Development of an Automated Workflow for Reinforced Concrete Structural Quantity Takeoff and Cost Estimation Using Visual Programming in a BIM Environment

Waraphong Saenpaeng[1],*, Suradet Tantrairatn[2] and Aphai Chaphirom[3]
[1] *School of System Engineering, Institute of Engineering, Suranaree University of Technology University Avenue, Muang, Nakhon Ratchasima, 30000, Thailand*
[2] *School of Mechanical Engineering, Institute of Engineering, Suranaree University of Technology, University Avenue, Muang, Nakhon Ratchasima, 30000, Thailand*
[3] *School of Civil Engineering, Institute of Engineering, Suranaree University of Technology University Avenue, Muang, Nakhon Ratchasima, 30000, Thailand*
***Corresponding Author Email:** m6600822@g.sut.ac.th
Received: May 19, 2025; **Revised:** Aug 31, 2025; **Accepted:** Sep 08, 2025

Abstract

In the construction industry, traditional quantity takeoff (QTO) methods still rely on manual measurement from 2D drawings, which are time-consuming, prone to human error, and difficult to verify. As Building Information Modeling (BIM) adoption grows, especially following the release of national BIM standards in 2020, there is increasing interest in developing automated and data-driven workflows to improve the accuracy and efficiency of material quantity estimation. This study proposes an integrated workflow for the automated quantity takeoff and cost estimation of reinforced concrete structures using BIM and visual programming. The workflow leverages Dynamo in Autodesk Revit to extract structured rebar and concrete data from BIM models, which is then exported to Excel using VBA macros for sorting and cleaning data and visualized in Power BI dashboards. A case study of a 7-story residential building demonstrates the application of the proposed workflow. Results show a significant reduction in processing time from several hours using manual Revit QTO to just a few minutes while maintaining high accuracy, standardization, and traceability. The dashboard allows multi-dimensional analysis by material type, structural component, and building floor, supporting effective decision-making in construction cost management. The findings point out the prospects for scalable deployment of this workflow in digital construction environments.

Keywords: BIM, Visual Programming, Quantity Takeoff, Cost Estimation, Data Visualization

1. Introduction

Accurate quantity takeoff (QTO) is a critical aspect of budgeting, procurement, and scheduling in construction projects. Traditional methods relying on manual quantity extraction and 2D plans are inefficient and prone to repetitive errors [1–2]. Currently, the use of Building Information Modeling (BIM), particularly through parametric 3D modeling, increases the potential to improve these processes. However, accurate material quantity takeoff in the context of real-world projects remains a challenge, especially in terms of creating sustainable and reusable digital tools.

BIM technology is recognized as an important tool for addressing these issues. BIM helps create 3D building models on computers, allowing for the detection of problems before actual construction, and enhancing project management capabilities such as accurate material quantity calculation, conflict checking in designs, and systematic data management. In Thailand, BIM has been used since 2012, especially in project design and planning. The release of BIM standards by the Engineering Institute of Thailand in 2020 has helped create a framework for BIM application that is appropriate for the national context.

Dynamo, an extension of Autodesk Revit in the form of visual programming, has become an important tool for automatically extracting data from BIM models and linking it to Excel for further processing, as well as displaying it in dashboard format through Power BI for effective cost analysis [1–2].

Despite these advancements, there remain several challenges related to model accuracy, data integrity, and interoperability that need to be addressed through further research to improve the accuracy and reliability of QTO using BIM [2].

Another technology playing a role in the digital age is Business Intelligence (BI), which helps analyze large datasets and transform them into information that supports accurate and rapid strategic decision-making. Using BI, such as creating a dashboard to communicate construction cost data, allows managers to track progress and manage project budgets effectively [3]. Digregorio emphasizes the application of BI with BIM for real-time data management [4], and Zawada et al. proposed the concept of integrating BIM with Industry 4.0 technologies to meet modern project management needs sustainably [5].

This research aims to integrate BIM and BI to develop a new approach for material quantity takeoff, specifically applying Dynamo to extract reinforced concrete structure data, export it to Excel files, and analyze costs using Power BI. This is combined with automating workflows through Power Automate

Desktop to reduce errors, increase speed, and support decision-making in construction projects.

2. Literature Review

2.1 Concepts and Developments in Building Information Modeling (BIM)

The concept of Building Information Modeling (BIM) was first articulated by Eastman in 1975 and has since evolved into a foundational paradigm in the architecture, engineering, and construction (AEC) industry. BIM represents a digital process that integrates both geometric and semantic data, enabling the generation and management of information throughout the project lifecycle. According to the Royal Institute of British Architects (RIBA), BIM facilitates collaborative workflows by storing and sharing building data in a Common Data Environment (CDE), thereby enhancing interoperability across disciplines [6].

BIM maturity levels, initially defined by the UK government, describe the progression from Level 0 (2D CAD drawings) to Level 3 (integrated models with real-time collaboration). BIM has also expanded into multi-dimensional frameworks: 3D (geometry), 4D (scheduling), 5D (cost estimation), 6D (sustainability), 7D (facility management), 8D (safety), 9D (lean construction), and 10D (industrialized methods) [7].

The concept of Level of Development (LOD) further provides a standardized schema for assessing the granularity of BIM elements, ranging from LOD 100 (conceptual massing) to LOD 500 (as-built specifications). For structural QTO, LOD 350 is critical, as it provides sufficient detail to support clash detection and coordinated detailing.

2.2 ISO 19650 and Data Management Frameworks

ISO 19650 is a globally recognized series of standards that govern the organization and digitization of information in BIM-based processes. The framework—comprising ISO 19650-1 (concepts), 19650-2 (delivery), 19650-3 (operations), and 19650-4 (quality control)—provides a robust methodology for managing information across project phases [8–11].

The standard emphasizes the articulation of Information Requirements, including Organizational (OIR), Asset (AIR), Project (PIR), and Exchange Information Requirements (EIR), which inform the creation of Project Information Models (PIM) and Asset Information Models (AIM). A pivotal component of ISO 19650 is the CDE, structured into Work-in-Progress, Shared, Published, and Archived states. This structure enhances traceability, reduces rework, and supports data validation protocols outlined in ISO 19650-4. The latter introduces six quality dimensions conformance, continuity, communication, consistency, completeness, and CDE compliance that are increasingly being embedded into automated validation scripts through visual programming [12].

In this research, ISO 19650 principles underpin the entire workflow: from data extraction in Revit, processing in Dynamo, quality assurance through rule-based checks, to visualization in Power BI. This integration exemplifies the practical application of standardized information management in the architecture, engineering, and construction (AEC) context.

2.3 BIM-Based Material Takeoff: Accuracy, Limitations, and Comparative Studies

Traditional QTO from 2D drawings is labor-intensive and error-prone. BIM enables object-based modeling, where each element (beams, columns, slabs) encapsulates material, geometric, and cost-related metadata. This supports automated and dynamic QTO, enhancing traceability and reducing human error [3].

