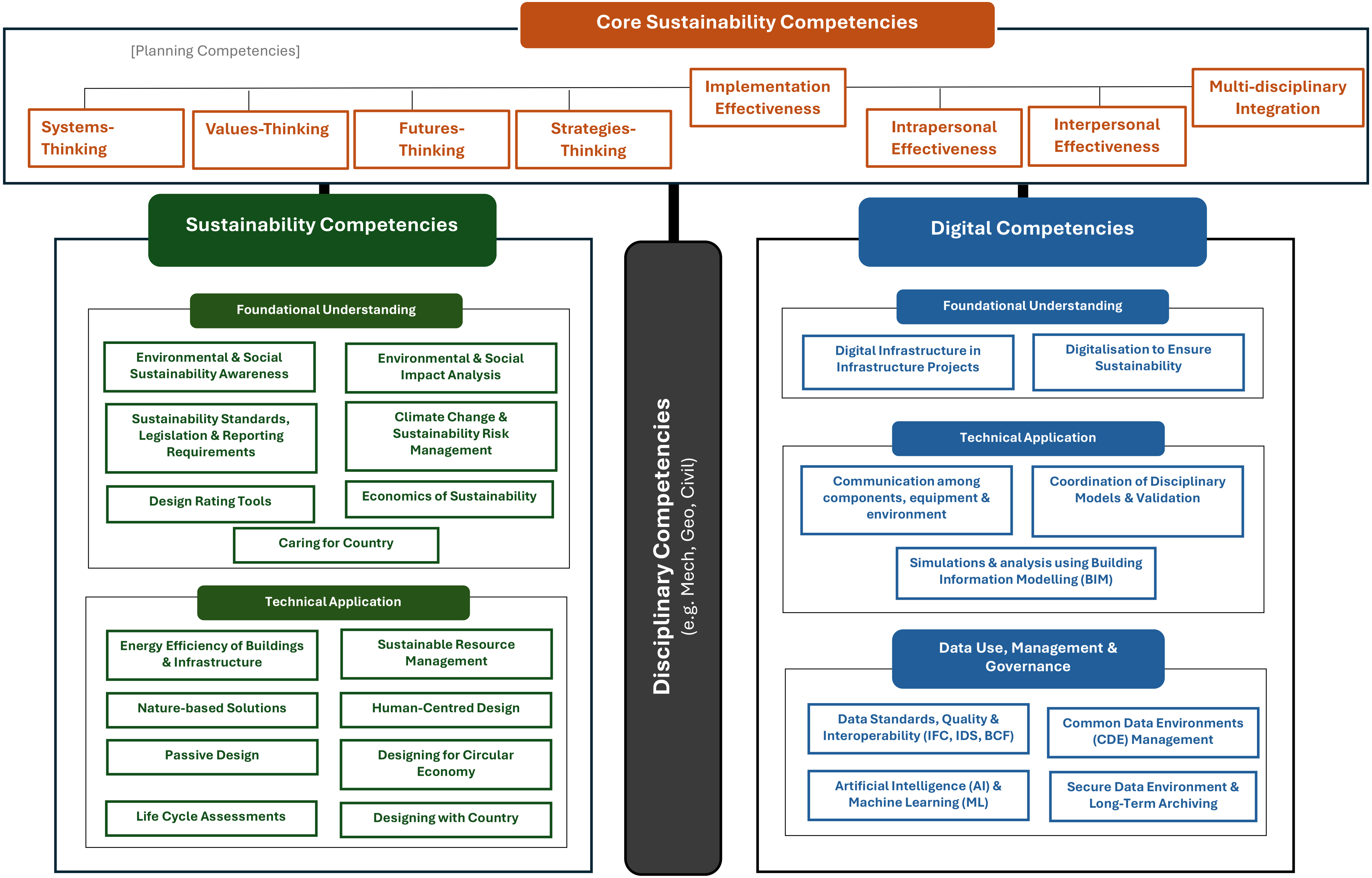
Procurement Processes and Bid Preparation

Providing a common language for clients and suppliers to specify required areas of competency for the delivery of specific projects and enable comparison of responses from potential suppliers.

