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BIM COMPETENCY REQUIREMENTS FOR CHINA RAILWAY INFRASTRUCTURE PROJECT

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Abstract

BIM delivery in railway infrastructure is shaped by dense subsystem interfaces and formal review-and-acceptance gates, which place strong demands on traceable, auditable information. However, BIM competency descriptions in the literature remain largely generic and provide limited guidance for railway-specific delivery governance and role profiling. This study investigates the BIM competencies required for railway infrastructure projects through a qualitative design using a structured interview protocol with open-ended prompts. Ten railway BIM practitioners were interviewed, and transcripts were analysed thematically; themes were developed inductively and reported using Succar's Core-Domain-Execution layers. The findings indicate that competency is primarily judged by the ability to produce review-ready packages under controlled coordination and change, rather than by software proficiency alone. Five competency clusters were identified: data governance and traceability; integration and platform-enabled coordination; compliance and configuration discipline; model and workflow execution for deliverable production; and lifecycle readiness supported by scenario thinking and reality-capture/verification. The study proposes a preliminary railway-contextualised competency structure and links clusters to delivery nodes and verifiable artefacts to support assessment and training design.

Keywords: railway infrastructure, BIM, competency requirements, thematic analysis, delivery governance

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INTRODUCTION

Railway infrastructure delivery is inherently information-intensive and interface-dense, involving tightly coupled civil, track, power, signaling, and systems engineering disciplines, multiple organizational actors, and a requirement for information continuity over asset lifespans that commonly extend beyond 30-50 years. These characteristics materialize most clearly at specific delivery nodes rather than at the level of abstract processes. Typical examples include a federated multi-disciplinary model review in which interface clashes are identified, logged as issues, revised across authoring teams, re-submitted, and formally accepted within an assurance regime; or a design change that cascades through model versions, requiring configuration control and traceability to demonstrate compliance with safety and regulatory requirements. At the transition to operations, asset information must further satisfy criteria of completeness, consistency, and auditability to support maintenance, certification, and future renewal decisions. Under railway-specific constraints-most notably safety assurance, regulatory scrutiny, high interface density, and long service life-these delivery nodes transform BIM from a representational or coordination tool into a governance instrument, thereby imposing capability requirements that are more fine-grained, more rigorous, and explicitly verifiable than those typically observed in building projects (Hussain et al., 2024; Grossauer et al., 2022).

While BIM has been increasingly mandated and implemented in rail projects, existing BIM competency frameworks remain predominantly generic and articulated at a macro level, limiting their direct applicability to railway delivery governance, role definition, and training implementation. Two testable gaps emerge from recent literature. First, there is a lack of railway-specific, first-hand empirical evidence capturing how BIM competencies are understood and enacted by practitioners in real delivery contexts; much of the current research emphasizes technologies, standards, or organizational strategies, with limited attention to situated professional practice (Bartoněk et al., 2023; Shi & Guo, 2025). Second, prevailing frameworks rarely establish an explicit connection between competencies, concrete delivery nodes or task situations, and observable evidence of performance. This missing “competency-node-evidence” linkage constrains operability: competencies cannot be readily translated into role-based capability statements, curriculum modules, or auditable governance checkpoints within railway projects (Lee et al., 2023). As a result, competency frameworks risk remaining conceptually sound yet practically under-utilized.

In response, this study aims to identify the BIM competencies required for railway infrastructure projects, addressing the research question: what BIM competencies are perceived by practitioners as essential for managing information-intensive delivery nodes in railway infrastructure projects? Drawing analytically on established BIM competency thinking-particularly the three-level logic distinguishing task, process, and organizational capabilities-this study

makes three contributions. First, it proposes a preliminary railway-specific BIM competency structure organised along these three levels, explicitly grounded in the delivery characteristics of rail infrastructure. Second, it develops an initial inventory linking competencies to concrete delivery nodes and task situations, providing actionable inputs for subsequent scale development, training modules, and role profiling. Third, it offers insights for delivery governance and capability development, informing how competencies may be embedded in assurance processes, organizational roles, and project controls (Hussain et al., 2024; Laishram & Sood, 2024). The scope of the study is intentionally bounded: the findings are exploratory, reflect practitioner-perceived competencies rather than normative standards, and require further validation before the proposed structure can be treated as a taxonomy or industry framework.

