



Standards, Methods, Procedures, and Technology (SMPT) for Innovation in BIM Projects: Enhancing Quantification and Scheduling through Customized Add-Ins

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ARTICLE INFO

KEYWORDS

Building information modelling (BIM); ISO 19650 compliance; Revit API customization; Quantification and scheduling in construction

HOW TO CITE

Kapogiannis¹, G., Yang², T., Talbot³*, B., Gerges⁴, M., Reppas⁵, N., Mytilinaios⁶, A., & Manzoor⁷, B. (2026). Standards, Methods, Procedures, and Technology (SMPT) for Innovation in BIM Projects: Enhancing Quantification and Scheduling through Customized Add-Ins. Emirati Journal of Civil Engineering and Applications, 4(2), 79-98.

<https://doi.org/10.54878/zd8hbc31>

ABSTRACT

This study introduces an ISO 19650-compliant SMPT (Standards, Methods, Procedures, Technology) framework and a four-step Filter-Extract-Derive-Schedule fast-track implemented as a Revit Add-in. Our approach batch-retrieves concrete columns, walls, and slabs as Solids while uniformly voiding openings; secondly analytically derives vertical surface areas via a closed-form quadratic solution from known height, volume, and total surface area; and third links net quantities to industry productivity rates to output construction durations—all in one click. Cross-validated through literature benchmarking and controlled experiments on an LOD-350 reference model, the Add-in delivers an integrated geometry-quantity-duration pipeline inside native Revit schedules and supports ISO 19650 Level-3 information governance. Researchers also provide an SMPT implementation flowchart, KPI template, and forward-compatible scripts to enable replication without Dynamo. The method is extensible to beams, foundations, and O&M, and demonstrates that a standards-compliant, technology-driven workflow can materially enhance BIM performance for concrete construction. Henceforth, our research contribution represents not just a technical improvement but a paradigm shift, moving from external scripting to native embedded automation, from fragmented rules to unified geometric logic, from approximations to closed-form mathematical rigor, from manual linking to automated scheduling integration, and from ad hoc workflows to standards-compliant, audit-ready pipelines. This integration of mathematical novelty, process efficiency, and standards alignment establishes the innovation of the proposed workflow, positioning it as a significant advancement with impact across both academic research and industry practice.



Double-blind peer review by independent reviewers.

Received: 12 Jul 2026, Accepted: 15 Nov 2026, Published: 07 Dec 2026

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1. Introduction

The Architecture, Engineering and Construction (AEC) industry is undergoing a profound digital transformation, driven by the need to improve efficiency (Ling & Leo, 2000), accuracy (Martínez, Solís, & Caldas, 2024; Talbot, 2021), and collaboration (Kapogiannis, 2018) across all project stages. Among the technologies enabling this shift, Building Information Modelling (BIM) has become a central paradigm for the management of project information and the coordination of multidisciplinary processes (Azhar, 2011; Eastman, 2011). BIM integrates geometric, spatial, and semantic data into a shared digital environment, facilitating more informed decision-making and reducing inefficiencies such as design errors, rework, and material waste (Barlish & Sullivan, 2012). By enabling real-time information exchange between stakeholders, the BIM paradigm has proven instrumental in enhancing project performance, improving predictability, and supporting sustainable construction practices. Moreover (Molsa, Demian, & Gerges, 2023) states that BIM allows robust increasing collaboration and facilities sharing between different stakeholders at different phases of the project. In addition, (Khalafallah et al., 2023) states that both designers and contractors believe enhances communication amongst stakeholders and minimise change orders.

However, despite these advantages, current BIM platforms still present notable limitations in reinforced-concrete including FRP (Fibre reinforced polymers) (Demian, 2010) quantity take-off and construction scheduling. While the (BSI, 2025) ISO 19650 series provide a robust framework for managing information through structured Standards, Methods and Procedures (SMP), it does not offer explicit mechanisms for operational integration with digital tools (Çepni, 2021). As a result, practitioners frequently face challenges when attempting to translate information management standards into automated, auditable workflows within BIM environments, even when environmental data are connected to them through sensors (Kensek, 2014; Wu & Tam, 2025). Moreover, widely used platforms such as Revit lack built-in capabilities to compute and schedule key geometric attributes, such as vertical surface area, which are essential for reliable formwork estimation and productivity analysis in concrete construction (Choy & Ruwanpura, 2006; Lee, 2019).

Existing approaches such as Dynamo4D (Kensek, 2014) and related scripting-based methods automate aspects of scheduling but remain constrained by their reliance on external visual programming environments, fragmented

geometric rules, approximate calculations, and multi-step manual execution (Autodesk, 2020; Autodesk, 2021; Novatr, 2025). These limitations hinder reproducibility, auditability, and seamless integration with productivity data (Tesla, 2024; Engineering.com, 2023). In contrast, the proposed four-step Filter–Extract–Derive–Schedule workflow introduces a distinct paradigm by embedding automation natively within Revit as a custom C# Add-in, thereby eliminating external dependencies and ensuring interoperability. The workflow applies a unified geometric deduction rule across columns, walls, and slabs, introduces a closed-form quadratic solution for vertical surface area to enhance mathematical rigor, and automatically links net quantities with productivity rates to generate construction durations. Furthermore, its one-click execution consolidates the entire pipeline into a single automated process, shifting practice from ad hoc scripting toward standardized, audit-ready, and ISO 19650-compliant information management aligned with the SMPT framework (BSI, 2025; ISO, 2018; UK BIM Framework, 2019). These methodological advance bridges design data and construction planning seamlessly, offering both academic novelty and practical industry impact (could potentially close the gap on easier adoption of BIM in the AEC sector (Liu & Issa, 2012).

In more detail, to address these gaps, this study proposes a novel four-step Filter–Extract–Derive–Schedule workflow, implemented as a custom C# Revit Add-in, that automates the process of quantity extraction and schedule generation. The approach operates entirely within the Revit environment and eliminates the need for Dynamo or external scripts. Specifically:

1. Filter–Extract batch-retrieves columns, walls, and slabs as Solids, applying a unified rule for opening-area deduction to ensure geometric consistency.
2. Derive computes vertical surface area using a closed-form quadratic solution derived from existing geometric parameters (height, volume, total surface area).
3. Schedule links the resulting net quantities with established productivity rates to produce accurate construction durations.
4. One-click execution integrates all these steps into a single automated process.

The workflow is illustrated in Figure 1, which summarises the logical structure of the Filter-Extract-Derive-Schedule process and its alignment with the SMPT (Standards, Methods, Procedures, Technology) framework. This figure highlights how each module interacts with ISO 19650's information management principles to ensure standard compliance, data traceability, and auditability. Validated through literature benchmarking and controlled experimental testing on a Level of Development (LOD) 350 reference model, the Add-in produces a fully integrated geometry-quantity-duration dataset embedded within native Revit schedules. In addition, the study introduces an SMPT implementation flowchart, KPI verification template, and version-control scripts to support wider adoption and scalability across project types.

quantities directly from structural elements, BIM calculations simplify the process of measuring and provide clearer estimates in terms of costs and timeframe in contrast to traditional CAD QTO (Sheikhhoshkar et al., 2019). In addition, comparative studies show that BIM significantly lowers QTO errors for concrete and steel, while also improving control over design and construction processes when models are properly structured (Godager et al., 2022).

