

## EVALUATING THE IMPACT OF BUILDING INFORMATION MODELING (BIM) ON PROJECT PERFORMANCE IN THE BUILT ASSET INDUSTRY: DEVELOPMENT OF AN INFORMATION PROCESSING INDEX AT CSCE-2025

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**ABSTRACT:** Building Information Modeling (BIM) is widely recognized for its potential to enhance efficiency, coordination, and data-driven decision-making in construction. Yet, despite increasing adoption, its measurable impact on cost, schedule, and quality outcomes remains largely anecdotal and insufficiently validated. Existing evaluation methods often rely on binary or checklist-based assessments, focusing on whether BIM is used, rather than how it is integrated into workflows. These approaches overlook critical factors such as model structure, data richness, and practical application in project delivery.

To address this gap, this study introduces the **Information Processing Index (IPI)**, a model-centric framework for evaluating BIM integration depth, referred to as **BIM intensity**. The IPI comprises three core dimensions: (1) **container** (model organization and classification), (2) content (metadata richness and consistency), and (3) **use** (integration of BIM in project workflows). Together, these dimensions offer a structured, data-driven approach for assessing the quality and utility of BIM within project environments.

BIM intensity is proposed as a quantifiable metric that reflects the depth, frequency, and consistency of BIM usage across project phases. Positioned as a moderating variable, it links implementation practices with performance outcomes such as cost control and constructability. While the IPI is currently at a conceptual development stage, it is part of a broader research program aimed at exploring BIM's impact on Project Performance. A case study approach is planned to validate the framework, which is ultimately envisioned as an automated tool that generates BIM intensity scores from model inputs.

### INTRODUCTION

The construction and built asset industry is undergoing a digital transformation driven by structured data workflows and integrated platforms. At the forefront of this shift is Building Information Modeling (BIM), a methodology that extends beyond 3D modeling to integrate geometric, semantic, and parametric data, supporting the full lifecycle of design, construction, and operations; (Liu et al., 2020; Poirier et al., 2015b).

BIM adoption continues to grow globally, propelled by its ability to streamline workflows, improve interdisciplinary communication, and reduce errors. Many governments and private organizations have implemented BIM mandates to standardize practices and drive innovation. Countries such as the UK, Singapore, have taken the lead, while others are gradually advancing toward broader integration (Hu & Dossick, 2024). Beyond design and construction, BIM supports applications in facility management, sustainability analysis, and digital twin development. These capabilities are further enhanced through integration with Artificial Intelligence, Internet of Things, and cloud technologies (Sanhudo et al., 2018).

Research has consistently linked BIM to increased project performance through improved efficiency, cost control, and quality assurance. It facilitates better coordination, minimizes delays through 3D visualization and clash detection, and supports automation of critical tasks. The use of quantity takeoff (QTO) allows for precise cost estimation and real-time budget forecasting, helping reduce overruns and improve resource planning (Wong et al., 2015). Similarly, rule-based validation and real-time monitoring contribute to enhanced quality control and risk mitigation.

However, despite its widespread adoption, BIM's actual impact on project performance remains insufficiently measured. Existing evaluation methods often rely on binary classifications. Projects are labeled as either BIM-enabled or not, without accounting for the depth, frequency, or quality of BIM integration. Most assessments focus on whether BIM tools are in place or whether formal processes exist, overlooking how thoroughly BIM is embedded in project workflows and decision-making.

Intuitively, the more consistently and effectively BIM is integrated into a project, the greater its potential to deliver meaningful performance outcomes. Current frameworks tend to emphasize adoption rates and compliance maturity without evaluating how intensely BIM is used. Many do not assess critical dimensions such as model structure, data richness, and workflow utility. These factors directly influence the reliability and impact of BIM. Furthermore, evaluations often rely on subjective surveys rather than measurable, objective indicators, which limits their accuracy and comparability.