Recent studies have confirmed the benefits of BIM-based QTO:

- Valinejadshoubi et al. demonstrated a 10% reduction in required rebar following design changes, attributed to real-time QTO updates [2].
- Cepni & Akcamete established a correlation between higher LOD (especially LOD 350–400) and the precision of formwork takeoff [1].
- Pimchanok et al. found that integrating BIM in Thai construction projects led to a 17% reduction in steel waste due to optimized planning [13].

However, BIM-QTO results are highly dependent on model completeness and parameter consistency. Errors in rebar modeling, inconsistent parameter naming, and absence of standardized data formats undermine accuracy [3]. Consequently, auxiliary tools—rule-based Dynamo scripts, external Excel integrations, and visual dashboards—have been developed to validate and supplement BIM-QTO processes.

To provide a comprehensive overview, **Table 1** contrasts prior BIM-based RC QTO workflows in terms of structural coverage, parameter/data management, toolchains, and limitations. The synthesis underscores that while prior works improved accuracy and efficiency, they seldom established standardized ISO 19650–aligned parameter schemas or fully automated workflows. These shortcomings highlight the originality of the present study, which integrates ISO-compliant parameterization, CDE-driven data management, and end-to-end automation through Dynamo and Power Automate Desktop.

Table 1 Prior BIM/RC QTO Workflows versus the Present Study

Study	Objective / Scope	RC Structural Coverage	Parameter & Data Management	Workflow / Tools	Reported Benefit	Limitations
[2]	Automated BIM-QTO framework	Concrete + limited rebar	Basic Revit parameters	BIM → verification module	Faster QTO; accuracy check module	No ISO 19650 integration; CDE not emphasized
[1]	Automated formwork & RC QTO	Columns, beams, formwork	Custom Revit parameters	Revit + Dynamo scripts	Time efficiency: complex geometry handled	Validation ad hoc; no systematic parameter schema
[13]	BIM for RC QTO & Bar-Cut List planning	Foundations, beams, columns (reinforcement)	Revit native parameters; no ISO schema	Revit (manual planning of Bar-Cut List)	Reduced rebar wastes up to 17%; supports planning and Shop Drawing	
[17]	BI for cost data visualization	Project-level cost breakdown	BI-centric, no ISO-linked schema	Power BI dashboards	Improved decision-making	BIM-to-BI link not automated; manual data prep
[1–4],[13]	CAD vs BIM QTO (RC)	Reinforcement & concrete quantities	Conventional CAD/BIM attributes	Manual CAD schedules vs Revit QTO	Showed BIM advantage in accuracy	Limited to dataset comparison; no automation chain
This Study (present)	Integrated ISO 19650–aligned RC QTO automation	RC structure (concrete, formwork, reinforcement)	Standardized parameter schema; CDE compliance	Revit (LOD 350) → Dynamo → Excel → PAD → Power BI	End-to-end automation; ISO 19650 QA; versioning and real-time cost tracking	Scope limited to RC; generalization needs multi-project validation

Note: QTO = Quantity Takeoff; RC = Reinforced Concrete; CDE = Common Data Environment; LOD = Level of Development; QA = Quality Assurance; PAD = Power Automate Desktop; BI = Business Intelligence.

2.4 Explicit Research Gap

Despite the considerable progress achieved through BIM-based quantity takeoff (QTO) research, critical shortcomings remain that limit the reliability, scalability, and integration of current workflows particularly for reinforced concrete (RC) structures. A synthesis of prior studies (**Table 1**) highlights the following deficiencies:

- **Parameter and schema inconsistency:** Most previous workflows rely on native or ad hoc Revit parameters without alignment to ISO 19650 standards. The absence of standardized parameter schemas leads to inconsistent data capture, limited interoperability, and difficulties in downstream analysis.
- **Lack of CDE-driven data management:** Although BIM environments emphasize collaborative information sharing, few studies have operationalized Common Data Environment (CDE) protocols to structure and validate QTO data. This omission undermines traceability, version control, and data reliability across project stakeholders.
- **Simplification of RC and rebar complexities:** Reinforcement modeling presents unique challenges such as hooks, laps, and splice rules that are often simplified or excluded in automated QTO workflows. Consequently, results fail to capture the actual procurement and construction realities of RC projects.
- **Limited validation of accuracy and completeness:** Many studies report improvements in efficiency or reductions in waste, but validation is typically case-specific, lacking systematic, repeatable benchmarking against baseline BIM schedules or procurement data. This restricts confidence in applying these methods to larger or more diverse projects.
- **Incomplete automation across platforms:** Prior workflows have improved data extraction within BIM tools (e.g., Revit, Dynamo) and visualization within BI platforms (e.g., Power BI). However, most stop short of delivering end-to-end automation that integrates data flow seamlessly from modeling, through parameter validation, to cost visualization and decision support.

Addressing these gaps, the present study contributes an ISO 19650–aligned, CDE-compliant, and fully automated RC QTO framework. The workflow integrates Revit (LOD 350 modeling), Dynamo (rule-based parameter checks), Excel (unit-cost linkage), Power Automate Desktop (automation of data handling), and Power BI (analytics and dashboards). This design ensures not only efficiency and accuracy but also traceability, reproducibility, and compliance with international standards—offering a structured solution that surpasses the fragmented approaches observed in prior research.

2.5 Visual Programming with Dynamo for Quantity Takeoff Automation

Visual Programming with Dynamo for Quantity Takeoff Automation

Dynamo is a node-based visual programming platform embedded within the Revit ecosystem. It enables users—particularly non-programmers—to construct logic-driven workflows for data extraction, transformation, and integration [14]. Dynamo's extensibility has made it a preferred tool for developing customized QTO modules, especially in complex structural projects.

Several use cases illustrate Dynamo's efficacy:

- Quantity Precision Check (QPC) Modules, as implemented by Valinejadshoubi et al., flagged up to 39% of data inconsistencies in wall elements [2].
- Formwork QTO workflows, developed by Cepni et al., automated takeoff for non-orthogonal geometry (e.g., inclined columns), with accuracy verified against manual counts [1].
- External Data Integration, where Dynamo synchronizes Revit parameters with Excel-based databases, enables dynamic cost updating an essential feature for real-time budget control.

In the present study, Dynamo scripts automate rebar quantity extraction based on structural categories and floor levels, perform unit conversions and material classification, and feed this data into Excel for cost analysis.

2.6 Business Intelligence (BI) for Construction Data Visualization

Business Intelligence (BI) tools, particularly Microsoft Power BI, play a critical role in transforming raw BIM data into actionable insights. BI encompasses data warehousing, Online Analytical Processing (OLAP), and interactive dashboards, which support multi-dimensional analysis for project monitoring [15–16]

In construction contexts, BI enhances decision-making by:

- Allowing dynamic cost breakdown by floor, structural type, or material.
- Enabling version control and historical tracking of QTO changes.
- Supporting cross-functional collaboration through shared dashboards.