LITERATURE REVIEW

BIM competency has been discussed in the literature using a range of definitions and levels of abstraction, often reflecting the specific objectives of each study. For the purpose of this research, BIM competency is defined as a context-dependent and integrative ability that is directly related to project delivery requirements, enacted through specific task situations, and observable through task execution and its associated evidence. This working definition emphasizes performance in context rather than possession of isolated skills. Accordingly, a distinction is made between skills as discrete technical or tool-based proficiencies, competencies as the ability to integrate multiple skills to achieve observable outcomes in specific tasks or situations, and capabilities as organizational-level, repeatable system abilities embedded in processes and governance structures. Consistent with the exploratory nature of this study, competency is treated as an analytical construct rather than a normative benchmark. The focus is on identifying competency requirements relevant to railway project delivery, rather than on measuring competency maturity, validating scales, or proposing prescriptive standards.

Existing BIM competency research has predominantly focused on building projects or on the general architecture, engineering, and construction (AEC) domain, with relatively limited attention to infrastructure contexts and even fewer studies explicitly addressing railways. Prior work has commonly adopted high-level competency frameworks, role-based classifications, or maturity models aimed at assessing organizational readiness or professional development needs (Lee et al., 2023; Laishram & Sood, 2024). While these studies provide valuable insights, several operational limitations can be identified when viewed from a railway delivery perspective. First, competencies are frequently articulated in generic terms, with limited linkage to specific delivery nodes or recurring task situations where competencies are enacted and assessed. Second, the mechanisms connecting organizational governance requirements to

frontline execution tasks are often underexplored, leaving the role of competency in mediating this relationship insufficiently explained. Third, the resulting competency descriptions are difficult to translate into actionable outputs such as role profiles, targeted training modules, or auditable governance checkpoints. In this study, delivery nodes are understood as recurring task situations at which BIM-related competencies are enacted, evaluated, or contested within project governance, a clarification that directly addresses these limitations and frames the subsequent review.

Railway infrastructure context and competency implications

Railway infrastructure projects exhibit a set of delivery characteristics that intensify the need for context-specific BIM competencies and expose the limitations of generic competency formulations. High levels of system integration and interface density across civil works, track, signaling, power, and communications demand robust competencies in interface management and cross-disciplinary coordination, often enacted through iterative review and resolution cycles. Stringent review, approval, and safety assurance processes place additional emphasis on competencies related to model quality control, regulatory awareness, and the ability to demonstrate compliance through verifiable information (Hussain et al., 2024). Design changes in railway projects frequently propagate across multiple systems and contractual boundaries, thereby elevating the importance of version control, configuration management, and traceability competencies (Grossauer et al., 2022). Moreover, the exceptionally long lifecycle of railway assets, coupled with operation and maintenance dominating whole-life costs, requires competencies in information governance, asset data completeness, and long-term information usability (Bartoněk et al., 2023). Taken together, these characteristics form a mechanism chain through which railway-specific constraints translate into differentiated competency requirements. Consequently, BIM competencies in railway projects need to be explicitly identified, contextualized around delivery nodes, and structured in a way that supports delivery governance and capability development.

Succar framework as analytical baseline

To provide a theoretically grounded and internally consistent structure for analysing BIM competencies, this study adopts the BIM competency framework developed by Bilal Succar as its analytical baseline. Within this framework, BIM competency is defined as the personal traits, professional knowledge, and technical abilities required by an individual to perform a BIM-related activity or deliver a BIM-related outcome, where such abilities, activities, or outcomes are measurable against performance standards. This definition explicitly situates competency at the intersection of ability, activity, and observable outcome, rather than framing it as an abstract attribute or a role-based qualification. While not

intended as a comprehensive theory of professional competence, Succar's framework offers a clear and coherent logic for organising individual BIM competencies through three complementary tiers-core, domain, and execution competencies-which together describe how competencies manifest and combine in practice. In this study, the framework is neither evaluated, adapted, nor extended, nor is it compared against alternative competency models; it is employed solely as a post-analytic structuring and reporting baseline.