However, most of such findings is based on a techno-optimistic viewpoint, which tends to focus on successful pilot projects or adopters but ignores the issue of implementation failure or organizational resistance. Therefore, it seems necessary to explore whether such gains in coordination and error rate reduction are structural or highly contextual. First, these comparative

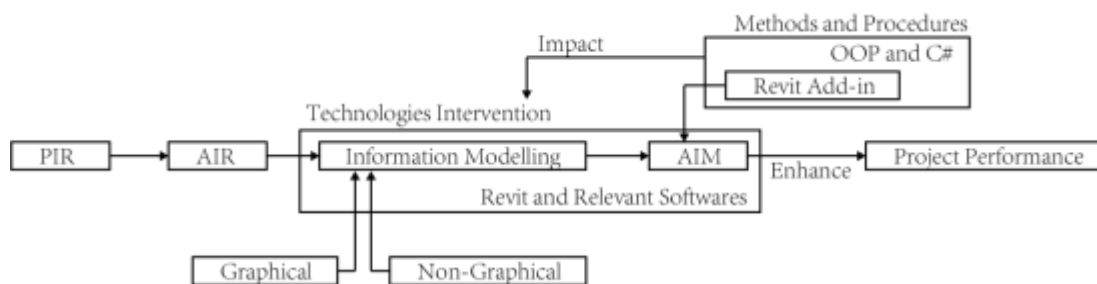


Figure 1. Using BIM Paradigm to Enhance Project Performance

By transforming ISO 19650's conceptual framework into an actionable digital workflow, this research contributes a reproducible, standards-compliant, and automation-ready method for concrete quantity take-off and scheduling. The proposed approach not only improves computational accuracy and reduces manual intervention but also strengthens the link between standardised information management and real-world project delivery, thereby advancing BIM's role as a catalyst for performance optimisation in the AEC industry.

2. Literature Review

2.1 BIM based quantity take off and scheduling for reinforced concrete

There is significant unanimity in the literature about several claimed advantages for BIM over manual 2D methods, particularly in terms of measurement speed and consistency. According to numerous scholarly studies, BIM based quantity take off (QTO) improves speed and consistency over manual 2D methods, particularly for reinforced concrete structures (Lee, Won, & Leite, 2023). Using the volume of concrete and reinforcement

benefits are typically demonstrated using pilot-project case studies and limited comparisons, rather than experimental methods. For instance, higher accuracy is usually calculated in relation to manual 2D take-offs or estimated with the help of models, rather than confirmed by physical measurement or as-built data (Saavedra et al., 2025). Also, evidence about productivity gains usually comes from the ranking preferences of early-adopter practitioners, who have a drastically different opinion on technology compared to non-adopters (Eadie et al., 2013). In addition, the absence of blind validation, reliance on small samples (limited to just one building below 250 m²) (Kim et al., 2019), and selection bias of the target sample of early-adopter organizations (Lourenço, Arantes, & Costa, 2025) make it difficult to generalise the results. Altogether, such design flaws hinder both internal validity (credibility of the results) and external validity (generalisability of the results to non-adopters and more complex building forms). Finally, only a few studies report the margin of error in quantity take-off errors in specific concrete formwork features (especially the net areas of formwork with holes) or validating quantities by means of field measurements (Saavedra et al., 2025). It seems likely that the obtained results may be subject to cognitive bias of the techno-enthusiasts (Eadie et al., 2013). rather than robust, reproducible performance improvements.

Empirical research into whether information richness in BIM facilitates downstream operational benefits, like consistent formwork scheduling, daily pours, or productivity comparisons, rather than serving solely as a design coordination and clash prevention tool, remains sparse. This narrowly focused approach to BIM's benefits poses a severe problem for reinforced concrete projects, where the applicability of BIM relies on its ability to support repetitive site activities and short-interval planning (Pham et al., 2024). This constitutes a critical omission, because for site teams the effectiveness of BIM lies in its ability to incorporate construction-specific calculations into scheduling workflows, demonstrating how well model data supports repetitive, labour-intensive activities such as formwork erection, pouring cycles and stripping sequences.

At the implementation level, most existing QTO procedures in BIM models rely on standard Revit schedules or simple parameter combinations for calculating element volume, length, and gross area but fail to factor in construction-related properties such as net vertical formwork area and zone-based calculations needed for daily planning (Sheikhhoshkar et al., 2019; Godager et al., 2022). studies on daily concrete and formwork requirements suggest that object-based QTO frequently fails to fulfil planners' needs, especially concerning overlapping objects, joints, and openings, making further calculation adjustments necessary (Malla, Tummalapudi, & Delhi, 2024). One clear trend among several studies is the low transparency of their formulas: calculations for vertical formwork areas and openings are frequently performed using heuristic values or opaque scripts, with only overall accuracy rates provided (Khosakitchalert, Yabuki, Fukuda, 2020). From an information management perspective, this issue makes the results harder to reproduce and complicates the evaluation of their adequacy for contractual purposes or productivity assessments (Choi, Kim, & Kim, 2014).

Rather than representing a full paradigm shift, many BIM-based QTO tools effectively digitise traditional quantity-surveying practice: manual checks, ad hoc parameters and disconnected Excel schedules are migrated into the model environment without being fundamentally re-engineered (Pham et al., 2024). Such an evolutionary approach explains the simultaneous presence of proven time efficiencies and frequent mistakes despite the increased complexity of the interface, as the core algorithmic reasoning is still disjointed even while the interface is more advanced (Choi, Kim, & Kim, 2014). Addressing these limitations requires not merely faster digital measurement, but mathematically explicit, reproducible derivation of

construction-relevant attributes embedded directly in scheduling workflows, a capability absent from existing literature

2.2 ISO 19650, information governance and SMPT concepts

The ISO 19650 series became the primary guide of choice for managing information in BIM-assisted projects, emphasizing the importance of structure information requirements, collaboration processes, and common data environments (CDEs) (Valinejadshoubi et al., 2024). Studies emphasise that these standards can optimise lifecycle performance only if information needs are explicitly defined and translated into practical workflows and deliverables (Lindholm, Johansson, & Yitmen, 2025). Studies dedicated to the topic of BIM enterprise adoption revealed that such concepts as information requirements, level of information need and CDE based on the containers are vital in connecting project information to organization and asset management objectives (Xie et al., 2023). From the standpoint of SMPT framework, ISO 19650 introduces "Standards, Methods and Procedures" needed to specify, delivery and verify BIM data, while the role of "Technology" is supposed to be performed by means of tools and platform (Kaya & Özener, 2024). In other words, ISO 19650 defines the "rules of the game" for BIM information governance yet does not explain how exactly they could be operationalized technology settings (Abanda et al., 2025).

Nevertheless, several studies pointed to the existence of a gap: many companies experience trouble implementing ISO 19650 into practice by applying existing digital tools (Lindholm, Johansson, & Yitmen, 2025; Pan et al., 2023). Users complain about the lack of clarity when it comes to ISO 19650, as well as difficulties associated with the management of multiple CDEs and the realization of consistent, verifiable information delivery even under mandate conditions (Lindholm, Johansson, & Yitmen, 2025; Pan et al., 2023; Sibaii, Granja, & Azenha, 2025). Hence, academic literature promotes the development of process models, frameworks and platforms capable of "decoding" ISO 19650 (Valinejadshoubi et al., 2024; Lindholm, Johansson, & Yitmen, 2025; Ghannad et al., 2019).