Golestanizadeh et al. emphasize that BI is not merely a technical layer but a strategic enabler of organizational learning and continuous improvement. [17] The current research builds on this premise by linking Dynamo-generated Excel data with Power BI dashboards, thereby enabling real-time visual tracking of material quantities and costs.

3. Research Methodology

This research follows an applied research design aiming to develop an automated cost estimation tool through visual programming integrated with Building Information Modeling (BIM). The core objective is to automate the workflow from model-based quantity takeoff to cost analysis using a structured and standardized pipeline composed of BIM modeling, visual programming (Dynamo), data processing (Excel VBA), business intelligence tools (Power BI), and automation via Power Automate Desktop.

3.1 Research Design

The research commenced with a comprehensive literature review to survey related academic publications, industry standards, and practical applications of BIM-based cost estimation.

Key areas of focus included:

- Integration of BIM and visual programming for quantity takeoff
- Use of Dynamo for parametric data extraction
- Standardization based on ISO 19650 for CDE-based information management
- Classification systems including UniFormat, MasterFormat, and OmniClass
- ACI 318-19 standards for rebar modeling and lap splice definitions

The case study was conducted using a 7-story reinforced concrete residential building. The Revit model includes structural components such as foundations, columns, beams, slabs, staircases, and shear walls. Structural classification codes were assigned using three schema fields in Revit: Assembly Code (UniFormat), Keynote (MasterFormat), and OmniClass Number.

3.2 Workflow Development

BIM Modeling: Using Autodesk Revit 2024, the researcher modeled structural components with precise dimensions and assigned metadata such as bar diameter, concrete grade, and lap splice length based on ACI 318-19. The structural framework of the building model developed in Autodesk Revit is illustrated in **Figure 1**, which represents the reinforced concrete structural system used for this study.

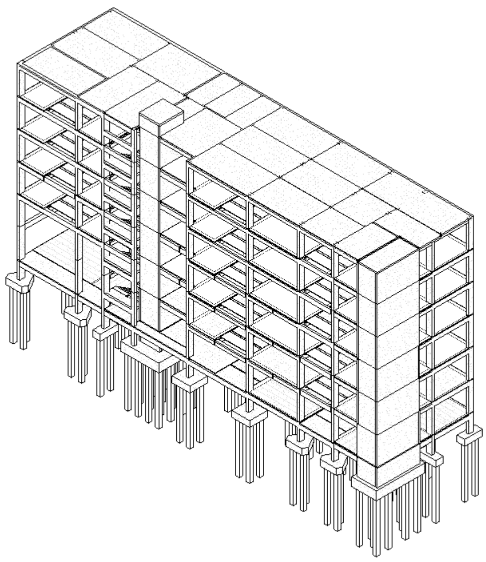

Figure 1 Structural BIM model in Revit

The placement of reinforcement steel within structural components is depicted in **Figure 2**, showing how rebar elements are embedded in beams, columns, and slabs.

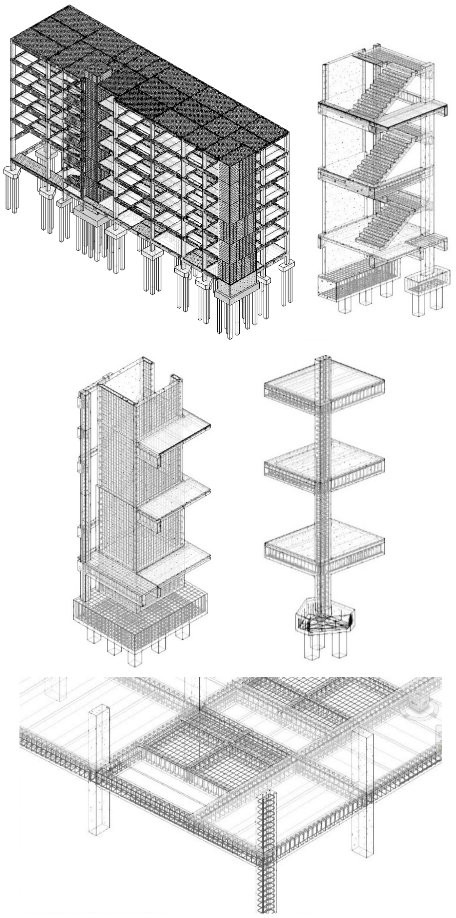

Figure 2 Reinforcement steel rebar in host elements.

Figure 3 presents the instance properties of structural rebar in Autodesk Revit, categorized by construction, structural, and dimensional data used for quantity takeoff automation. This picture shows the hierarchy of parameters for the structural reinforcement element (DB16) in Autodesk Revit. The properties are fundamental for data extraction in the BIM-based quantity estimation process.

Key parameters include: Construction: key identities and geometries, such as segmentation (e.g., FS40-2); and shapes (e.g., M_17), which are crucial for separating rebar sets. Classification by partition in the Dynamo script (**Figure 3(a)**).

Structure and dimensions: Collect volumetric and dimensional data (e.g., length of bars and total length of bars) that are important for cost estimation and structural integrity analysis (**Figure 3(b)**).

Identity and host information: Includes metadata such as host numbers, host markers, and base levels that specify the location and grouping of rebar structures in the building model, which are essential for layer grouping and procurement (**Figure 3(c)**).

The proposed workflow omits a separate Bar Cut List because all dimensional parameters of each rebar instance are fully defined within the BIM model, in compliance with ACI 318-19. In Revit, each rebar element stores standardized properties under the *Dimensions* group, including:

- **Bar Length**: Actual length of each rebar, including bends and lap splices.
- **Total Bar Length**: Product of bar length and quantity, essential for weight and cost calculation.
- **Shape Parameters (A–R)**: Segmented lengths based on the assigned bar shape (e.g., M_17), corresponding to standard shape definitions.

These embedded parameters act as a digital Bar Cut List with greater precision and adaptability. Since each bar is linked to its host element (e.g., FS40-2) with metadata such as *Host Number*, *Partition*, and *Structural Level*, the workflow maintains traceability and supports model-based classification, extraction, and analysis.

Thus, the decision to exclude a separate Bar Cut List table is methodologically justified: the rebar geometry is embedded and extracted programmatically via Dynamo, eliminating redundancy and ensuring consistency with LOD 350 modeling and international detailing standards.

In Autodesk Revit 2024, it involves modeling the components of reinforced concrete parts. This not only includes geometric precision but also detailed embedded data management that defines the semantic context of each object. These parameters are the foundation for subsequent tasks such as Automatic quantity calculations, pricing, updating visual programming environments such as Dynamo, etc. The properties of types in reinforced concrete elements (see **Figure 4**), which can be organized into the following general categories.