For clarity, Table 1 summarises the three BIM competency tiers as defined by Succar, together with their conceptual scope and typical manifestations in BIM-related activities. The table strictly follows the terminology and intent of the original framework and is included to make explicit the analytical structure underpinning this study, rather than to reinterpret or modify the framework.

Table 1. BIM competency tiers according to Succar

BIM competency tier	Definition	Typical manifestation in BIM-related activities
Core competencies	Personal abilities attributable to an individual that enable the performance of measurable activities or the delivery of outcomes, including inherent traits, qualifications, situational enablers, and experience-related indicators.	Professional attitudes, educational background, experience profiles, and personal attributes conditioning engagement in BIM-enabled work.
Domain competencies	Professional abilities that enable individuals to perform multi-task activities and deliver complex outcomes within a BIM context, encompassing managerial, functional, technical, and supportive competencies.	Managing, coordinating, analysing, and facilitating BIM processes across disciplines and project stages.
Execution competencies	Abilities to use specific tools, techniques, and equipment to conduct an activity or deliver a measurable outcome.	Use of BIM software applications, data exchange tools, modelling techniques, and related technologies.

Source: Succar's BIM Competency (2013)

In operational terms, the framework is applied through a hybrid analytical approach. BIM competency themes are first identified inductively from empirical material, without using Succar's Core-Domain-Execution structure as an a priori coding framework. These empirically derived competencies are then mapped onto the three-tier structure of core, domain, and execution competencies to support systematic organisation and transparent reporting. Mapping decisions are guided by the dominant nature of each competency-whether it primarily reflects personal attributes, professional abilities, or tool-based execution-while recognising that effective BIM-enabled performance typically draws upon

competencies across all three tiers. This use of Succar's framework enables the identified competencies to be structured and interpreted in a consistent manner, while remaining aligned with the exploratory aim of the study to identify railway-specific BIM competency requirements. Accordingly, Succar's framework does not determine the initial coding or theme generation.

RESEARCH METHODOLOGY

This study employed a qualitative exploratory design to identify BIM competency requirements as perceived by practitioners involved in railway infrastructure delivery. The design was appropriate because the objective was to elicit context-specific, practice-grounded accounts rather than to test hypotheses or claim statistical generalisability. Data were generated through semi-structured interviews conducted using a structured protocol and open-ended prompts to enhance cross-case comparability while allowing depth and flexibility. Probing followed a consistent logic to capture (i) the delivery node or governance gate in which a competency was required, (ii) the verifiable evidence produced (e.g., model packages, review outputs, issue/closure logs, change records), and (iii) critical incidents involving deviation, failure, and rectification.

The primary analytical sample comprised ten railway BIM practitioners ($n = 10$) recruited through purposeful sampling with a maximum-variation rationale to achieve heterogeneity in role responsibility, organisational context, lifecycle-stage exposure, and interface scope. The sample covered contractor/O&M and several design-related organisational or functional contexts, including subcontracting, design institutes, design/management, and design/R&D, and included participants whose work spanned design production, construction coordination, formal review/acceptance activities, and handover or O&M-readiness preparation. Interface exposure ranged from discipline-specific work requiring structured hand-offs to interface-dense, multi-system coordination involving civil, track, signalling, and electrification stakeholders. Eligibility was restricted to practitioners with direct involvement in railway BIM delivery within the preceding 12 months to ensure experience-near accounts. Following preliminary analysis, five additional interviews ($n = 5$) were conducted as a thematic sufficiency check after the initial theme structure had been established. These follow-up interviews used the same protocol and were assessed against the established codebook to test for the emergence of substantively new competency clusters; none were identified, supporting the stability of the thematic structure within the defined scope. Accordingly, the thematic results and participant-coverage summaries reported in this article are based exclusively on the ten primary analytical participants (P01-P10); the five follow-up interviews were used only to assess thematic sufficiency and were not included in the reported coverage counts. All interviews were undertaken with informed consent, audio-recorded, transcribed verbatim, anonymised, and

focused on experiences from the past 12 months; typical interview durations were approximately 40-60 minutes. The practitioner profiles of the primary analytical sample are summarised in Table 2.