To better understand BIM's true contribution, there is a clear need to move beyond surface-level assessments. The concept of BIM intensity, defined as the depth of integration of BIM across a project, offers a more robust approach. BIM intensity can vary significantly between projects and is likely to influence the effectiveness of BIM to improve Project Performance.

This study responds to that need by introducing a model-centric framework called the Information Processing Index (IPI). It is designed to quantify BIM intensity and evaluate how effectively BIM models are structured, enriched, and applied across the project lifecycle. By assessing the organization of data, the consistency and quality of embedded information, and the practical use of models in project workflows, the IPI aims to establish a clear link between BIM implementation depth and project performance.

The study is part of a broader research agenda focused on evaluating the impact of BIM in the built asset industry. Within this program, the IPI serves as a foundational component, offering a structured and scalable methodology for assessing BIM implementation. Central to this framework is the positioning of BIM intensity as a moderating variable that influences the relationship between BIM practices and project outcomes. By embedding this perspective into a measurable framework, the research seeks to provide practitioners, researchers, and policymakers with an actionable tool for optimizing BIM use and unlocking its full value in practice.

## **1. LITERATURE REVIEW**

This section reviews existing research on BIM's impact on project performance, current evaluation of information processing, and the limitations of current evaluation methods. It establishes the foundation for the proposed Information Processing Index (IPI).

### **1.1 BIM and Project Performance**

Building Information Modeling (BIM) is widely acknowledged for its ability to enhance project outcomes across key performance dimensions, including cost, schedule, quality, and collaboration. Numerous studies have demonstrated that BIM contributes to reducing delays, minimizing rework, improving design coordination, and increasing the accuracy of cost estimation (Cao et al., 2022; Wong et al., 2015).

BIM improves cost efficiency by enabling precise quantity takeoffs, real-time budget forecasting, and 5D cost modeling, which help reduce cost overruns and strengthen financial control (Cao et al., 2022).

Schedule performance is enhanced through 4D BIM simulations that support construction sequencing, risk anticipation, and timeline optimization (Ahankoob et al., 2022). From a quality and risk mitigation perspective, BIM enables clash detection and constructability assessments that reduce design errors, rework, and change orders.

Beyond technical performance, BIM strengthens collaboration by providing a shared digital environment where stakeholders can exchange real-time information, streamline approvals, and coordinate more effectively. This is particularly valuable in complex projects that require high levels of interdisciplinary integration (Farr et al., 2014).

However, while the benefits of BIM are well documented, many studies generalize its impact without considering how deeply or consistently BIM is integrated across project phases. The degree of BIM use, not just its presence can significantly affect performance outcomes. For instance, (Cao et al., 2022) found that varying levels of BIM use produce different results in terms of cost and schedule control. Similarly, (Wong et al., 2015) linked BIM capability to measurable gains in quantity surveying and delivery performance. Contractor experience and consistent BIM integration play a key role in unlocking its full value (Ahankoob et al., 2022).

These findings suggest that the depth and quality of BIM integration are critical in determining its true contribution to project performance. As such, there is a growing need for evaluation methods that move beyond binary adoption metrics and assess how thoroughly BIM is embedded into project workflows and decision-making.

## 1.2 Existing BIM Evaluation Methods

The rapid advancement and diversification of Building Information Modeling (BIM) technologies have led to the development of various tools and frameworks aimed at assessing BIM capability and maturity (Yilmaz et al., 2019). These tools are essential not only for benchmarking BIM performance but also for guiding its systematic improvement. In this context, it is important to differentiate between BIM capability, which refers to the ability to produce BIM-related deliverables and services, and BIM maturity, which concerns the consistency, quality, and integration depth of those outputs over time (Succar et al., 2012).

Despite growing recognition of BIM's potential, most current evaluation approaches remain limited in scope. They typically emphasize surface-level indicators such as BIM adoption status, compliance with standards, or progression along a generic maturity scale. These assessments are often binary or staged in nature and fail to reflect how BIM is structured, enriched, and applied within actual project workflows.