A recurring limitation in this literature is the gap between high-level information-management frameworks and their concrete instantiation in software environments. Several studies focus exclusively on process maps, responsibility matrices, and information delivery milestones, implicitly relying on the assumption that data and workflow management systems will enable compliance with these frameworks based on existing

tools (Godager et al., 2022; Kaya & Özener, 2024). Specifically, several articles offer well-defined models of BIM execution, including BIM information delivery plans and responsibility matrices, without considering whether existing CDEs and BIM authoring solutions can implement data structure compliance through built-in functionality such as rule engines (Godager et al., 2022; Kaya & Özener, 2024). gap was not explored in relation to whether Level 2/3 BIM standards can truly be implemented in mainstream software platforms due to the availability of relevant capabilities (Godager et al., 2022; Kaya & Özener, 2024; Liao et al., 2025). consequently, "ISO-compliance" often tends to be largely descriptive and based on documentation and ad hoc verification rather than empirical evidence (Pan et al., 2023; Kaya & Özener, 2024).

This disconnect is especially problematic for advanced geometric attributes and downstream uses such as formwork estimation, productivity analysis and 4D scheduling, which depend on reproducible derivations of non-native parameters (e.g. net vertical surface area); attributes that are seldom specified as explicit, verifiable calculation rules within ISO-aligned execution plans (Khosakitchalert, Yabuki, Fukuda, 2020; Choi, Kim, & Kim, 2014). Positioning a customised Revit Add-in explicitly within an SMPT logic responds to an under-addressed need in the ISO 19650 literature: translating standards into executable rules, governing geometry extraction, quantity deduction and duration computation, that can be inspected, version-controlled and reused across projects, rather than treated as project-by-project interpretations (Godager et al., 2022). This move from describing the "best practices of good information management" towards making the rule sets that describe how to automate geometry extraction, quantity takeoff, and duration calculations inspectable, version-controlled, and reusable is an answer to one of the unexploited needs in the ISO 19650 literature (Pan et al., 2023; Kaya & Özener, 2024).

2.3 Visual-programming approaches for automation in Revit

Because of Revit's limited features, many researchers and professionals rely on visual programming languages like Dynamo enhanced with Python or scripting capabilities to automate QTO, rule checks, and 4D processes (Saavedra, Meléndez, & Garcés, 2025). Visual programming has been applied in reinforced concrete construction to automate data extraction, exportation to Excel, and analysis of quantities with business intelligence tools; the application has resulted in significantly shortened processing times with an

acceptable level of accuracy (Sheikhkhoshkar et al., 2019). In other cases, Revit-Dynamo models have been integrated with MATLAB or scheduling software to optimize joint layouts, pour sequences, and daily material flows, thus moving towards data-driven planning (Malla, Tummalapudi, & Delhi, 2024).

While these studies provide proof-of-concept regarding the potential efficiency increases, their evaluation remains limited in several ways. Efficiency is usually measured in terms of the time saved in one project or pilot study without much consideration for the reliability of such scripts in case of model modification, different LODs, or coding styles (Cho et al., 2024). There are very few contributions reporting failure cases such as broken graphs upon software update, different parameter names, or replacing families, which makes one suspect a potential "success bias" in publication and a lack of generalisability of results to real-life conditions.

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Similarly, visual programming is frequently used in automated rule-checking systems where compliance rules are implemented using Dynamo graphs and scripts (Saavedra, Meléndez, & Garcés, 2025; Abanda et al., 2025). Reviews on the topic of automation in Revit mention the power of such tools but highlight their technical limitations since the scripts are normally project-specific, spread out through several files and packages, and rely on local configuration and "script champions" (Pham et al., 2024). Thus, reproducibility, verification, and maintainability of scripts become recurring topics of discussion. Most of the reviewed processes involve approximate geometric methods and multi-step processes (export, clean up, import) in place of closed mathematical calculations implemented within one environment (Saavedra, Meléndez, & Garcés, 2025). As such, the burden lies not with software developers but with in-house experts which pose certain risks for the sustainability of scripts. Little is known about script governance (who checks assumptions about geometry, controls the process of updates, and proves compliance with ISO 19650 style standards).

The lack of governance discussion from ISO 19650 and SMPT points of view seems conspicuous. Despite being described as neutral “tools,” visual programming environments establish informal standards and procedures, which consist of conventions of naming elements, approximated geometric representations that are not formally documented, and ad hoc versioning practices (Divin, 2020). The literature lacks investigation into interactions between such de facto standards and the formal information requirements as well as discussions about how to audit, certify, and reuse a Dynamo graph in accordance with Level 3 information governance (Abanda et al., 2025). Thus, visual scripting tends to be discussed as a purely technical solution rather than a management of information subject.

Thus, although Dynamo allows speeding up some operations, its use can lead to development of non-transparent processes that are largely personal, deviating from the focus of the introduction on auditing processes and compliance with ISO 19650 Level 3 information governance. Additionally, current solutions to visual programming problems often involve approximate heuristics and an export–cleaning–reimport process chain, rather than closed-form mathematical calculations performed in a single environment (Pham et al., 2024). Such situation gives additional grounds for transition to compiled, native Dynamo add-ins that include standard geometric calculations and scheduling algorithms in their codebases. In that sense, visual programming may function more effectively as an experimental prototyping environment than as a delivery mechanism for contract-critical workflows requiring ISO 19650 Level 3 governance.

2.4 Toward native, ISO 19650-aligned add-ins for geometry–quantity–duration pipelines

More recent work moves beyond generic scripting toward native automation using Revit’s API and compiled plug-ins. Reviews note that C# add-ins can encapsulate complex logic, provide more stable user interfaces and integrate more tightly with model data than Dynamo graphs alone (Pham et al., 2024). Several domain-specific systems, such as Revit plug-ins for MEP rule checking or automated QTO with quality checks, demonstrate how native tools can enforce structured rule sets, validate model integrity and push results directly into BIM schedules and dashboards (Pan et al., 2013). Research on API-based automation of QTO demonstrates that coded routines can systematically filter elements by discipline and work area, reducing manual effort and improving consistency relative to visual-programming approaches.

Nonetheless, significant gaps remain. Existing solutions often address isolated tasks (e.g., compliance checking, rebar extraction, or zone-based concrete quantities) and still depend on external spreadsheets and separate scheduling tools for duration calculation (Sheikhhoshkar et al., 2019; Lee, Won, & Leite, 2023; Malla, Tummalapudi, & Delhi, 2024). There is little evidence of a fully integrated geometry–quantity–duration pipeline that operates entirely inside Revit, applies a unified geometric deduction rule across columns, walls and slabs, computes critical but non-native attributes such as vertical surface area through closed-form solutions, and directly links net quantities with standard productivity rates to generate construction durations in one click. At the same time, ISO 19650-oriented studies continue to call for workflows and platforms that “decode” information-management standards into tangible, data-centric CDE integration and auditable processes (Valinejadshoubi et al., 2024; Lindholm, Johansson, & Yitmen, 2025; Sibaii, Granja, & Azenha, 2025).

Yet the two strands of literature: API-based automation and ISO 19650-oriented information management, rarely intersect in a substantive way (Abanda et al., 2025). Automation papers seldom position their plug-ins explicitly within an SMP(T) structure or specify how rule sets, parameter mappings and logs would be version-controlled as information containers. Conversely, ISO-focused studies often assume that compliant technological implementations will emerge generically from “BIM tools” without scrutinising the affordances and constraints of specific platforms such as Revit. This mutual blind spot leaves a conceptual and practical gap exactly where geometry, quantities and durations should be integrated.