Table 2. Practitioner profiles of the primary analytical sample (n = 10)

Participant	Experience (Professional / Railway BIM)	Position / Principal Role	Organisational / Functional Context	Project-stage Involvement
P01	6 / 4 years	O&M Engineer / O&M Party	Contractor / O&M	Implementatio n / O&M
P02	4 / 2 years	BIM Engineer / Modelling / Consultancy	Design / Subcontractor	Construction Deepening
P03	5 / 3 years	BIM Engineer / Design Party	Design Institute	Design / Construction
P04	6 / 4 years	BIM Lead / Design / Management	Design Institute	Full Lifecycle
P05	11 / 8 years	Deputy Director / Design Party	Design / Management	Full Lifecycle
P06	5 / 4 years	Software Designer / R&D Party	Design Institute	Design / R&D
P07	11 / 11 years	Tunnel R&D Lead / R&D Party	Design / R&D	Design / R&D
P08	7 / 7 years	Roadbed R&D Lead / R&D Party	Design / R&D	Design / R&D
P09	6 / 6 years	Bridge Design / R&D / R&D Party	Design / R&D	Design / Implementatio n
P10	8 / 8 years	Software Developer / R&D Party	Design Institute	R&D / Production

Note: Experience is reported as total professional experience / railway BIM experience. O&M = operation and maintenance; R&D = research and development.

Data analysis followed a stepwise thematic analysis procedure involving repeated familiarisation with transcripts, coding of meaning units, clustering into candidate themes, and iterative refinement through review and naming. Coding was inductive and grounded in the empirical material, with analytic attention directed to how competencies were described in relation to delivery governance and evidence production, rather than as decontextualised “software skills”. As a post-analytic structuring step, finalised themes were mapped onto Succar’s core, domain, and execution competency tiers to support

transparent reporting. This mapping was applied as a reporting scaffold rather than as an a priori coding framework; Succar's categories were not used to generate the codes or themes, and the framework itself was not adapted. Decisions were guided by each theme's dominant functional locus and typical context of enactment, and cross-tier relevance was noted where empirically indicated. Trustworthiness was strengthened through maintenance of a codebook, analytic memos, and an audit trail, supplemented by second-researcher review of the codebook and theme assignments using two transcripts (20% of the primary dataset) and representative coded extracts, with discrepancies resolved through discussion. A light form of member checking was conducted by sharing a concise summary of key themes with three participants for confirmation of interpretive accuracy. Ethical safeguards included informed consent, anonymisation, and secure storage with controlled access in line with institutional requirements.

Table 3 provides illustrative examples linking participant extracts, the competency coding used to organise the coded material, the final theme clusters, and the subsequent Succar-layer reporting assignment. The examples are illustrative rather than a complete coding audit trail. The broader clusters were developed through iterative grouping and refinement of related coded material; only after the clusters were finalised were they mapped onto Succar's Core-Domain-Execution structure.

Table 3. Illustrative examples of coding and thematic development

Participant	Illustrative interview extract	Competency coding	Final theme cluster	Succar reporting layer
P06	<i>"Digital delivery requires each component to contain the necessary information before the model is uploaded to a platform for subsequent operation and maintenance."</i>	D9 - Lifecycle Information Governance and Continuity Management	Data governance & traceability	Domain
P08	<i>"Collaborative design involving multidisciplinary data exchange requires the establishment of a shared data centre."</i>	D4 - Supportive	Integration & platform coordination	Domain / Execution
P10	<i>"Standards and workflows are interrelated and should be developed together."</i>	D7 - Implementation	Compliance & configuration discipline	Domain
P09	<i>"Coordinate points can be extracted from models and exported as data files for direct use in surveying and setting-out."</i>	E4 - Techniques	Model & workflow execution	Execution
P01	<i>"Existing assets may be reconstructed through UAV, GIS, and scanning technologies to supplement operation and maintenance information."</i>	E6 - Integrated GIS-BIM and Digital Surveying Execution	O&M readiness: scenario & reality capture	Execution