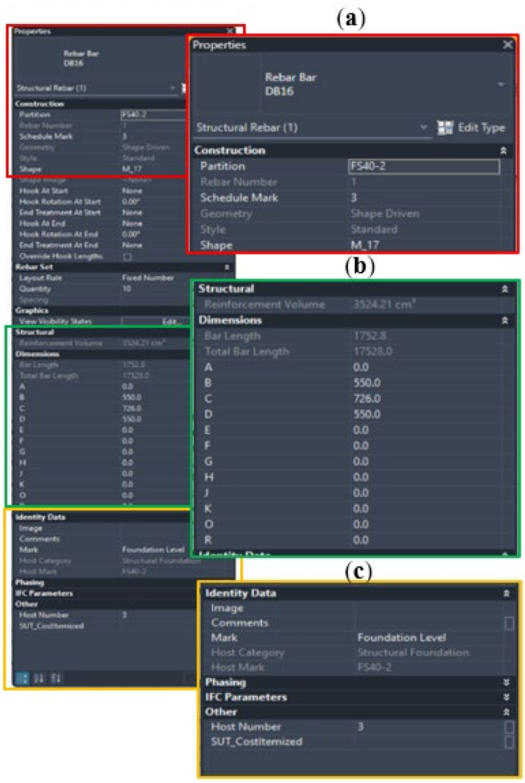

Figure 3 Instance properties of structural rebar in Revit (**a**) Construction data (**b**) Structural data (**c**) Identity data.

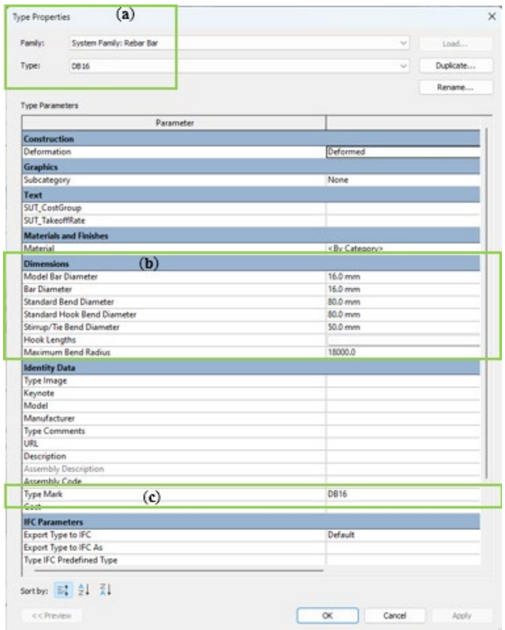

Figure 4 Type Properties of Rebar Element in Revit (**a**) Type of reinforcement (**b**) Material and Dimensional Properties (**c**) Identity Data and Type Mark

Figure 4(a) The type of reinforcement has been defined in the Revit Family. In the image below, you can see that this selected example is a System Family: Rebar Bar type specified as DB16, which is a reinforcement bar with a standard diameter of 16 mm. These unchangeable characteristics serve as the fundamental identifiers in the project. They are the strengths of the ability to collaborate. Maintain consistent classification and link the model with other business assets such as cost databases or procurement schedules. Such classification promotes cooperation and reduces miscommunication.

Figure 4(b) Material and Dimensional Properties: The main part of the Type properties includes parameters that are directly linked to the physical characteristics and object creator of the rebar. This includes the diameter, which specifies the actual size displayed in the 3D space. For example, here, there is a rebar size of 16 mm. It also includes standard bends and hook lengths, which are crucial for precision in detailing and guidelines for production. The requirements of these fields must be accurate to create a reliable rebar bending schedule. Calculate the material weight accurately and maintain data accuracy while connecting to structural design software in the next step. These various values can also be accessed by directly pulling parameters in Dynamo to assist in research and automation through analysis and simulation. These various values can still be accessed by directly pulling parameters in Dynamo to assist with research and automation through analysis and simulation.

Figure 4(c) Identity Data and Type Mark: identification section provides type markers (e.g., "DB16") which serve as labels for filtering data and referencing various components throughout the modeling and documentation process. This section plays a crucial role in making the model readable, especially when it includes exporting datasets for cost estimation or quantity surveying processes.
Additionally, the optional Assembly Code parameter helps link model components with standard classifications such as OmniClass or MasterFormat. This feature facilitates integration with Bills of Quantities (BOQs), creating a connection between the model data and the project's high-level capabilities.

3.2.1 Automated Quantity Takeoff with Dynamo: Architecture and Data Flow

Purpose: We implemented a modular visual-programming workflow in Dynamo for Revit to automate the extraction of material quantities for reinforced-concrete structures. The design emphasizes determinism, schema consistency, and downstream interoperability with Excel and Power BI within an ISO 19650–aligned CDE.

Figure 5 illustrates the overview of essential node groups used in the proposed Dynamo workflow, showing how data are categorized, structured, and prepared for automated export to Excel and Power BI.

Figure 5 Overview of Essential Node Groups for the Dynamo Workflow

Design principles: (i) one element category per module (columns, beams, slabs, walls, foundations, piles, rebar), (ii) explicit parameter binding and unit normalization (SI: mm→m, m³, kg), (iii) stable rounding rules (2 d.p. for quantities), and (iv) structured export to an authoritative Excel workbook (.xlsm) for macro-based preprocessing and Power BI ingestion.

Data flow: Each node group follows the same pattern:

Category selection & element collection—Categories→All Elements of Category.

Parameter binding—Element. GetParameterValue ByName for required fields (e.g., Level, Type, Structural Material, BarType, Dia_mm, Volume), with Element.Name for readable labels.

Preprocessing/standardization — unit conversion and Math.Round to enforce numeric precision; mapping lists for level codes and bar sizes.

Structuring—List.Create→List.Transpose to form a row–column table per scope.

Export—Data.ExportToExcel to named worksheets in the macro-enabled template; overwrite the authoritative sheet and hand off to the VBA routine for sorting, validation, and archival snapshot.

Reproducibility/QA. Each run writes the same schema given the same model state; parameter names are fixed; units are normalized; and exports are idempotent. The subsequent Excel macro performs deterministic floor ordering and aggregation (see §Excel Templates and Preprocessing → VBA-based Deterministic Preprocessing).

The modular visual-programming layout (Takeoff Structural Data Export) in Dynamo for Revit. Each node group corresponds to a structural scope (rebar, columns, beams, slabs, walls, foundations, piles) and implements the same pipeline: category selection, parameter extraction, preprocessing, tabulation, and structured export to an .xlsm template.

The script is modular and replicable, enabling scalable deployment across multiple projects or building types.

The architecture ensures:

- Category-specific filtering for accuracy,
- Parameter selection that aligns with quantity and cost estimation needs,
- Data formatting and export ready for Excel-based processing and Power BI dashboards.

Example 1: Structural Rebar Group

This group extracts essential properties of all reinforcement elements (rebars) embedded within the model:

STRUCTURAL REBAR MODULE

Components and Workflow:

Category Node: Set to Structural Rebar to isolate rebar elements only.

All Elements of Category Node: Gathers all instances of reinforcement in the Revit model.

Element.ElementType Node: that specify elementType to define the type of each component.