The literature reveals no existing framework that simultaneously addresses these requirements (Kaya & Özener, 2024). While native C# add-ins offer technical stability, current implementations remain isolated, addressing either geometric extraction, compliance checking, or scheduling separately, without unified deduction rules spanning columns, walls and slabs (Sheikhhoshkar et al., 2019). Furthermore, no reviewed study derives vertical surface area through closed-form mathematical solutions from existing Revit parameters; instead, all rely on heuristic approximations or external calculation steps (Saenpaeng et al., 2025). Finally, despite calls for ISO 19650-aligned automation, existing tools lack the “constructive rigidity”, standardised, version-controlled logic with audit trails, necessary for contractual or safety-critical quantity workflows (Cho et al., 2025). This convergence of gaps; fragmented

pipelines, approximate geometry, and weak governance integration, defines the space for an integrated geometry–quantity–duration approach. Consequently, the literature presents a tri-partite fragmentation: (1) empirical studies lacking ground-truth validation; (2) automation scripts lacking governance rigor; and (3) native tools lacking geometric-quantity-temporal integration (Kaya & Özener, 2024). This study addresses these gaps through a unified, SMPT-aligned methodology.

3. Methodology

To address the research question, three interrelated objectives were defined. First, A) the study establishes the respective roles of Autodesk Revit as a BIM authoring platform and the C# programming language as an extension tool in BIM workflows (Ding, Zhou, & Akinci, 2014). This involves examining how Revit and its Application Programming Interface (API) facilitate (or limit) project information management, and how C# can be used to extend Revit's native functionality. Second, B) the study defines requirements for extending Revit via its API to support the proposed workflow, formalizing the logic of Filter–Extract–Derive–Schedule. In this phase, the specific functions, algorithms, and data structures needed to implement the plug-in are identified and designed. Third, C) the research evaluates the plug-in's impact on QTO and scheduling accuracy by deploying it in a test scenario. This involves comparing the plug-in's outputs (e.g. concrete quantities and activity durations) to results from traditional manual methods or Revit's default tools, thereby quantifying improvements in precision and efficiency.

A mixed-method research design was adopted, combining a literature review with a design-intervention experiment to fulfil the above objectives. For Objectives A and B (analysis and design of the solution), a systematic literature review was conducted to map Revit's known capabilities and limitations and to survey prior applications of C# in BIM automation. Key sources included foundational BIM texts and industry standards (Eastman et al., 2011) as well as recent studies on bespoke BIM tool development. This review informed the plug-in development by highlighting common shortcomings in current QTO and scheduling practices, such as the difficulty of obtaining accurate formwork areas directly from BIM models and by compiling best practices for BIM software customization (Eroğlu, 2019). It also situated the research within the broader BIM paradigm that emphasizes people, process, and technology: technical solutions must align with established processes, standards, and collaboration workflows. Insights from the

literature thus guided the definition of the plug-in's functionality and ensured its alignment with prevailing BIM standards and conventions.

For Objective C (evaluation), a design-intervention methodology was employed. The custom Revit add-in was developed in C# and then tested within a controlled BIM project environment to observe its performance in extracting quantities and generating construction schedules similar to the study that Sun and team shown on their paper in relation cost and schedule risk early warning (Sun, Man, & Wang, 2015). Hence, the experimental scenario allowed direct comparison between the plug-in's automated outputs and baseline outcomes from manual or default software procedures. Quantitative metrics were collected—such as the accuracy of quantity calculations (e.g. comparing the plug-in's concrete volume and formwork area results to ground-truth values) and the time taken to produce a complete quantity take-off or schedule. In addition, qualitative observations were documented regarding the tool's ease of use and its integration into the standard BIM workflow. The combined analysis of these metrics provided an empirical basis to evaluate improvements in precision and efficiency. Overall, the deployment results were used to assess how effectively the “Filter–Extract–Derive–Schedule” plug-in enhances QTO and scheduling accuracy, and to what extent it can streamline the BIM project lifecycle compared to existing practices.

The final phase of the research involved evaluating the performance of the developed Revit Add-in to determine its effectiveness in enhancing quantification within BIM workflows. The evaluation process included a comparative analysis between the experimental results obtained using the Add-in and established benchmarks identified in the literature (Barlish & Sullivan, 2012; Gilligan & Kunz, 2007). The assessment focused on three core metrics: quantification accuracy, operational efficiency, and user satisfaction. Accuracy was measured by comparing the quantity take-offs generated by the Add-in with manually verified values (Zhang, Wang, & Chen, 2025). Efficiency was assessed based on the time reduction achieved when performing quantification tasks using the tool compared to conventional manual methods. Additionally, qualitative feedback was collected from users to evaluate the tool's usability, interface clarity, and functional reliability. This evaluation framework provided both quantitative and qualitative insights into the Add-in's impact on BIM-based quantification processes.

Meanwhile, there is recent literature continues to highlight the necessity of assessing BIM-based tools through the dual lenses of accuracy and operational

efficiency. For example (Ji, Goh, & Tay, 2025). illustrate that automated BIM platforms can deliver highly precise quantity take-offs, thereby minimizing errors in procurement and cost estimation. In addition (Gerges et al., 2019) states that BIM can play a key role in the design stage is the early detection of errors and reducing number of changes through effective coordination between the designer and the client. Conversely, (Martínez, Solis, & Caldas, 2024) highlights to the trade-offs taken in various BIM integration strategies (Martínez, Solis, & Caldas, 2024), noting that while plugin-based workflows offer notable time efficiencies, they may occasionally sacrifice accuracy when compared to traditional methods.

Moreover, (Wu, Li, & Tam, 2025) further highlight the impact of interoperability constraints on the consistency and performance of Revit-centric workflows, particularly when interfacing with external analysis platforms such as Athena and SimaPro (despite we are in 2025 and interoperability remains a bottleneck). In addition (Zhang, Wang, & Chen, 2025) emphasize that user satisfaction remains a pivotal determinant in BIM adoption, advocating for intuitive user interfaces and dependable functionality in add-in development. Additionally, the release of Revit 2026 (Augi, 2025) introduces significant advancements in interface responsiveness and computational speed, establishing a new benchmark against which emerging BIM add-ins should be evaluated.

Data is collected through two main sources a) Literature Review: Gathering secondary data from existing publications to build a theoretical framework and 2) Experimental Data: Primary data obtained from the performance tests of the Revit Add-in. Data analysis involves a) Qualitative Analysis: Thematic analysis of the literature review to identify key factors influencing the use of Revit and C# in BIM implementation and b) Quantitative Analysis: Statistical analysis of the experimental data to measure the performance improvements achieved by the Revit Add-in.

4. Results

4.1 Revit-plugin Development

In alignment with ISO 19650's mandate for verifiable geometric quantities, this study introduces a Revit plug-in developed within a literature-informed, design-intervention framework. The proposed solution operationalizes a four-step metrology fast-track Filter-Extract-Derive-Schedule (FEDS), that automates geometric data acquisition, surface area estimation, and

schedule generation within a BIM environment. In the Filter & Extract stage, native Autodesk Revit API capabilities are employed to isolate the three most common cast-in-place concrete elements such as: columns, walls, and slabs. A rule-based logic is embedded to automatically deduct opening areas (e.g. doors, windows, voids) from surface calculations, applying consistent logic across all element types without manual override.