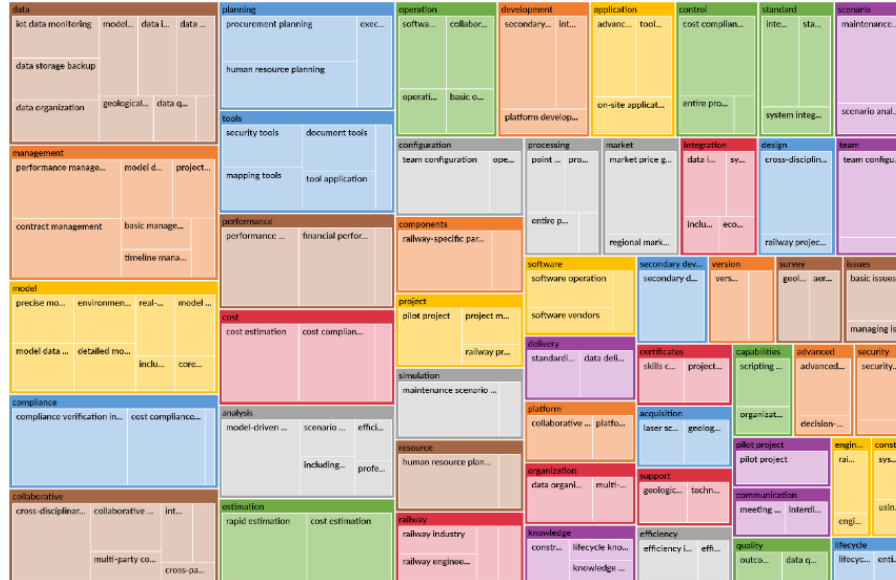


Figure 1. NVivo treemap of coded material distribution across competency clusters
Source: Authors' NVivo output (treemap), generated from coded transcripts

ANALYSIS AND DISCUSSION

The analysis indicates that practitioners describe BIM competency requirements for railway infrastructure through an integration- and delivery-oriented lens. The NVivo treemap (Figure 1) provides an overview of where coded material concentrates across the dataset, showing substantial attention to data work, project governance, compliance and control, standards and versioning, collaborative arrangements, and operation-facing concerns. Rather than treating this distribution as evidence of “importance” on its own, the figure is used here to orient the thematic narrative. The substantive results are reported through theme clusters with evidence strength (Table 4) and then translated into delivery-node requirements through verifiable artefacts (Table 5).

Table 4 summarises the theme clusters and their relative strength in the dataset. Two observations matter for how railway BIM competency is best interpreted. First, the clusters are not confined to modelling execution; they consistently span governance, coordination, and gatekeeping functions that determine whether outputs can pass review and acceptance. Second, the distribution captured in Figure 1 aligns with this broader conception: integration- and control-related coding appears alongside technical work, indicating that practitioners often judge competence by the ability to deliver controlled, reviewable outputs rather than by software proficiency alone. This framing is important because it sets up the logic for presenting results as a chain from information governance to integrated delivery and operational usability.

Table 4. Theme clusters and NVivo evidence strength

Theme cluster	Succar layer	Coverage (x/10)	Refs(n)
Data governance & traceability	Domain	9/10	42
Integration & platform coordination	Domain/Execution	10/10	58
Compliance & configuration discipline	Domain	8/10	33
Model & workflow execution	Execution	9/10	49
O&M readiness: scenario & reality capture	Execution	7/10	27

A major cluster in Table 4 concerns data governance and traceability, which participants consistently treated as a baseline condition for reliable railway BIM delivery. In Figure 1, data-related nodes occupy a large share, covering routine but consequential work such as storage/backup, organisation, quality checks, and monitoring or domain-specific datasets. In the interviews, these were not framed as general “digitalisation” requirements; instead, they were described as practical competencies required to keep information recoverable, auditable, and trustworthy across stages. In railway delivery, where subsystems are tightly coupled and decisions may need to be revisited long after design, weak traceability becomes a governance risk rather than a simple efficiency problem. This helps explain why data governance appears as a recurring competency requirement and why it is treated as foundational to later integration and acceptance activities.