Treating BIM adoption as a checklist activity overlooking how BIM is used in practice, keeps evaluation at a superficial level (Franz & Messner, 2019). The true value of BIM lies in its ability to enhance information management and support informed decision-making, factors that are not captured through static maturity assessments (Demian & Walters, 2014).

While existing evaluation models provide a foundational framework for understanding BIM implementation, they often fall short in capturing the full extent of BIM utilization. In particular, they overlook the depth and consistency with which BIM is integrated into everyday practices across different project phases.

To date, several BIM maturity models have been introduced to support organizations in evaluating and improving their BIM practices. These include:

Model	Developer	Purpose	Evaluation Method	Evaluation Metrics
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<b>NBIMS CMM</b>	National BIM Standard (NBIMS)	Assess BIM maturity in building/infrastructure design practices	Excel-based scoring with adjustable weights	Data richness, process integration, interoperability (IFC), accuracy
<b>BIM MM</b>	B. Succar	Evaluate BIM maturity of teams/orgs; addresses NBIMS gaps	Online rating (free for individuals, paid for teams)	Process, people, standards, software, hardware, data
<b>BIM QuickScan</b>	TNO (Netherlands)	Benchmark BIM use in organizations; identify strengths and weaknesses	Questionnaire + interviews; online results with benchmarking	Strategy, culture, tools, standards (10 categories)
<b>VDC Scorecard</b>	Stanford (CIFE)	Compare project performance against industry benchmarks	Four-part survey (planning, adoption, tech, performance); benchmarking enabled	BIM/VDC usage, innovation, team collaboration
<b>BIMCS (BIM Cloud Score)</b>	Du, Liu, Issa	Compare BIM performance across users; identify gaps via benchmarking	Online scoring; automated analysis; works as plugin or standalone tool	Productivity, quality, usefulness, modeling accuracy

*Table 1 - Comparative Overview of Existing BIM Evaluation and Maturity Models*

These evaluation methods have limitations, including a lack of measurement for BIM's level of integration within a project, limited focus on information processing, and the absence of a direct link between BIM use intensity and real-world project efficiency gains. To address these gaps, this research proposes a structured Information Processing Index (IPI) that evaluates BIM intensity and model structure based on three dimensions: container, which assesses model organization, classification systems, and structured data exports; content, which evaluates metadata richness, attribute consistency, and information completeness; and use, which measures how well BIM supports key project functions such as coordination, cost estimating, and visualization. By shifting from a compliance-based to a data-driven evaluation model, this research aims to provide a more precise, actionable methodology for assessing BIM's impact on project performance.

### 1.3 The Importance of Information Structure and Quality

BIM serves as a digital information hub, integrating vast amounts of data across design, construction, and operation phases (Ahankoob et al., 2021). However, its effectiveness depends on how well this information is structured, shared, and utilized (Demian & Walters, 2014; Farr et al., 2014). High-quality BIM models enable precise decision-making by ensuring that information is well-organized, consistently classified, and accessible. Poorly structured models can lead to data redundancy, misinterpretation, and inefficiencies in coordination efforts (Du et al., 2014). Inconsistent classification systems, variations in attribute definitions, and a lack of standardized data organization hinder seamless data exchange and reduce the reliability of BIM-based decision-making.

Effective BIM implementation depends on more than tool adoption, it requires careful attention to how information is created, classified, and maintained. High-quality models require well-defined metadata, consistent object classification, and structured compliance with BIM requirements, all of which are frequent

pain points in practice (Tsay et al., 2023). According to (Du et al., 2014), the reliability of data exchange in collaborative environments is contingent on model structure, classification systems, and consistent naming practices. Poor structuring leads to data redundancy, misinterpretation, and inefficient workflows, ultimately compromising project coordination.