The Derive stage encapsulates a novel closed-form solution that leverages known geometric parameters (height, volume, and total surface area) to back-calculate the remaining dimensions (width and length). This enables real-time computation of vertical surface areas for formwork estimation, eliminating the need for external exports or manual formula derivation. Moreover, in the Schedule step, derived net surface areas are divided by industry-standard productivity rates of 40 m²/day for columns, 80 m²/day for walls, and 8.8 m²/day for slabs, to automatically generate task durations. These values are written directly into embedded Revit schedules in a single click. The plug-in executes the full geometry-to-schedule chain entirely within Revit, without reliance on Dynamo, external scripts, or user programming, delivering rapid and repeatable one-click outputs for geometry → quantity → duration. The below Figures 2–4 illustrate key segments of the underlying C# code corresponding to each step of the FEDS workflow, thereby demonstrating the full implementation logic and system architecture.

```

IList<Element> walls_selected = new List<Element>();
IList<Element> columns_selected = new List<Element>();
IList<Element> floors_selected = new List<Element>();

if (0 == selectedIds.Count){
    TaskDialog.Show("Revit", "You haven't selected any elements.");
} else{
    foreach (ElementId id in selectedIds){
        Element element = document.GetElement(id);
        switch (element.Category.Name){
            case "Structural Columns":
                columns_selected.Add(element);
                break;
            case "Walls":
                walls_selected.Add(element);
                break;
            case "Floors":
                floors_selected.Add(element);
                break;
            default:
                break;
        }
    }
}

```

Figure 2. C# Revit API function developed for automated extraction of structural element quantities (floors, columns, and walls) from the Project Information Model (PIM), supporting construction time estimation and integration into the Asset Information Model (AIM).

```
foreach (Element e in columns){
    Parameter vol = FindParameter(e, ParameterType.Volume);
    Parameter h = FindParameter(e, "Length");
    Parameter area_sum = FindParameter(e, ParameterType.Area);
    double V = double.Parse(GetParameterInformation(vol, document))
    double H = double.Parse(GetParameterInformation(h, document)) /
    double A = double.Parse(GetParameterInformation(area_sum, document))
    double X = V / H;
    double Y = (A - X) / H;
    double width = 0;

    if (Math.Pow(Y, 2) - 4 * X <= 0){
        width = Y / 2;
    }else{
        width = (Y - Math.Sqrt(Math.Pow(Y, 2) - 4 * X)) / 2;
    }
    table_columns[count_column, 0] = e.Name;
    table_columns[count_column, 1] = e.Id.ToString();
    table_columns[count_column, 2] = GetParameterInformation(h, document);
    table_columns[count_column, 3] = Math.Round(width * H, 2).ToString();
    table_columns[count_column, 4] = GetParameterInformation(vol, document);
    area_columns += width * H;
    vol_columns += double.Parse(table_columns[count_column, 4]);
    count_column++;
}
```

Figure 3. Custom C# function to calculate vertical surface area from known volume, height, and surface area using quadratic derivation in Revit.

```
#region table

table.Controls.Clear();
table.RowCount = 5;
table.ColumnCount = colcont_walls;
table.CellBorderStyle = TableLayoutPanelCellBorderStyle.Single;
table.Refresh();
int width = 100;
int height = 50;
table.Width = colcont_walls * width;
table.Height = table.RowCount * height;

for (int i = 0; i < table.RowCount; i++){
    table.RowStyles.Add(new RowStyle(SizeType.Absolute, height));
}
for (int i = 0; i < table.ColumnCount; i++){
    table.ColumnStyles.Add(new ColumnStyle(SizeType.Absolute, width));
}

for (int i = 0; i < table.ColumnCount; i++){
    for (int j = 0; j < table.RowCount; j++){
        TextBox tCell = new TextBox();
        tCell.ReadOnly = true;
        tCell.BorderStyle = BorderStyle.None;
        tCell.BackColor = System.Drawing.Color.LightBlue;
        tCell.Font = new Font("Arial", 12, FontStyle.Regular);
        tCell.Name = "Cell " + i.ToString() + " " + j.ToString();
        tCell.Text = table_walls[i,j];
        table.Controls.Add(tCell, i, j);
    }
}

#endregion
```

Figure 4. Custom C# implementation for tabulating and displaying extracted BIM data to enhance visualization and support decision-making within the Revit environment.

4.2 Test of the developed plugin

Now, by following the Filter-Extract-Derive-Schedule four-step metrology fast-track, researchers proceed directly from geometric extraction and structuring to duration estimation by using industry-standard productivity benchmarks (m^2 element/day). To suppress cross-project variance, the schedule module embeds the

reinforced-concrete frame productivity rates collated (Talbot, 2021) and executes under ISO 19650 Level-3 compliance. Furthermore, plugin trials (Figures 5–7) demonstrate that column, wall and slab heights, vertical surface areas and volumes are accurately extracted and visualised, while the resulting schedule predictions accord

with construction-management principles. Hence, the outputs provide reliable data for project planning and work sequencing, proving the tool's usefulness and consistency in real engineering settings.

Table 1. Baseline productivity

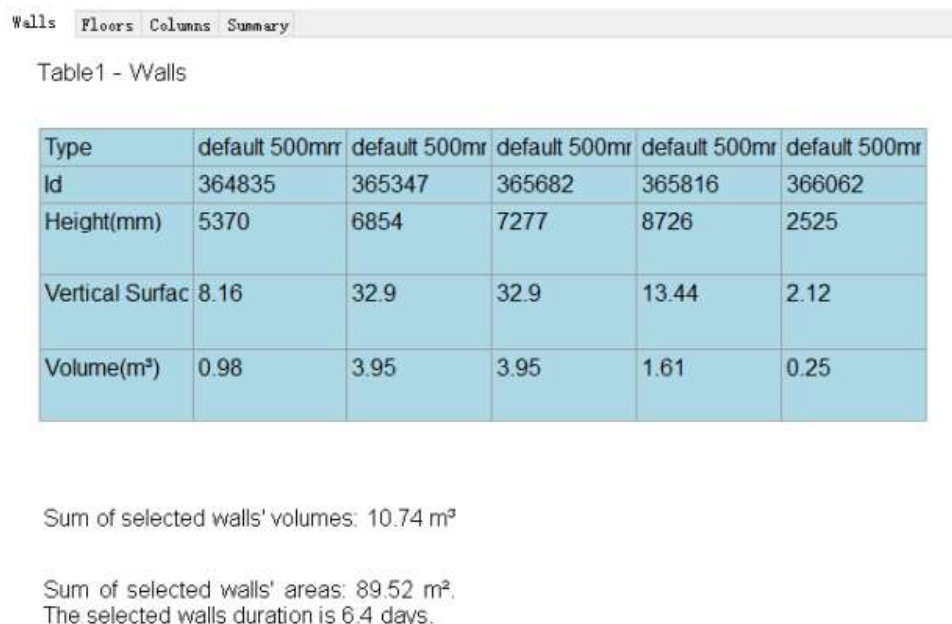
Description	Mean Value
Formwork Output	8.822 m ² /carpenter/day
Column Construction	40 m ² /carpenter/day
Wall Construction	80 m ² /carpenter/day

Having now extracted and structured the data, the schedule durations may then be determined through the application of productivity rates expressed in m² per element per day. It is noted by (Talbot, 2021) that the productivity rates used by planners to develop construction schedules are unreliable and lacking in accuracy, not only across industry but even within the same organization (Talbot & Kapogiannis, 2016). So, the baseline productivity rates in reinforced concrete frame construction were explored by Talbot (2021) and have been used to inform the baseline productivity rates used for this study, as shown in Table 1 below.