The theme cluster centred on integration and collaborative coordination emerges as a distinctive organising feature of the dataset. Its prominence in Table 4 is consistent with Figure 1, where integration- and platform-related coding sits adjacent to team configuration and cross-disciplinary design work. Participants framed integration as a practical capability: aligning disciplinary contributions into a shared baseline, managing interface dependencies, and sustaining closure through iterative review cycles. What makes this cluster analytically important is its procedural character. Integration is repeatedly tied to platform-mediated practices-permissions, audit trails, structured exchanges, and issue logs-suggesting that competence is associated with running collaboration as a controlled process rather than relying on informal coordination. This cluster therefore bridges organisational arrangements and task-level routines, and it provides the connective tissue linking upstream information governance to downstream deliverable acceptance.

A further cluster concerns compliance-oriented control and configuration discipline, including version and change management. Table 4 indicates that compliance and control are not peripheral topics in the competency narrative; they are part of what practitioners consider necessary for “successful delivery”. Figure 1 reinforces this by showing substantial coding around control/compliance and versioning alongside more technical areas. Participants

described competence in terms of producing outputs that can withstand review and audit: packaging submissions, applying checks, documenting non-conformities, recording rectification actions, and maintaining approved baselines across milestones. Version discipline is especially consequential in railway projects because changes propagate across interdependent systems and can affect safety-critical interfaces. In this sense, competence is framed not only as the ability to update models, but as the ability to preserve an auditable record of what changed, why it changed, and which baseline is approved for downstream use.

Execution-oriented themes in Table 4 do include modelling and toolchain work, but the interviews tend to evaluate execution through the lens of deliverability and evidence. In Figure 1, model- and tool-related coding is positioned near verification- and process-oriented nodes, which is consistent with how participants described their work: producing models at stage-appropriate detail, ensuring information completeness, running coordination checks, and completing workflows in ways that generate inspectable records. This implies a stricter competence standard than “being proficient” with a tool. Competence is expressed as the ability to deliver review-ready packages repeatedly and reliably—packages that include not only models but also the outputs that make quality and compliance visible (e.g., coordination reports and closure records).

Operation-facing competencies appear as a meaningful component of the dataset, particularly through maintenance-related scenarios and verification-oriented practices. In Figure 1, scenario and operation nodes sit alongside acquisition/survey-related coding, while Table 4 captures this as a distinct theme cluster. Participants did not treat O&M as a distant downstream concern; rather, they associated competence with whether delivered information remains usable for verification and decision-making beyond design and construction. Where reality capture and survey-related practices are discussed, they are typically connected to the credibility of “as-built” states and the reliability of handover information. Similarly, maintenance scenarios and operational viewpoints signal a lifecycle orientation: competence includes anticipating how information will be interrogated in operational contexts, not merely how it is produced during delivery.

Table 5. Linking theme clusters to railway delivery nodes and verifiable artefacts

Theme cluster	Delivery node and competency requirement	Verifiable artefacts
Data governance & traceability	Review & acceptance: Configure auditable information governance to ensure submission packages are traceable, secure, and review-ready.	Review checklist; rectification/closure log; CDE permission and audit logs; naming/classification rules; structured transmittals.

Theme cluster	Delivery node and competency requirement	Verifiable artefacts
Integration & platform coordination	Handover to O&M: Maintain a reusable, standardised documentation system to support lifecycle continuity and accountability.	Handover package index; asset data dictionary; archival catalogue; metadata completeness check report; long-term storage/backup record.
	Interface coordination: Translate cross-disciplinary requirements into coordinated actions and close interface issues with accountable records.	Interface register; coordination minutes; RACI/issue assignment; issue log with closure evidence; clash/coordination report.
	Model federation & integration milestone: Operate platforms and interoperability workflows to federate models and stabilise integrated baselines.	Federated model release record; clash detection report; model exchange records (e.g., IFC/NWC); integration acceptance sign-off; platform activity logs.
Compliance & configuration discipline	BEP/standards parameterisation: Convert policy/standard requirements into BEP constraints and checking rules governing downstream deliverables.	BEP key-parameter table; checking rule set; standardised delivery protocol; compliance information extraction sheet.
	Change/version control gate: Enforce controlled change propagation and baseline discipline under multi-party approvals.	Version register; baseline approval record; change request + approval trail; compliance verification report; delta/diff record of key model outputs.
Model & workflow execution	Drawing & data delivery: Produce discipline models and extracted outputs through repeatable workflows supporting formal submission.	Standard drawing set; model-derived schedules/quantities; delivery package (RVT/IFC + drawings); QC checklist; transmittal.
	Quantity/cost submission: Execute model-based measurement and cost workflows with traceable inputs and outputs.	QTO sheet; cost estimate summary; change impact comparison; measurement rule documentation; model snapshot/baseline referenced in submission.
O&M readiness: scenario & reality capture	As-built verification: Capture reality conditions and validate as-built fidelity to reduce downstream uncertainty for O&M.	Point-cloud dataset; processing report; deviation/comparison report; as-built model release; verification sign-off record.
	Scenario-based O&M readiness: Prepare scenario-oriented information products for maintenance planning and operational decision-making.	Maintenance scenario outputs; simulation notes; visual briefing package; asset information checklist aligned to O&M use cases.