Code Block:

"Mark": Level of Building

"Partition": Host structural group (e.g., FS40-4 for Foundation)

"Type Mark": Rebar type mark (e.g., DB16, DB20)

"Bar Diameter": Steel size for procurement planning

"Reinforcement Volume": For calculating total weight

"Host Number": For associating each bar to its host structure

Output: A structured list of all rebar properties, organized by host element and exported to Excel for later cost computation and visualization in Power BI.

Figure 6 illustrates the category selection and parameter definition nodes used in the Dynamo workflow, showing how structural rebar parameters are organized for automated data extraction and export.

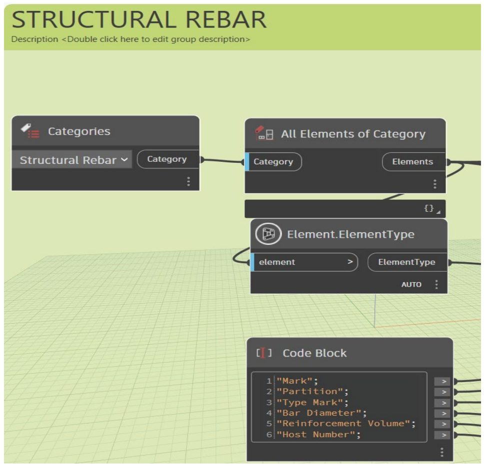

Figure 6 Category Selection and Parameter Definition for Structural Rebar.

PARAMETER OF ELEMENT

This group is responsible for retrieving physical and metadata properties from each structural element, followed by necessary unit conversions and rounding for quantity and cost computation. The node arrangement for parameter extraction and data preprocessing in the Dynamo workflow is shown in **Figure 7**.

- **Element.GetParameterValueByName Nodes**
  - Retrieves multiple element-level properties by name, including:
    - "Mark"
    - "Partition"
    - "Type Mark"
    - "Bar Diameter"
    - "Reinforcement Volume"
    - "Host Number"
- **Mathematical Nodes for Unit Normalization**
  - The "Reinforcement Volume" value extracted from Revit (in cm³) is converted to kg by:
    - Multiply by 7.85 then
    - Dividing by 1,000 then
    - Rounding to 3 decimal places using Math.Round Node
    - All rebar elements multiply by Host Number

Wire will connect to List Create Node for create a data

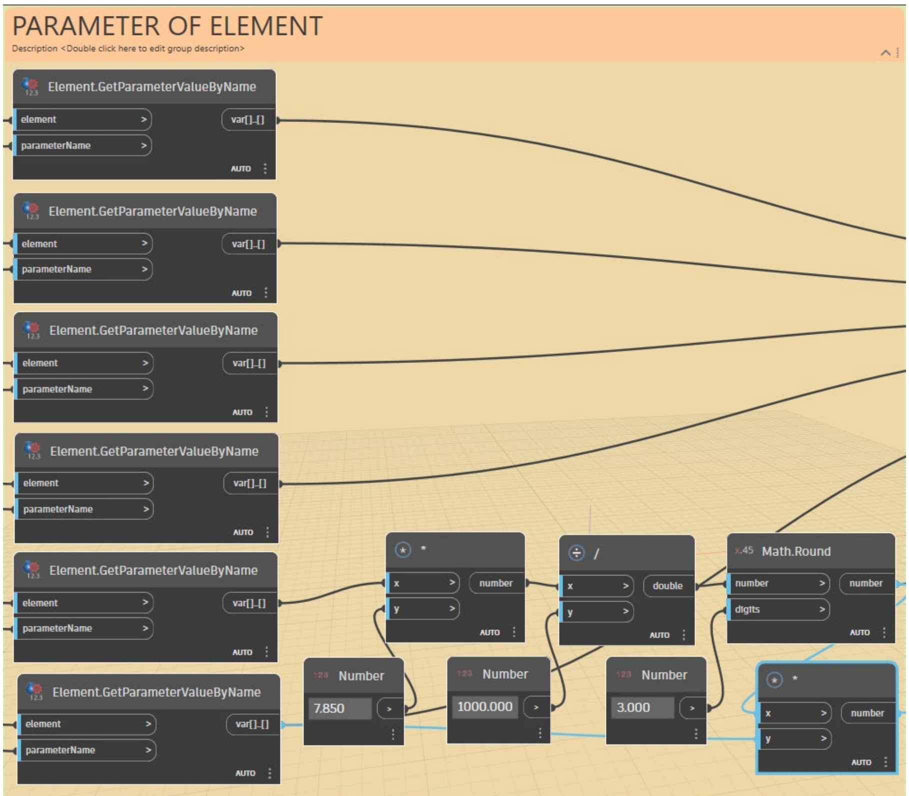

Figure 7 Group of nodes for Parameter Extraction and Data Preprocessing

CREATE EXCEL.XLSM

This group automates the process of exporting extracted and structured data into a predefined Excel macro-enabled template. It ensures a seamless transfer of structured material quantity data for downstream processing in Power BI.

File Path Node:

- Specifies the target Excel file path: .\Export Data From BIM\Structural_QTO_Data_Template.xlsm.
- The file is used as a master template for structured data output.

Code Block Node

- Defines key export parameters:
- Sheet name ("Rebar Quantity List"),
- Starting row (2),
- Starting column (0).

List.Create + List.Transpose Nodes

- Collects all parameter values and formats them into a transposed list structure, matching Excel's row-column format.

Data.ExportToExcel Node

- Exports the transposed data list to the specified worksheet in the .xlsm file.
- Automatically overwrites existing content and converts values to string format for compatibility

This automation eliminates the need for manual file handling and enables repeatable, structured exports aligned with ISO 19650-compliant CDE workflows. The data export procedure from Dynamo to Excel is demonstrated in **Figure 8**, highlighting the structured automation of quantity data transfer.

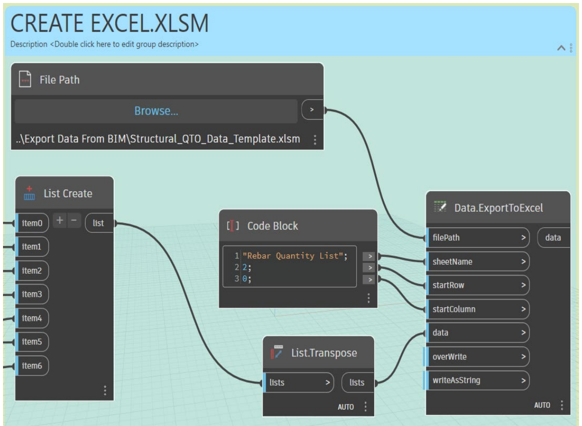

Figure 8 Group of nodes for Structured Data Export to Excel

Example 2: Structural Concrete Column Group

This group is responsible for identifying and extracting relevant parameters from all structural concrete column elements within the BIM model. It serves as the initial filtering mechanism to isolate columns as a distinct category, ensuring the dataset is appropriately segmented for quantity computation and cost analysis.

STRUCTURAL CONCRETE COLUMN MODULE

Components and Workflow:

Category Node: Set to "Structural Columns" to isolate only vertical structural elements cast in concrete. This ensures that the output does not include walls, slabs, or beams, preserving categorical integrity.