Complementing this view, (Chen & Yeoh, 2020) emphasize that the quality of information embedded in BIM, such as metadata accuracy, completeness, and consistency, is crucial for downstream processes like cost estimation, asset management, and digital handover. Their framework categorizes information quality issues into four key dimensions:

- **Completeness Issues:** Evaluating missing or incomplete attributes and duplicated elements
- **Correctness Issues:** Evaluates Elements with zero length or size and Physically misaligned objects that exceed allowable tolerances
- **Consistency Issues:** Evaluates Semantically inconsistent elements
- **Coherence Issues:** Evaluates Misalignment between BIM data mappings across different applications

This emphasis on quality is further supported by (Tsay et al., 2023), who note that insufficient or inconsistent data within BIM models is a major obstacle to meeting owner requirements, especially in facility management contexts. They identify a series of compliance issues that can compromise data quality and model reliability:

- **Geometric Modeling Requirements:** Assesses whether sheet plotting and modeling strategies are clearly defined and adhered to
- **Model Warnings:** Evaluates unresolved warnings such as overlapping elements or improperly enclosed spaces
- **Object Categorization:** Checks whether elements are assigned to appropriate categories (e.g., specialty equipment vs. plumbing fixtures)
- **Geometry Level of Detail (LOD):** Measures whether model elements meet expected geometric development standards
- **OmniClass / Assembly Code Usage:** Verifies proper classification and coding of tracked elements
- **Phasing Consistency:** Reviews whether phasing is logically applied and consistently implemented across models
- **Views and Schedules:** Examines whether views and schedules are generated appropriately, and whether non-compliant or "sticky" data (e.g., imported DWGs) remains in the model

Collectively, these studies underscore a critical insight: without rigorous information quality controls, BIM models cannot fulfill their intended purpose of enabling accurate analysis, reliable collaboration, and informed decision-making throughout the building lifecycle.

#### **1.4 Embedding BIM into Workflow and Decision-Making**

The benefits of BIM are not realized through adoption alone, but through consistent, purposeful integration into core project workflows. Research by (Ahankoob et al., 2022) highlights that sporadic or superficial use of BIM does not yield the same performance improvements as projects where BIM is used regularly in tasks like clash detection, construction sequencing, or cost tracking.

BIM is not just a digital modeling tool, but as a configurable information system that can shape design and construction decision-making when applied effectively (Farr et al., 2014). In this view, BIM's real value is activated through its embeddedness in daily workflows, not simply by its availability.

Demian & Walters, (2014) offer a practical framework for evaluating BIM's contribution to project information management. Their study focuses on how BIM affects the flow, quality, and relevance of information, particularly when compared to traditional systems such as email, ERP tools, and extranets. Key metrics include:

- Volume of Information Flow: Assesses the quantity of data transmitted through each communication channel, highlighting shifts in distribution patterns with BIM adoption
- Accuracy and Timeliness of Information Exchange: Evaluates the precision and speed of data sharing, with BIM enabling more accurate and timely communication than manual methods
- Appropriateness of Information: Measures whether the information shared is relevant and task-specific, ensuring that stakeholders receive only what is needed
- Visualization of Information Flow: Tracks how information circulates over time across different platforms, offering insights into process efficiency and system effectiveness

These insights underscore the importance of evaluating not only whether BIM is present on a project, but how deeply it is integrated into essential project functions. Without meaningful implementation, the transformative potential of BIM remains unrealized.

## 2. CONCEPTUAL FRAMEWORK

This section defines BIM intensity and introduces the Information Processing Index (IPI) as a structured methodology for evaluating BIM's effectiveness. It describes the three core dimensions of the IPI: container, content, and utility. A preliminary case study is planned to validate the IPI framework and demonstrate its applicability in real-world projects. These axes are inspired by information quality and workflow integration principles and are intended to complement existing BIM maturity frameworks/models. This framework remains at a conceptual development stage, pending empirical application and validation.

### 2.1 Concept of BIM Intensity

The effectiveness of Building Information Modeling (BIM) in enhancing project outcomes depends not simply on its adoption, but on the depth and consistency of its integration within project workflows (Lidelöw et al., 2023; Poirier et al., 2015a). This study introduces BIM Intensity as a moderating variable that quantifies the extent to which BIM contributes to project efficiency and performance. BIM intensity refers to the depth, frequency, and consistency of BIM integration across project workflows.