Alignment Across Adjacent Professions

The Framework has relevance for related professions, such as architecture and planning and could be extended specifically for this purpose.

Figure 1. TSI Competency Framework



Application in Practice

This competency framework can be used to assess individual, team, or organisational learning needs and to design learning curricula. It is a foundation that can be finetuned for different levels of competence for different roles and individuals, depending on the organisational requirements.

When combined with the Levels structure in the Engineers Australia's Engineering Skills Framework[14] it can be used to target specific role requirements or the capabilities of an individual. Further, Bloom's Taxonomy [15,18] can be used with the competency descriptors to develop learning objectives and therefore shape educational programs.

Case Study: Staffing a Best Practice Sustainable Infrastructure Project

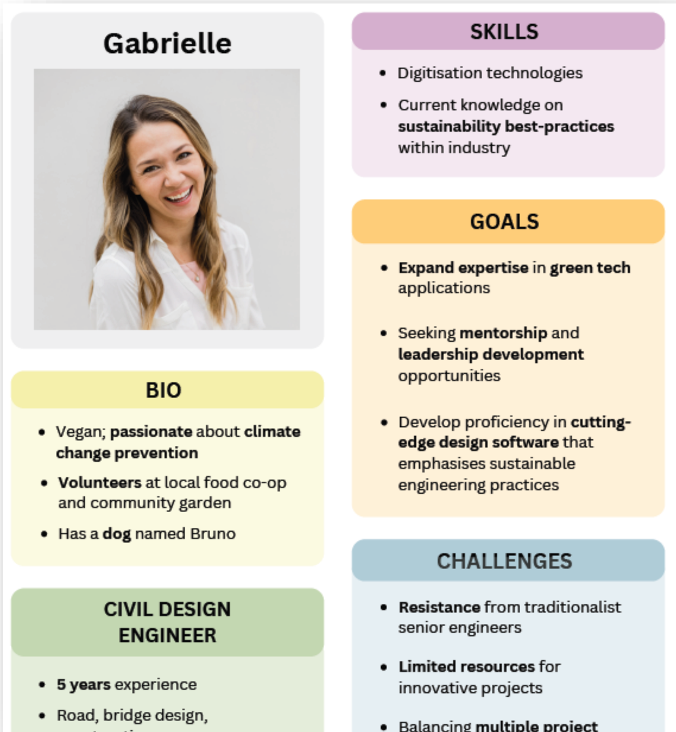
Development Planning: Stephen's new role is as a Project Director for a major infrastructure project with a goal to be fully carbon neutral and to embed circularity over the asset lifecycle. With his extensive experience in leading large projects, he is well equipped for the role, but he knows there are some areas where he needs to understand more.

He draws on the TSI Competency Framework and the levels in the EEA Engineering Skills Framework* to identify the key areas where his skills match the role requirements and where he has some developmental gaps to address.

Competency	Current Level	Required Level
Systems Thinking	Ensure	Vison/ Direction
Implementation effectiveness	Ensure	Vision/ Direction
Digital information in Infrastructure Projects	Supervise/ Guide	Improve
Digitalisation to Ensure Sustainability	Support	Improve
Design for the Circular Economy	Action/ Apply	Improve

Talent Acquisition and Management: As Stephen works with the HR team to identify the roles needed for the project, the TSI Competency Framework provides guidance to define specific skills and knowledge key members of his team will need. Through the selection process for his lead Civil Design engineer, he identifies Gabrielle meets his core requirements, while recognising there are some areas where she can still develop and grow through his mentorship.

Competency	Current Level	Required Level
Multi-disciplinary Integration	Apply	Supervise/ Guide
Environment & Social Impact Analysis	Supervise/ Guide	Supervise/ Guide
Digitalisation to Ensure Sustainability	Supervise/ Guide	Supervise/ Guide
Design for the Circular Economy	Ensure	Ensure



* See https://eea.org.au/engineering-skills-framework for a full description of the Levels

Conclusion

The University of Queensland's Sustainable Infrastructure Research Hub focuses on advancing sustainability transitions in the infrastructure sector by fostering collaboration among industry, government, and academic stakeholders.