All Elements of Category Node: Collects all instances of structural columns found within the Revit model. Outputs an element list for downstream parameter extraction.

Code Block Node: Specifies the desired parameters to retrieve from each column:

"Base Level": Indicates the floor level or construction stage in which the column is located.

"Type": Retrieves the type definition (e.g., C1-300 × 600, C1A-300 × 300) used to associate with design standards or construction specifications.

"Structural Material": Confirms the material assignment for structural classification (e.g., Concrete, Cast in place gray).

"Volume": Captures the net volume (in m^3) of each column instance for use in concrete quantity takeoff.

Output and Integration: The resulting data stream includes a well-structured list of concrete column attributes segmented by type and building level. This data is routed to subsequent nodes for quantity consolidation, unit conversion, and final export.

The modular approach supports ISO 19650-aligned data classification and contributes to traceable, repeatable, and auditable cost analysis workflows. **Figure 9** illustrates the category selection and parameter definition for structural concrete columns, showing how BIM data are categorized for automated QTO extraction.

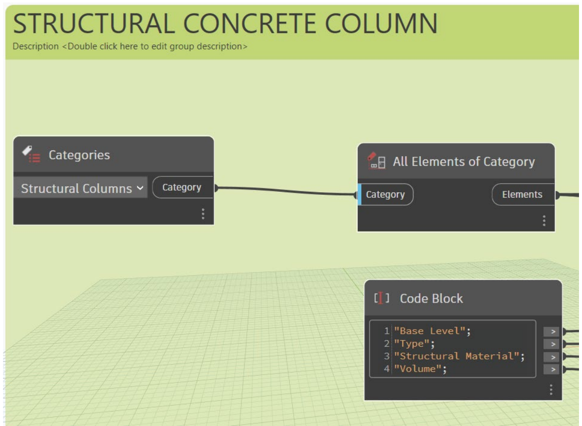

Figure 9 Category Selection and Parameter Definition for Structural Concrete Columns

PARAMETER OF ELEMENT

This group is responsible for retrieving physical and metadata properties from each structural element, followed by necessary unit conversions and rounding for quantity and cost computation.

- **Element.GetParameterValueByName Nodes**
  - Retrieves specific parameter values properties by name, including:
    - "Base Level"
    - "Type"
    - "Structural Material"
    - "Volume"
  - Element.Name
    - Translates element identifiers into readable string names, ensuring that parameter values are clearly associated with the element type.
  - Math.Round
    - Applied to numerical outputs (e.g., lengths, areas, or volumes) to reduce precision to two decimal places for consistency in downstream cost analysis.
  - Number Node
    - Defines the rounding precision (2.000), controlling decimal formatting in the exported dataset.

Wire will connect to List Create Node for create a data

The parameter extraction process for concrete elements within the Dynamo environment is depicted in **Figure 10**.

Figure 10 Group of nodes for Parameter Extraction and Data Preprocessing

CREATE EXCEL.XLSM

The third major component of the Dynamo workflow focuses on the automation of data export into an Excel-based environment. This step is critical in bridging the gap between BIM data extraction and downstream analytical processes, particularly in Power BI. The script utilizes a predefined macro-enabled template (Structural_QTO_Data_Template.xlsm) as the standardized repository for structured material quantity data. By directly linking Dynamo with Excel, the workflow eliminates manual interventions, minimizes human error, and ensures consistent alignment with ISO 19650–compliant Common Data Environment (CDE) practices.

The export procedure is initiated through the File Path node, which specifies the directory and filename of the target Excel template. This master file acts as the container for all subsequent structured outputs. The Code Block node defines essential parameters for the export process, including the worksheet name (“Rebar Quantity List”), the starting row (2), and the starting column (0). These parameters ensure that the exported data conforms to a predictable tabular format within Excel, facilitating interoperability with data visualization platforms such as Power BI.

Data consolidation and formatting are handled by the List.Create and List.Transpose nodes. While List.Create aggregates the extracted parameters into composite lists, the List.Transpose node restructures the data into a row–column alignment compatible with Excel’s table schema. Finally, the Data.Export ToExcel node executes the transfer of data into the designated worksheet, automatically overwriting previous content to maintain synchronization with the latest model revisions. By converting all values into string format, this step ensures compatibility with Excel’s cell formatting, thereby supporting both further computational analysis and visual reporting.

This automated mechanism streamlines the entire data management process, enabling repeatable, reliable, and scalable exports. In doing so, it not only reduces the effort of manual file handling but also establishes a structured data pipeline that underpins cost estimation and business intelligence applications within BIM-based workflows.

The export module specifies the target workbook and sheet, start row/column, and an overwrite policy; consolidates lists; transposes to a row–column table; and writes values as strings to preserve schema compatibility across locales.

Figure 11 presents the group of nodes responsible for exporting structured data from Dynamo to Excel, forming the final stage of the automated workflow.

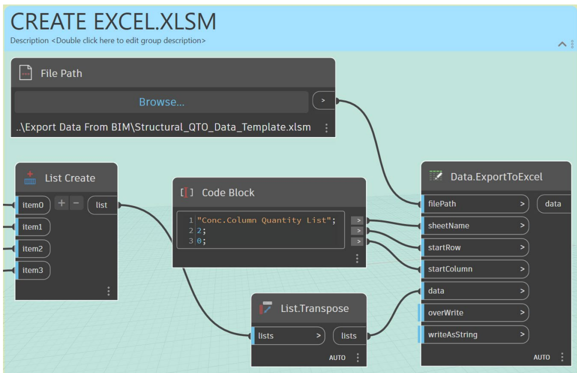

Figure 11 Group of nodes for Structured Data Export to Excel

Excel and Preprocessing

An Excel workbook (.xlsm) with 9 structured worksheets was created to store exported data. VBA macros were written to clean, sort, and classify data (e.g., by building level and pile type) to prepare for analysis in Power BI. The structured Excel template for recording rebar quantity takeoff data exported from the Dynamo workflow is presented in **Table 2**.

Table 2 Excel template for structural rebar

STRUCTURAL REBAR QUANTITY LIST						
Level	Type	Bar Type	Dia mm	W. kg	Host No.	Total W. kg

The standardized Excel format for structural concrete column quantity data is shown in **Table 3**.

Table 3 Excel template for concrete columns

STRUCTURAL CONC.COLUMN QUANTITY LIST			
Level	Type	Material	Concrete Volume (Cu.m)

Microsoft Visual Basic for Application (VBA)

A VBA will organize the structural levels in the data. The amount of reinforcement steel will be systematically arranged. The Excel file generated from the Dynamo script is used to execute the SortSheetByFloorOrder function, which sorts the reinforcement steel data according to specific levels, such as the foundation level, underground level, and from the first floor to the roof level.