Considering both the BIM paradigm and in alignment with ISO 19650 criteria, a customized tool has been

developed by applying appropriate methods and procedures to meet the specified functional requirements. The test results are presented in figures 5-7 illustrating the successful extraction and visualization of key parameters—height, vertical surface area, and volume—for major structural elements such as walls, floors, and columns. In addition to the geometric data outputs, the construction schedule is estimated based on established principles in construction management. These estimations are derived from the extracted quantities and support practical planning and sequencing of construction activities.

Figure 5. Results of Wall Schedule and Cost



Walls	Floors	Columns	Summary
-------	--------	---------	---------

Table2 - Floors

Type	150mm	
Id	366924	
Height(mm)	150	
Horizontal Surf	27.30	
Volume(m³)	4.10	

<

Sum of floors' volumes: 4.1 m³

Sum of selected floors' areas: 27.3 m²
The selected floors duration is 0.3 days.

Figure 6. Results of Floor Schedule and Cost

Walls	Floors	Columns	Summary
-------	--------	---------	---------

Table3 - Columns

Type	500 x 500 mm	500 x 500 mm	500 x 500 mm	400 x 500 mm	500 x 500 mm	400 x 500 mm	500 x 500 mm
Id	326756	325991	326975	331556	331800	334377	334483
Height(mm)	4440	4000	4440	4440	4440	4440	4440
Vertical Surf	2.22	2	2.22	1.78	2.22	1.78	2.22
Volume(m³)	1.11	1.00	1.11	0.89	1.11	0.89	1.11

Sum of selected columns' volumes: 31.23 m³

Sum of selected columns' areas: 55.7476 m²
The selected columns duration is 6 days.

Figure 7. Results of Column Schedule and Cost

4.3. Results and Limitations

The literature review underscores the critical role of ISO 19650 in regulating information management criteria, highlighting the importance of implementing suitable technologies that adhere to established standards, methods, and procedures. ISO 19650 is a series of international standards for managing information over the whole life cycle of a built asset using building information modeling (BIM). It provides a framework for collaborative working and a structured approach to information management, ensuring that data is accurate, accessible, and reusable across the project lifecycle (BSI, 2025). Although Autodesk Revit offers numerous functions for creating and managing building information models, it cannot fully meet all modeling

requirements, both graphical and non-graphical. This is where customization becomes essential. The Revit API (Application Programming Interface) allows developers to create custom tools and extensions to enhance Revit's capabilities. This is particularly important for addressing unique project requirements that standard software functionalities may not cover. Customization through the Revit API, using Object-Oriented Programming (OOP) technologies, is crucial for enhancing project performance within the BIM paradigm. OOP languages like C# enable developers to build modular and scalable solutions that can be easily integrated into existing workflows. By developing custom add-ins, project teams can automate repetitive tasks, improve data accuracy, and enhance overall productivity, thus aligning with the efficiency goals of ISO 19650 (Autodesk, 2021).

A limitation of this study lies in the calculation and presentation of column surface areas (figure 3-5). The tabulated data represent the surface area of a single column face rather than the full external surface area, which may cause misinterpretation. For symmetrical sections, such as a 500 × 500 mm column, the value of 2.22 m² corresponds to one face ($0.5 \times 0.5 \times 4.44 = 2.22 \text{ m}^2$), while the actual surface area across all four faces is 8.88 m². The issue is more significant for non-symmetrical columns (e.g., 400 × 500 mm), where faces differ in size. In this case, calculation of 0.888 m² per 400 × 500 face does not align with the 1.78 m² reported in the table. This discrepancy suggests a potential inconsistency in the computational method or source code implementation (C#). Consequently, the accuracy of the surface area values for non-symmetrical sections requires further verification.

4.4. Findings and critical analysis

Applying Project Information Requirements (PIRs), as specified under ISO 19650, into executable software modules through a structured object-oriented framework using Autodesk Revit API and C#. A modular four-step architecture: Filter-Extract-Derive-Schedule (FEDS) was developed to encapsulate the full BIM-to-schedule workflow. Within this framework, the Filter-Extract class performs batch acquisition of geometric data for the three most common cast-in-place concrete elements (columns, walls, and slabs), embedding a consistent rule for the deduction of opening areas. This ensures topological integrity and metric consistency in the extracted input data. In particular, the Derive class implements a closed-form quadratic solver that computes missing dimensions (width and length) at runtime based on known volume, height, and surface area parameters. This enables the immediate and model-native calculation of vertical surface areas such as a capability not natively available in

Revit's schedule functions without external data exports

or manual formulas (Figure 8).

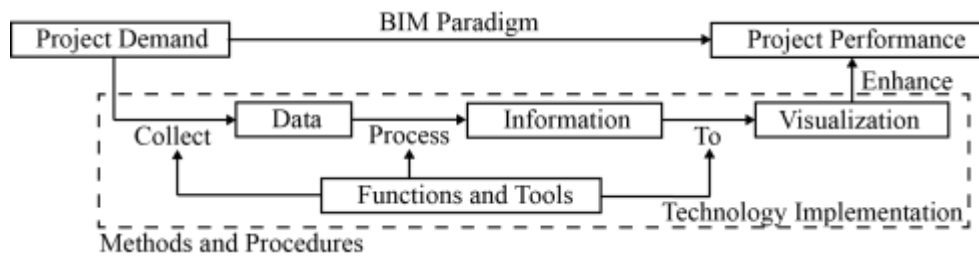


Figure 8. Mind Map From Methods and Procedures to Technology

Moreover, the schedule class links these calculated net surface areas with industry-recognized productivity benchmarks (e.g. 40 m²/day for columns, 80 m²/day for walls, 8.8 m²/day for slabs) so to generate duration datasets that meet the auditing requirements outlined in Asset Information Requirements (AIR). Therefore, a high-cohesion, low-coupling design principle governs the architecture: each class exposes services through public interfaces, enabling thus plug-and-play deployment across different project contexts and Revit versions. Henceforth, this unique approach ensures long-term scalability, maintainability, and compliance adaptability, offering a robust technical foundation for iterative enhancement and multi-project implementation.

4.5. Validation and Comparison with other solutions in the market

Field tests and pilot deployments of the plug-in validate the feasibility and robustness of the FEDS framework under real-world project conditions. When ISO 19650's SMP (Standards-Methods-Procedures) specifications are operationalised through the FEDS workflow, the often-perceived trade-off between standardisation and flexibility is effectively resolved. All computations are executed within the same Revit model environment, eliminating the need for external transfers to Excel or third-party platforms. This integrated approach significantly reduces common sources of project risk, such as data loss, version mismatches, and manual transcription errors.

Furthermore, the plug-in supports real-time iteration throughout the design lifecycle. Teams can refresh "geometry-quantity-duration" datasets instantaneously, allowing for audit-ready outputs and proactive identification of resource constraints and schedule bottlenecks (Liu & Issa, 2012; Liu, Al-Hussein, & Liu, 2015). This contributes not only to improved schedule accuracy but also to greater transparency and traceability in project delivery.

In more detail, to formalize validation and respond to reviewer concerns, the study defined clear Key Performance Indicators (KPIs) accuracy, time saved, and error rates—based on reproducible measurement protocols (Talbot & Kapogiannis, 2016) as also Kapogiannis and team identified in their paper (Kapogiannis & Alkhard, 2021). Accuracy was calculated as the percentage deviation between extracted/scheduled values and baseline audited quantities, ensuring geometric and schedule fidelity. Time saved was measured by recording task completion times across manual, Revit default, plugin, and commercial workflows, with results expressed as percentage reduction relative to manual baselines. Error rates were defined as the proportion of incorrect or missing outputs compared to total outputs checked, with thresholds set at >1% deviation for quantities and >0.5 day deviation for durations. Sampling included symmetrical and nonsymmetrical columns, walls with and without openings, and slabs of varying thickness, repeated across multiple project models to suppress crossproject variance. Controls ensured consistent openingdeduction rules, uniform productivity rates (Talbot, 2021), and fixed crew assumptions across all methods. Replication (3–5 runs per task) and aggregation (median values with ranges) were used to ensure robustness, while discrepancies in column surface area calculations were noted as a limitation requiring further verification of source code implementation.