While many projects report using BIM, the intensity of its use varies significantly. BIM Intensity accounts for this variability by measuring how frequently BIM is applied, how well it is embedded in decision-making and project management processes, and the richness and quality of information embedded within the model. Projects with high BIM Intensity are characterized by continuous, structured data flows and consistent BIM integration across all phases of the project, from design through construction to operations. Key indicators of BIM Intensity include:

- Frequency of use: How often BIM is applied across different phases and tasks.
- Integration with project management: The extent to which BIM supports planning, scheduling, cost estimation, coordination, and communication
- Interoperability: The ability of the BIM model to interface with other tools, such as cost and scheduling software
- Information richness: The completeness, consistency, and accuracy of metadata within the model

While some projects use BIM primarily for visualization or documentation in isolated phases, others embed it across the entire lifecycle, from design and coordination to cost planning and construction execution. Projects with high BIM intensity use BIM as a core platform for real-time data exchange, automated reporting, scenario analysis, and performance monitoring (Poirier et al., 2015a). In such environments, BIM is not just a tool but a strategic asset, enabling more informed decision-making and more efficient project delivery.

BIM intensity is quantitatively assessed using a combination of indicators that reflect model usage frequency, information richness, and workflow integration. The goal is to move beyond binary assessments

of BIM adoption by generating a composite score that reflects how comprehensively BIM is embedded into project practices across phases.

## 2.2 Dimensions of the IPI framework

To operationalize this assessment, the Information Processing Index (IPI) is introduced. Similar to the structured indicators proposed by (Poirier et al., n.d.) to evaluate BIM model evolution, the IPI introduces quantifiable metrics to assess how BIM supports information processing across the lifecycle. The IPI is structured around three core dimensions: container, content, and use. Each representing a distinct yet interrelated aspect of how BIM supports project success.

1. The container axis evaluates the structure and organization of the BIM model. It addresses how well data is classified, labeled, and hierarchically organized. A well-structured model ensures that information is logically grouped, easily retrievable, and interoperable across platforms (Poirier et al., n.d.). This axis draws from information architecture principles, where clarity and consistency in model organization directly affect usability, especially in multidisciplinary environments. A strong container structure enhances coordination, facilitates data handover, and reduces confusion or duplication across project teams
2. The content axis assesses the accuracy, completeness, and consistency of metadata embedded within the model. It involves evaluating model size, model density, LOD compliance, consistency of parameter naming in categories, and the overall information quantity embedded in the model. Reliable data is essential for supporting downstream tasks such as cost estimation, scheduling, and asset management. This dimension is grounded in information quality frameworks, which emphasize the importance of valid, structured, and context-rich data in enabling trustworthy decision-making. High content quality ensures that the BIM model serves as a dependable source of information throughout the project lifecycle.
3. The use axis examines how effectively the BIM model is leveraged to support actual project workflows. This includes action rate, revision rate, BIM platform utilization, information extracted directly from the model, and clash resolution rate. (Demian & Walters, 2014) stress the importance of measuring not just BIM adoption but the extent and frequency of its application. This dimension reflects workflow integration, focusing on whether BIM is a passive repository or an active tool for project execution. High scores in this area indicate that BIM is playing a central, functional role in daily project operations, directly contributing to performance outcomes.

By combining these three dimensions, the IPI provides a multidimensional assessment of BIM implementation depth. It captures how BIM is structured (container), what information it contains (content), and how it is applied in practice (use). This structured approach moves beyond checklist-based maturity models, offering a scalable method for assessing the practical contribution of BIM to project delivery.

A summary of the proposed IPI metrics, their functions, and their role in evaluating BIM implementation across project phases is presented in **Error! Reference source not found.** (see Annex A).