Module 1 (Code) for Sorting by Floor:

```
Sub SortSheetsByFloorOrder()
  Dim ws As Worksheet
  Dim lastRow As Long
  Dim i As Long
  Dim levelCol As Long
  Dim orderCol As Long
  Dim headerRow As Long: headerRow = 2 ' Header is on row 2
  Dim levelName As String

  Application.ScreenUpdating = False
  Application.Calculation = xlCalculationManual

  For Each ws In ThisWorkbook.Worksheets
    On Error GoTo SkipSheet

    ' Find column “Level” in row 2
    levelCol = 0
    For i = 1 To ws.Cells(headerRow, Columns.Count).End(xlToLeft).Column
      If Trim(LCase(ws.Cells(headerRow, i).Value)) = “level” Then
        levelCol = i
        Exit For
      End If
```

```
        Next i
        If levelCol = 0 Then GoTo SkipSheet

        ' Determine last row of data in Level column
        lastRow = ws.Cells(ws.Rows.Count, levelCol).End
(xlUp).Row
        If lastRow <= headerRow Then GoTo SkipSheet

        ' Create helper column FloorOrder
        orderCol = ws.Cells(headerRow, Columns.Count).
End(xlToLeft).Column + 1
        ws.Cells(headerRow, orderCol).Value = "FloorOrder"

    ' Assign sort index for each row
    For i = headerRow + 1 To lastRow
    levelName = Trim(ws.Cells(i, levelCol).Value)
    Select Case levelName
    Case "Footing Level": ws.Cells(i, orderCol).Value = 1
    Case "Ground Level": ws.Cells(i, orderCol).Value = 2
    Case "1st Floor": ws.Cells(i, orderCol).Value = 3
    Case "2nd Floor": ws.Cells(i, orderCol).Value = 4
    Case "3rd Floor": ws.Cells(i, orderCol).Value = 5
    Case "4th Floor": ws.Cells(i, orderCol).Value = 6
    Case "5th Floor": ws.Cells(i, orderCol).Value = 7
    Case "6th Floor": ws.Cells(i, orderCol).Value = 8
    Case "7th Floor": ws.Cells(i, orderCol).Value = 9
    Case "Roof Top": ws.Cells(i, orderCol).Value = 10
    Case Else: ws.Cells(i, orderCol).Value = 99
        End Select
    Next i

   ' Perform sort using FloorOrder starting from Row 2
        With ws.Sort
          .SortFields.Clear
          .SortFields.Add2 Key:=ws.Range(ws.Cells(header
Row + 1, orderCol), ws.Cells(lastRow, orderCol)), _
            SortOn:=xlSortOnValues,
Order:=xlAscending, DataOption:=xlSortNormal
          .SetRange ws.Range(ws.Cells(headerRow, 1),
ws.Cells(lastRow, orderCol))
          .Header = xlYes
          .MatchCase = False
          .Orientation = xlTopToBottom
          .Apply
        End With

        ' Delete FloorOrder helper column
        ws.Columns(orderCol).Delete

  SkipSheet:
        On Error GoTo 0
    Next ws

    Application.Calculation = xlCalculationAutomatic
    Application.ScreenUpdating = True
    MsgBox "Sorting complete for all worksheets,
starting from row 3.", vbInformation
  End Sub
```

3.2.2 Automation Using Power Automate Desktop

Purpose: We implemented Microsoft Power Automate Desktop (PAD) as a desktop orchestration layer to operationalize the post-export pipeline from Dynamo for Revit to Excel and onward to Power BI. The automation removes manual intervention, enforces a deterministic sequence of preprocessing steps, and preserves ISO 19650–aligned CDE discipline (authoritative vs. archived outputs).

Environment: Windows 11, Office 365 (Excel, macro-enabled), Power BI Desktop (June 2025 build); regional settings fixed to SI units and dot decimal.

Workflow (Main Flow):

Single-instance guard & readiness check.

Create a mutex file to prevent concurrent runs; verify that the latest Dynamo export exists and is not being written (size stable for N seconds).

Launch Excel (authoritative template).

Open Structural_QTO_Data_Template.xlsm using a persistent ExcelInstance. The workbook contains domain-specific sheets (e.g., Rebar, Beam, Column, Slab, Wall, Foundation, Pile).

Run macro 1 — SortSheetsByFloorOrder.

Apply a canonical level sequence (Foundation → Underground → Ground → 1st … Roof). The macro detects the Level header case-insensitively, assigns a helper FloorOrder index, performs a stable sort, and clears the helper column.

Run macro 2 — Clean_Quantity_Sheets.

Standardize schemas on Slab and Wall (trim, remove blanks/duplicates, enforce data types and allowed values, normalize units, apply rounding to 2 d.p.).

Run macro 3 — ExtractPileGroup.

Aggregate the Pile Quantity List by Type and compute a Quantity field (count of piles per type), writing results to the authoritative sheet.

Persist outputs.

Save changes to the authoritative workbook (overwrite policy) and write a daily snapshot BOQ_Data_YYYYMMDD.xlsx to the project archive.

Open visualization.

Launch CP Land Structural BIM Model Data Analysis 2025-05-21.pbix. Power BI loads the updated Excel tables and renders dashboards for immediate review.

Post-run signaling and logging.

PAD reads a control flag from UnitCost_and_Control!B2 ("OK" / "FAIL"), records timestamps, row counts, and aggregate checks (e.g., ΣTotal_Weight_kg, ΣConcrete_Volume_m3) to a CSV log, removes the mutex, and closes applications gracefully.

The automated Excel-to-Power BI refresh workflow, integrating BIM-derived quantity data, is shown in **Figure 12**.

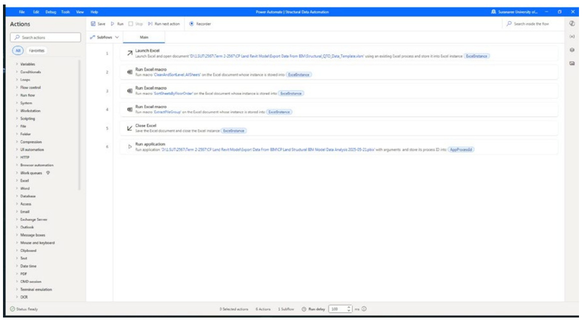

Figure 12 Automated Excel–to–Power BI Refresh Flow using Power Automate Desktop

Cost Analysis and Interactive Visualization in Power BI

Data Import and Query Transformation from Revit-Dynamo Output: In this study, structural material quantity data generated from Autodesk Revit via Dynamo visual programming was exported into a macro-enabled Excel file (.xlsm) serving as the authoritative data source for further analysis. To facilitate cost analysis and material visualization within Power BI, these exported datasets were imported and transformed using Power Query prior to modeling and dashboard construction.

The process of importing Excel workbooks containing BIM quantity data into Power BI is illustrated in **Figure 13**, which marks the initial step of the data transformation workflow.