Table 5 synthesises these findings into delivery-node requirements and clarifies how competence becomes assessable through verifiable artefacts. Across key railway delivery gates-such as interface coordination, review and acceptance,

change/version control, handover packaging, and as-built verification-the mapping shows that competency expectations consistently combine governance (data and platform control), coordination (integration and closure), and execution (review-ready outputs). This is where the railway-specific contribution becomes most explicit: the competencies are not presented as generic attributes, but as requirements attached to nodes where evidence is produced and checked. Taken together, the results support a layered interpretation of railway BIM competency as an integrated capability chain: data governance enables controlled integration; controlled integration supports compliance and acceptance; and these, in turn, condition whether outputs remain usable for verification and downstream operations.

The findings also have practical implications for competency development and project governance. For training, the clusters can inform modules organised around railway delivery nodes and observable artefacts rather than software commands alone. For professional certification or internal competency assessment, the competency-node-evidence logic can support evidence-based criteria in which practitioners demonstrate controlled model exchanges, issue closure, change traceability, or other reviewable outputs; however, this study does not establish a certification standard. For tendering, clients and lead organisations may use the clusters as a reference when specifying BIM personnel or team capability requirements, subject to project-specific validation. For BIM execution plans (BEPs), the identified requirements can be translated into role responsibilities, workflow controls, review gates, and expected deliverables so that competency expectations are linked to implementation arrangements. These applications should be treated as potential uses of the exploratory findings rather than validated prescriptions, and further testing across roles and projects is required before formal adoption.

CONCLUSION

This study addressed RQ1 by identifying the BIM competencies practitioners consider necessary for railway infrastructure projects. The interviews show that competency is typically judged at delivery gates-where outputs must be reviewable, traceable, and acceptable-rather than through tool familiarity in isolation. Five clusters capture how requirements are articulated in practice: information governance and traceability; integration and platform-enabled coordination under dense subsystem interfaces; compliance and configuration discipline under change; execution capability expressed through repeatable, review-ready modelling and delivery workflows; and lifecycle readiness supported by scenario-oriented thinking and reality-capture/verification practices.

The study contributes a preliminary, railway-contextualised competency structure organised with Succar's layers as a reporting baseline and

operationalised through delivery nodes and verifiable artefacts. This operational framing is the main point of difference from generic competency lists: it specifies where each requirement becomes visible (e.g., interface coordination, review and acceptance, change/version control, deliverable submission, as-built verification and handover) and what can be checked as evidence (e.g., issue-closure records, compliance check outputs, baseline registers, controlled transmittals, and handover packages). For practitioners, the results support competency development and role profiling that start from these gates and evidentiary outputs, so that training and assessment align with the controls and coordination cycles that dominate railway BIM delivery.

The findings remain exploratory and reflect practitioner-perceived requirements from a limited qualitative sample; they should not be treated as an industry standard, a validated taxonomy, or a validated measurement framework. Future work should (i) triangulate the competency claims against project documents and delivery requirements, (ii) translate the clusters into measurable indicators for survey-based assessment and validation, and (iii) test how requirements vary by role, stage, and interface intensity across different railway project types. These steps would strengthen external validity and support the development of robust competency assessment instruments and targeted capability-building programmes for railway infrastructure organisations.

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