The TSI Framework provides a structured approach for the industry to consistently integrate sustainability into all projects and programs by building it into to workforce development, operations, and decision-making.

Defining the key skills and behaviours needed to achieve sustainability goals enable organisations to align employee capabilities with strategic objectives such as reducing carbon emissions, improving resource efficiency, and fostering innovation.

If you are interested in learning more about the TSI Competency Framework or the UQ SIRH, please contact us at https://bel.uq.edu.au/research/sustainable-infrastructure-research-hub .

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Contributors

Many stakeholders were consulted in this work. We acknowledge and appreciate their input.

UQ Colleagues

Faculty of Engineering, Architecture and Information Technology, UQ Business School, UQ Indigenous Business Hub, and the Institute for Teaching and Learning Innovation.

Industry Partners

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We would also like to acknowledge **Engineers Australia** and **Engineering Education Australia** for their support of this project.

Citation

Martin, T. Echberg, J., Meath, C., Karlovsek, J. (2025). *Transition to Sustainable Infrastructure (TSI) Competency Framework for Engineers.* UQ Sustainable Infrastructure Research Hub. The University of Queensland. ISBN: 978-1-74272-498-0

Table 1. Competency Definitions and Sources

Competency	Description
1 - Core Sustainability Competencies	
1.1 Systems-Thinking	Apply models & complex approaches to analyse sustainability systems & problems across domains and scales, including cascading effects, inertia & feedback loop [10].
1.2 Futures-Thinking	Construct & complete simulations, forecasts & scenarios to anticipate future states and dynamics of complex systems & sustainability problems [10].
1.3 Values-Thinking	Identify, map, negotiate and apply sustainability values, principles and goals to assess current & future states of complex systems, as well as construct sustainability visions, strategies and interventions [10].
1.4 Strategies-Thinking	Construct and test viable strategies for intervention, transitions & transformations towards sustainability [10].
1.5 Implementation Effectiveness	Effectively & efficiently implement, adapt, transfer and scale sustainability strategies[10].
1.6 Interpersonal Effectiveness	Collaborate successfully in inter-disciplinary & professional teams and effectively involve stakeholders to advance sustainability [10]
1.7 Intrapersonal Effectiveness	Engage in resilience-oriented self-care to avoid burnout & personal challenges related to advancing sustainability transformation [10]
1.8 Multi-Disciplinary Integration	Apply collective problem-solving procedures to complex sustainability problems to develop & implement sustainability strategies [10]
2 – Sustainability Technical Competencies	
2.1 Environmental & Social Sustainability Awareness	Understands aspects of the natural environment including water, air, ground, and biodiversity and how they can impact on infrastructure and communities. [12]
2.2 Environmental & Social Impact Analysis	Understands the importance of Environmental and Social Impact Analysis, engages with all relevant stakeholders, and can integrate report findings into the design and delivery of infrastructure projects (Stakeholder addition).
2.3 Sustainability standards, legislation & reporting requirements	Applies knowledge and understanding of sustainability standards, legislation & reporting requirements to optimise outcomes for sustainable infrastructure projects. [13]
2.4 Climate Change and Sustainability Risk Management	Able to identify, assess, and manage risks associated with climate change to support the resilience and sustainability of infrastructure projects. [12]
2.5 Design Rating tools	Knowledge and understanding of design rating tools (e.g. ISC) used to determine the environmental impact of a project's site selection, design, construction, operation and maintenance practices, applied to improve the sustainability of the design solution. [3]
2.6 Economics of Sustainability	Analyse, evaluate, and integrate economic principles into design decisions to achieve long-term environmental, social, and financial sustainability in infrastructure projects. (Stakeholder addition)
2.7 Caring for Country	Understands the importance and impact of Aboriginal and Torres Strait Islanders' cultural identity, values, beliefs, and connections to Country, and applies this in furthering shared goals through sustainability in the context of built infrastructure. [17, 18]
2.8 Energy efficiency of buildings and infrastructure	Understanding and application of strategies to minimise energy consumption and enhance the energy performance of buildings and infrastructure systems. [12, 13]
2.9 Sustainable Resource Management	Designing to optimise the use of input resources to allow maximum value to be made of raw materials and reduce waste costs and impacts over the asset lifetime. [12, 3]
2.10 Nature-based Solutions	Applies the principles of nature-based design and demonstrates the ability to design, implement and evaluate infrastructure solutions that harness natural processes to address environmental, social, and economic challenges. (Stakeholder addition)
2.11 Human-Centred Design	Ability to apply human-centered design principles to engineering practices, ensuring solutions are accessible, inclusive, and sustainable. Including understanding user needs and experiences, engaging diverse stakeholders, and integrating these needs into the design and delivery of solutions. (Stakeholder addition)