<< Table 2 >>

See formulas in Appendix I

Moreover, based on the above, the current validation, while demonstrating clear gains in accuracy, efficiency, and reliability, remains limited in scope as it focuses only on columns, walls, and slabs within reinforced-concrete frames, with small-scale test cases that do not capture the full diversity of industry practice. However, benchmarking against commercial 4D/BIM scheduling platforms such as Synchro or Navisworks Manage was constrained by licensing and interoperability issues, and discrepancies in column surface area calculations

particularly for non-symmetrical sections suggest the need for further verification of computational methods and source code implementation. Moreover, reliance on baseline productivity rates (Talbot, 2021) may not reflect regional or organizational variations, and time-saved KPIs were measured under controlled conditions that may differ in real-world practice. That means, broader validation across additional structural elements, multi-project datasets, diverse practitioner groups, and systematic comparisons with commercial tools will be required to confirm robustness and generalizability.

5. Discussion

This study demonstrates that achieving high-precision quantity take-off and construction scheduling in complex AEC projects requires an effective synthesis of tool customisation and standards compliance (Doukari et al., 2013). While ISO 19650 provides a robust framework for information management, its practical implementation demands context-aware digital tools. The proposed Filter-Extract-Derive-Schedule (FEDS) workflow presents a viable response to this challenge by embedding standardised procedures within a modular, automation-ready Revit plug-in architecture similar to what Kim in 2013 proposed as an idea (Kim, Kim, & Son, 2013) but now is implemented through this unique approach.

The FEDS process offers several operational advantages. The Filter-Extract module introduces a unified rule set for opening-area deduction, ensuring geometric consistency across model elements such as columns, walls, and slabs. The Derive module fills a critical gap in Revit's default capabilities by calculating vertical surface areas through a closed-form quadratic solver, eliminating the need for external scripts or manual computation. The schedule module aligns net quantities with industry-standard productivity rates to automatically generate auditable task durations. This end-to-end workflow encapsulated as a high-cohesion, low-coupling class library satisfies SMP requirements for traceability while preserving the extensibility and modularity typical of object-oriented programming. In doing so, it demonstrates that standards compliance and functional customisation are not mutually exclusive but can be harmonised within a well-structured technical design.

However, the transition from conceptual workflow to practical deployment is not without barriers. The implementation of ISO 19650 often necessitates a reconfiguration of organisational information flows an effort that can be particularly burdensome for small and medium-sized enterprises (SMEs) lacking dedicated software teams or long-term maintenance budgets. While

the FEDS plug-in streamlines repetitive modelling and scheduling tasks, it introduces new dependencies on user understanding of mathematical logic (e.g. quadratic derivations) and schedule calibration methods. Initial training and upskilling are likely required to ensure accurate and consistent use across teams. Furthermore, differing interpretations of vertical surface area among designers, planners, and quantity surveyors may generate discrepancies in early-stage coordination. Such risks highlight the importance of shared visual outputs, clear documentation, and iterative reconciliation workflows to establish a common understanding of derived data across disciplines.

To extend the impact and generalisability of the FEDS approach, three key development directions are identified. First, the Filter-Extract module will be expanded to accommodate additional structural elements such as beams, foundations, and prefabricated assemblies. Integration with parametric design tools will also be explored to support more flexible modelling scenarios. Second, the derive module will incorporate Monte Carlo simulations, replacing static productivity values with probability distributions to better capture uncertainty in schedule forecasting. The researchers were inspired by Huang's work (Huang, Chen, & Sun, 2004) back in 2004 and try to take Wang's and team integration process (Wang et al., 2014) to become more automated. Third, enhanced data interoperability will be prioritised: schedule outputs will be designed for seamless integration with platforms such as Primavera P6 and Microsoft Project, enabling full 4D/5D collaboration across software ecosystems (Kim, Yu, & Kim, 2012).

Ultimately, the FEDS workflow and its supporting plug-in provide more than just a productivity boost, they lay the groundwork for a broader transition in AEC project delivery. By enabling auditable, real-time translation of BIM geometry into construction-ready quantities and durations, the system promotes a shift from document-based compliance to data-driven decision-making. Continuous feedback from end users and monitoring of key performance indicators (KPIs) will be essential to evolving the plug-in from a project-specific tool into a general-purpose middleware for smart quantity take-off and schedule management (Kim et al., 2013).

Table 3. summarises the key contributions, practical implications, implementation challenges, and proposed future enhancements of the research. It serves as a high-level synthesis of the findings and offers actionable insights for both industry practitioners and academic researchers aiming to operationalise BIM standards through custom technical solutions. Building on these

insights, Table 4 outlines an eleven-step roadmap for implementing customized BIM tools in alignment with ISO 19650 and the SMPT framework. The roadmap translates theoretical constructs into actionable stages from initial adoption of standards and structured information management, through to Revit add-in development, integration, evaluation, and continuous improvement. This stepwise approach ensures that digital solutions are not only technically sound but also embedded within broader project governance and quality assurance systems. It also creates a foundation for future research and technological innovation by defining clear

checkpoints for feedback, iteration, and strategic development.

Collectively, these tables serve as practical guides for organisations aiming to move from document-based compliance toward truly data-driven project delivery. By reinforcing the interplay between standards, methods, procedures, and technology, they support a more deliberate and sustainable approach to BIM-enabled digital transformation in the AEC industry.

Table 2. Summary of key factors affecting BIM implementation, including findings, implications, challenges, and critical analysis related to ISO 19650, Revit, and customization using OOP.

Aspect	Findings	Implications	Challenges	Critical Analysis
ISO 19650 Implementation	Regulates information management, ensures data accuracy and accessibility	Provides a structured approach for collaborative working and information management throughout the project lifecycle	Requires significant cultural shift, extensive training, and adoption of new technologies	Adoption varies across regions and project types; smaller firms may challenge with initial investment
Autodesk Revit	Widely used for BIM but has limitations in meeting all modeling requirements	Enhances project performance through modeling, supports standard BIM practices	Customization necessary to address unique project needs, reliance on SDK and API	Developing custom add-ins requires specialized programming knowledge; maintaining compatibility with Revit updates is costly
Customization via Revit API	Allows creation of custom tools and extensions using OOP technologies	Enables automation of repetitive tasks, improves data accuracy, enhances productivity, aligns with ISO 19650	Development process is time-consuming and resource-intensive	OOP's modularity and scalability are advantageous, but transition from POP can be challenging for some teams
Object-Oriented Programming (OOP)	Provides modular, reusable, and scalable solutions	Efficient tool development for specific project needs, better management and optimization of complex data structures	Requires proficiency in OOP principles and patterns, increased development time and costs	OOP promotes reusability and modularity, but the transition can demand significant training and adaptation
Standards, Methods, Procedures	Critical for effective information management within BIM framework	Ensures consistent and efficient information management practices, aligns with best practices,	Continuous monitoring and adaptation required for compliance	Interpretation and application can vary among stakeholders, necessitating clear communication and collaboration

		facilitates better decision-making and collaboration		
Customized BIM Tools	Developed via Revit API to address specific project needs in quantification, scheduling, and cost estimation	Tailored solutions enhance project performance, address unique challenges not covered by standard BIM software	Misalignment with project needs can lead to inefficiencies, significant training and support required for integration	Custom tools must be rigorously tested, the development process is iterative and resource-intensive
Compliance with ISO 19650	Ensures all information management practices adhere to established criteria and protocols	Maintains high-quality project delivery, ensures accurate and consistent information throughout the project lifecycle	Continuous compliance monitoring needed, potential conflicts and inconsistencies among stakeholders	Essential for maintaining information management standards, requires clear communication and collaboration among all participants
Research Implications	Highlights need for customized BIM tool development, underscores role of ISO 19650, demonstrates value of OOP technologies	Guides strategic technology adoption, promotes continuous learning and adaptation, supports high-quality project outcomes	Requires ongoing commitment to professional development and industry collaboration	Strategic approach to technology adoption is crucial, continuous evolution and adaptation necessary for competitive advantage