## 3. METHODOLOGY

This section outlines the research methodology adopted to develop and validate the Information Processing Index (IPI), a structured framework for assessing BIM intensity, defined as the depth, frequency, and consistency of BIM integration within project workflows. The methodology is designed to move beyond binary assessments of BIM adoption by providing a more detailed, model-centric analysis of how BIM supports project execution.

The implementation process is structured into four key stages. These stages include data collection, metric development, BIM intensity scoring, and validation through case studies.

The first stage focuses on data acquisition, drawing from a diverse range of project sources including literature, BIM Execution Plans (BEPs), construction documents, native BIM models (e.g., Revit/IFC), CDE-

based issue logs, and project performance records related to cost, schedule, and quality. This data establishes the foundation for the evaluation.

In the second stage, the IPI metrics are developed based on insights from the literature and observed industry gaps. These metrics are then applied to BIM models to evaluate them across the three core dimensions.

The third stage involves BIM intensity scoring, where individual metrics are normalized and aggregated to generate a composite score for each project. This score quantifies the extent to which BIM is embedded into project practices.

The fourth stage entails a correlation analysis, comparing BIM intensity scores with project performance indicators to explore potential relationships. A feedback loop is integrated to iteratively refine the IPI metrics based on empirical findings from the case studies.

Figure 1 presents the overall approach, emphasizing the interconnections between the data sources, research activities, and expected outcomes. The outcomes include a validated set of BIM intensity metrics, an empirical framework linking BIM use to project performance, and the development of an automated protocol for evaluating BIM intensity.

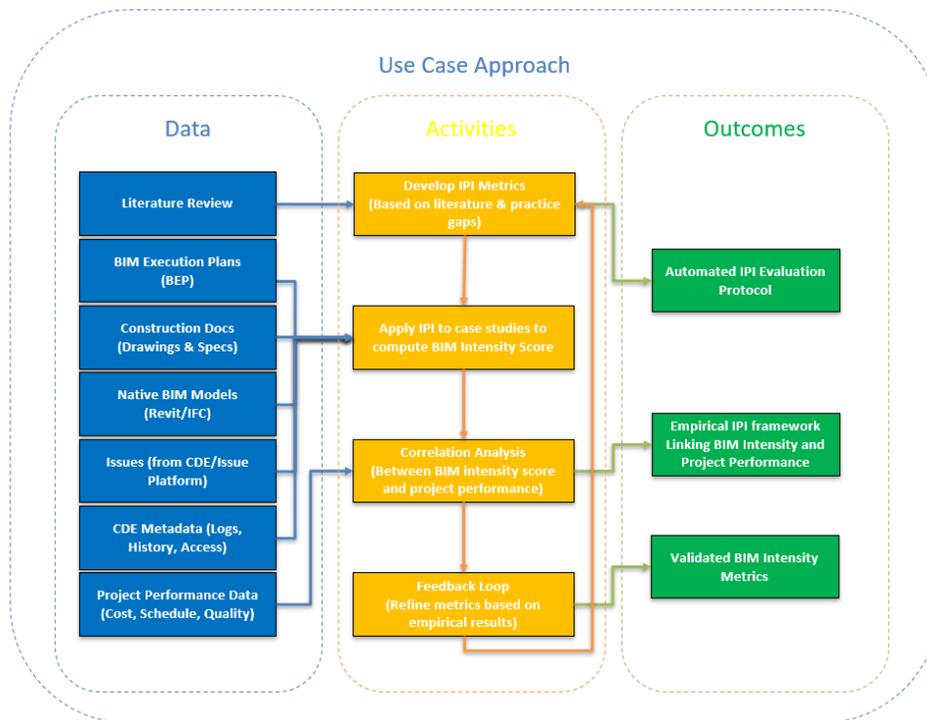


Figure 1 - Research Framework for Developing and Validating the BIM Information Processing Index (IPI)

By grounding the IPI in both theoretical constructs and practical data, this methodology aims to deliver a scalable evaluation framework that supports both academic research and industry application.