Competency	Description
2 - Technical Sustainability Competencies (continued)	
2.12 Passive Design	Knowledge and application of passive design principals to achieve sustainable outcomes through optimal use of site conditions to reduce energy consumption and emissions [3] .
2.13 Design for the Circular Economy	Understanding and application of Circular Economy principles to design out waste and pollution, keep products and materials in use and regenerate natural resources across project planning, design, implementation, operation and end of life phases at the project and material levels as well as the integration of the project with existing infrastructure and society practices. [12]
2.14 Life Cycle Assessments	Understanding and application of material, social and environmental LCA's of projects to support design decision making for reduced environmental and social impact in an efficient and impactful manner. [12]
2.15 Designing with Country	Demonstrates the ability to reflect on, learn from, and incorporate Aboriginal and Torres Strait Islander cultures, values, and knowledges into the design process. [17, 18]
3 - Digital Competencies	
3.1 Digital Information in Infrastructure Project	Ability to understand, evaluate alternative approaches and communicate to others about the use of Digital Information to support efficient project scoping, delivery, and operation, taking into account multiple stakeholders and the infrastructure asset's lifecycle. (Stakeholder addition)
3.2 Digitalisation to Ensure Sustainability	Ability to understand, evaluate alternative approaches and communicate to others about the use of Digitalisation to enable sustainable design and measurement of sustainability over time. (Stakeholder addition)
3.3 Communication among components, equipment, and environment	Knowledge and understanding of software (CAD) to create, modify, and analyse designs and the communication among components and equipment (Machine to Machine). [12]
3.4 Coordination of Disciplinary Models & Validation	Application of BIM models for rule-based analysis tools to coordinate clash detections. Demonstrate BIM validation to ensure projects meet standards and design intent. [7]
3.5 Simulation & Analysis using Building Information Modelling (BIM)	Ability to use BIM and related digital tools as a simulation and analysis tool to model scenarios to understand the impact on project metrics and sustainability outcomes over the lifetime of the asset. [7]
3.6 Data Standards, Quality & Interoperability (IFC, IDS, BCF)	Implementing advanced measurement systems to improve data acquisition precision, efficiency, and scalability-ensuring outputs comply with open data standards (e.g. IFC, IDS, BCF) to enable high-quality, interoperable information. [12]
3.7 Common Data Environment (CDE) Management	Applies plans, policies and practices that control, protect and optimise the value and governance of data assets to ensure a robust Common Data Environment (CDE). (Stakeholder addition)
3.8 Artificial Intelligence & Machine Learning	Building on knowledge of BIM, Digital Twins, and Big Data to apply AI and ML to drive technological advancements in smarter systems, automating complex processes and new possibilities for modelling within standard requirements. [12, 13]
3.9 Big Data & the Internet of Things	Understanding secure data storage and long-term archiving, and traceability of digital information throughout infrastructure asset lifecycle. Emphasis on structured data management to support compliance, enable future reuse, and uphold robust data governance practices. [12, 13]

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