Table 3. Structured steps for implementing customized BIM tools aligned with ISO 19650 and SMPT principles.

Step	Description	Outcome
1. Adoption of ISO 19650 Standard	Establish the overarching framework for managing information across the lifecycle of built assets.	Ensures data accuracy, accessibility, and reusability.
2. Structured Information Management (IM)	Implement a structured approach to information management under ISO 19650.	Facilitates collaborative working and effective data handling.
3. Development and Implementation of SMP	Establish and adhere to unified processes and procedures.	Reduces errors and enhances data reliability.
4. Assessment of Project Requirements	Conduct a thorough assessment of project-specific needs and requirements.	Clear understanding of project demands and objectives.
5. Customization via Revit API and OOP Technologies	Develop custom tools and extensions using Revit API and OOP technologies (e.g., C#).	Address unique project requirements, automate tasks, improve accuracy, and enhance productivity.
6. Development of Revit Add-Ins	Implement add-ins tailored to specific project needs in quantification and scheduling.	Customized solutions that improve project performance and streamline workflows.

7. Compliance with SMP and ISO 19650 Criteria	Ensure that all developed tools and processes adhere to established standards.	Consistent, accurate, and compliant information management practices.
8. Implementation of Customized BIM Tools	Integrate the customized Revit add-ins and BIM tools into the project workflow.	Enhanced project efficiency, accuracy, and collaboration.
9. Continuous Monitoring and Adaptation	Monitor the performance of implemented tools and processes, and adapt as needed.	Maintain high-quality project delivery and continuous improvement.
10. Evaluation and Feedback	Evaluate the effectiveness of customized solutions and gather stakeholder feedback.	Identify areas for further improvement and ensure stakeholder satisfaction.
11. Future Research and Development	Explore new technologies and methodologies to enhance BIM project performance.	Drive innovation and maintain competitive advantage in the AEC industry.

Henceforth, our research contribution represents not just a technical improvement but a paradigm shift, moving from external scripting to native embedded automation, from fragmented rules to unified geometric logic, from approximations to closed-form mathematical rigor, from manual linking to automated scheduling integration, and from ad hoc workflows to standards-compliant, audit-ready pipelines as Mikuliva (Mikulakova et al., 2010) highlights in the work published back in 2010. Hence, this integration of novelty, process efficiency, and standards alignment establishes the innovation of the proposed workflow, positioning it as a significant advancement with impact across both academic research and industry practice.

6. Conclusions

This study demonstrates that embedding Standards, Methods, Procedures, and Technology (SMPT) within BIM workflows can substantially enhance information quality and collaborative efficiency. The proposed “Filter–Extract–Derive–Schedule” fast-track, implemented as a Revit Add-In compliant with ISO 19650 Level 3, addresses a critical gap in native scheduling by enabling automated extraction of solids, precise derivation of vertical surface areas, and integration with industry productivity rates for audit-ready duration outputs. This structured approach delivers an instantaneous, reproducible “geometry–quantity–duration” decision view, confirming the feasibility and scalability of an SMPT-oriented roadmap for digital delivery in the AEC sector.

The current prototype is limited to concrete columns, walls, and slabs, and does not yet encompass the full asset life cycle. Future research should:

Extend the workflow to additional elements such as beams and foundations, and incorporate operations-and-maintenance phases;

Develop cross-platform interoperability interfaces;

Build an empirically validated productivity database to enable dynamic probabilistic scheduling.

Iterative refinement of the Filter–Extract–Derive–Schedule modules, combined with multi-disciplinary and multi-project validation, will accelerate the transition toward a more intelligent, standardised, and efficient digital delivery paradigm in the AEC industry.

7. Recommendations for Industry

On this ground, industry will utilise the proposed SMPTembedded “Filter–Extract–Derive–Schedule” workflow by operationalising BIM models as a governed, repeatable decision engine that converts model geometry into traceable quantities and audit-ready durations for faster 4D planning, programme assurance, and collaborative control—publishing a consistent “geometry–quantity–duration” snapshot through CDE-based workflows that align with ISO 19650’s lifecycle information management principles (requirements definition, container control, versioning, and information quality) and, over time, extending this capability into the operational phase via Asset Information Model (AIM) practices described in ISO 196503. Next, to make the approach scalable and industry-ready, the solution needs a broader element and trade coverage beyond concrete

(e.g., beams, foundations, then MEP/finishes). Moreover, an formalised information quality gates and governance embedded in EIR/PIR/AIR and CDE publishing processes alongside cross-platform interoperability outputs (e.g., openBIM-aligned exchanges) aiming to avoid single-platform dependency. Finally, an empirically validated, governed productivity-rate library that can evolve from deterministic rates to probabilistic ranges for risk-based scheduling—validated through multi-project, multi-disciplinary pilots and packaged as a maintainable, deployable add-in for consistent enterprise adoption.

Acknowledgments

The team would like to thank Mr Haobo Jiang, postgraduate student at the University of Nottingham for his valuable contribution in the development of this API.

Authors' contribution

Dr. Georgios Kapogiannis (GK), Dr. Tianlun Yang (TY), and Dr. Michael Gerges (MG) contributed to the development of the methodology and performed the analysis and contributed to the writing. Dr. Bary Talbot (BT) contributed to the conceptual review and provided industry insights plus the mathematical aspects of the research paper. Dr. Nikolaos Reppas (NR) was responsible for formatting, abstract writing, and the analysis of the results. Antonios Mytilinaios (AM) and Bilal Manzoor (BM) contributed to review the paper. Special thanks for the final editing to Mr Kheder Alothman.

Supplementary data

The authors confirm that the supplementary data are available upon request.

Data Availability Statement

All data generated and analysed during this study are contained within the dissertation document, including tables, figures and appendices. No separate dataset or solution file exists beyond what is presented in this manuscript. Due to the qualitative nature of the research and participant confidentiality requirements, raw data are not publicly accessible. This dissertation has been submitted to the University of Nottingham Ningbo China institutional repository in accordance with the University's open access policy.

Conflicts of interests

We can confirm that there are no any potential conflict(s) of interest like employment, consulting fees, research contracts, stock ownership, patent licenses, honoraria, advisory affiliations etc.

Ethical statement

This study did not involve any human participants or animal subjects and therefore did not require ethical approval. No experiments involving humans or animals were conducted, and no identifiable personal data were used. As such, ethics committee or institutional review board approval was not required for this research.

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