### 3.1 BIM Requirements Evaluation

Before assessing the quality and effectiveness of BIM models, it is essential to establish whether the models align with project-specific requirements outlined in the BIM Execution Plan (BEP). This step ensures that

the evaluation framework is tailored to the project's defined BIM objectives and deliverables. The assessment begins with an in-depth review of the BIM Execution Plan to understand the specific goals and expectations of the project, including intended applications such as clash detection, cost estimation, or facility management.

A key focus is placed on BIM uses and goals, which define the required granularity and reliability of BIM elements throughout different project phases. Verification is conducted to ensure that model elements meet required LOD specifications, ranging from conceptual representation (LOD 100) to detailed as-built documentation (LOD 500). This ensures that models contain sufficient detail for their intended purpose and can be effectively used for decision-making.

Interoperability standards are another critical aspect of this evaluation. The ability of BIM models to function across different software platforms, particularly through Industry Foundation Classes (IFC) exports, is assessed to ensure seamless collaboration. Compliance with a Common Data Environment (CDE) is also verified to determine whether models are managed, shared, and updated following structured collaboration protocols. This ensures that all stakeholders can access and utilize accurate information throughout the project lifecycle.

By conducting a BIM requirements evaluation upfront, the study ensures that the assessment is performed within the context of project-specific BIM standards and expectations. This step provides a foundation for subsequent evaluations by confirming that models align with predefined goals and technical requirements.

Automating the assessment process reduces manual review effort and subjective interpretation, while also enabling scalability across multiple projects.

### **3.2 Model Centric Evaluation Protocols**

Based on the IPI framework and its associated metrics, the research is currently contributing to the development of automated model checks, designed to evaluate BIM intensity directly from native or IFC models without manual review. This automation will also enhance repeatability, reduce subjectivity, and support the validation process.

Once requirements are established, BIM models are assessed using a model-centric approach based on the Information Processing Index (IPI). This step focuses on objectively evaluating the quality of information processing within the model, rather than relying on self-reported or process-based metrics.

### **3.3 Integrating BIM Intensity Measurement**

To test the hypothesis that BIM intensity influences project performance, the study integrates a BIM intensity measurement phase into its methodology. This measurement aims to capture how thoroughly and consistently BIM is used throughout the project lifecycle, beyond simple adoption indicators.

To validate the IPI framework and BIM intensity concept, a case study approach is adopted. Real-world BIM-enabled projects will be analyzed using the IPI, and BIM intensity scores will be correlated with performance indicators such as cost efficiency, schedule adherence, and quality outcomes.

The selection of case studies will be guided by specific criteria to ensure a diverse representation of BIM applications. Projects with differing levels of BIM intensity will be chosen to facilitate comparative analysis and assess how various levels of BIM integration impact project outcomes. Additionally, projects where BIM is applied to multiple use cases, such as coordination, scheduling, and cost estimating, will be selected to evaluate the versatility of the IPI. The availability of BIM models, project documentation, and performance data will also be key factors in the selection process to ensure there is sufficient information for analysis.

The findings will inform a feedback loop to refine the metrics and support the development of a standardized, automated BIM evaluation protocol.

#### **4. CONCLUSION**

This study presents the conceptual development of the Information Processing Index (IPI), a model-centric framework aimed at assessing the depth and quality of BIM integration, termed BIM intensity, within project workflows. By structuring the evaluation across three dimensions: (1) container, (2) content, and (3) use. The IPI offers a more detailed, multidimensional view of BIM implementation than conventional adoption or maturity models. This research responds to limitations in existing methods by emphasizing measurable indicators of information structure, metadata quality, and workflow integration. Although the framework is currently conceptual and has yet to be validated empirically, it is grounded in a robust review of BIM evaluation literature and theoretical models of information quality. Future work will involve applying the IPI to real-world case studies to test its utility, validate its metrics, and explore correlations between BIM intensity scores and project performance outcomes such as cost, schedule, and constructability. Through such validation, the IPI aims to serve as a scalable tool for industry practitioners and researchers seeking to assess and improve digital project delivery strategies.