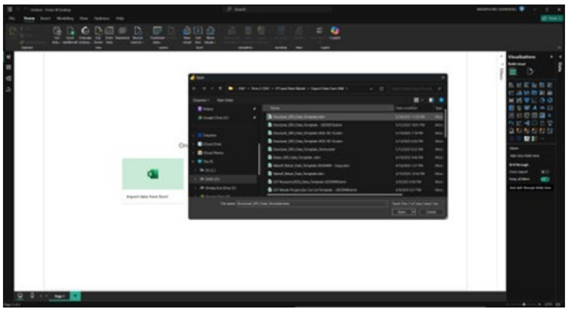

Figure 13 Importing Excel Workbook Containing BIM Quantity Data into Power BI

The import process began in Power BI Desktop (June 2025 version or equivalent), where the user selected the option to import data from an Excel workbook (see **Figure 13**). Upon opening the source file, a dialog box (Navigator) displayed all available worksheets categorized by structural elements—such as Conc Column Quantity List, Rebar Quantity List, and Unit Price. Relevant sheets were selected based on domain-specific analysis objectives (see **Figure 14**).

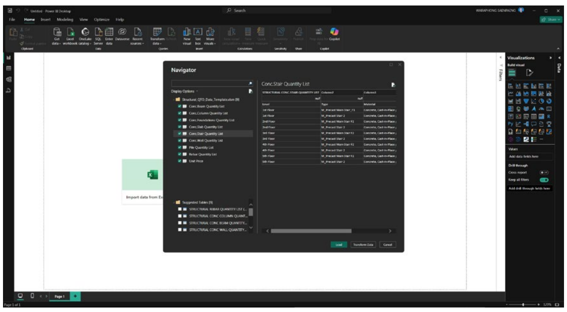

Figure 14 Selecting Specific Worksheets from the Dynamo Exported File Using Navigator Window

Once the sheets were selected, the Transform Data option launched the Power Query Editor, enabling the cleansing and reshaping of data to conform to analytical standards. Key actions within Power Query included:

Promoting the first row to headers (where necessary),

Explicitly defining data types, such as:

Level: Text

Type: Text

Material: Text

Concrete Volume (cu.m): Decimal Number (2 decimal precision)

Removing null rows and redundant columns, ensuring naming consistency across similar datasets, applying unit standardization aligned with SI units.

As shown in **Figure 15**, each structural element's quantity sheet (e.g., Conc Beam Quantity List) was validated for column consistency, such as Level, Type, Material, and Concrete Volume. Data profiling was conducted using Power BI's column profiling tools based on the first 1,000 rows to detect anomalies and inform data normalization.

These transformed queries were subsequently loaded into the Power BI data model, forming the foundation for constructing dimensional tables (e.g., DimLevel, DimMaterial, DimCost) and fact tables (e.g., Fact_Concrete, Fact_Rebar). This structure supported the later creation of DAX measures such as total volume per structural type, cost per material group, and bar weight per level.

The structured approach to importing and querying Revit-Dynamo data ensures the integrity and scalability of downstream analytics and visualization workflows.

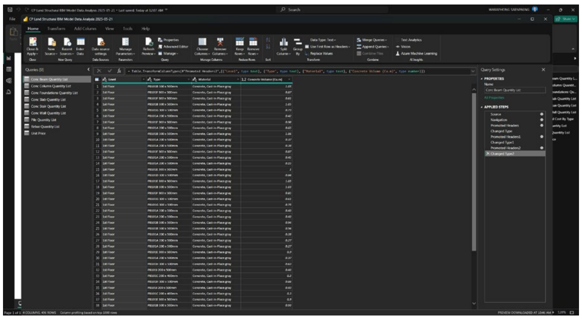

Figure 15 Power Query Editor Interface for Data Cleansing and Transformation

Cost Calculation and Data Modeling using DAX in Power BI:

To establish a reliable framework for automated cost estimation, the research integrated cost data with material quantity data within Power BI using Data Analysis Expressions (DAX). This step transforms domain-specific quantity tables (e.g., concrete columns, beams, slabs, rebar, piles) into unified fact tables, enabling comparative cost analysis across structural levels and component types.

The Power BI data model adopts a star schema architecture, in which fact tables such as Fact_Rebar and Material Cost by Type are connected to relevant dimension tables including LevelSortTable and Unit Price. Relationships were created based on fields like Level, Material, and Type to ensure consistency and integrity across datasets.

Figure 16 illustrates the complete data model in Power BI, highlighting the connections between quantity tables (e.g., Conc Column Quantity List) and the centralized Unit Price reference table. The fact table Material Cost by Type is populated using DAX expressions that perform rowwise calculations for concrete volumes, unit prices, and total costs, based on material type and structural category.

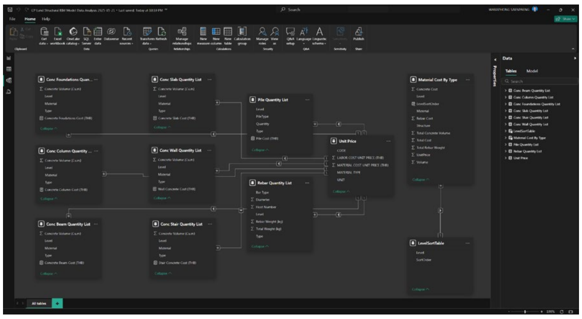

Figure 16 Power BI Data Model for Structural Quantity and Cost Integration

To compute total cost, each SELECTCOLUMNS function multiplies the concrete volume (in cubic meters) by the associated material unit cost (in THB/m³), which is dynamically retrieved using the RELATED() function from the Unit Price table. Furthermore, additional columns are derived for cost breakdowns, such as ConcreteCostOnly and RebarCostOnly, which facilitate comparative visualization across material categories.

This DAX-driven modeling approach ensures analytical flexibility, allowing stakeholders to slice data by structural level, material group, or component type while maintaining consistent business logic.

Figure 17 demonstrates the DAX expressions implemented in Power BI for calculating material costs and quantities, forming the analytical core of the proposed cost estimation workflow.

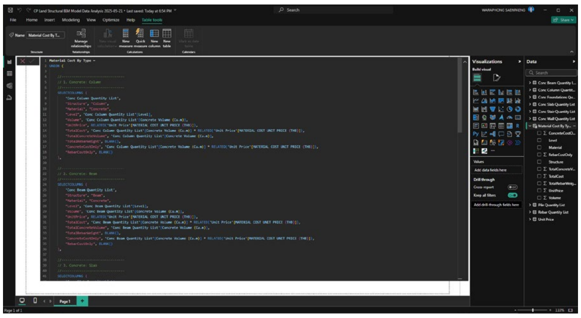

Figure 17 DAX Expressions for Calculated Columns in Material Cost by Type Table

3.3 Comparative Method Evaluation

To assess the benefits of the proposed method, a comparative analysis was conducted among three approaches: 1) traditional QTO using 2D drawings, 2) semi-automated QTO using Revit schedules, and 3) the proposed fully automated BIM-Dynamo-Power BI workflow. A comparative analysis of quantity takeoff and cost estimation methods between traditional, semi-automated, and the proposed automated workflow is summarized in **Table 4**.

Table 4 Comparative Analysis of Quantity Takeoff Methods

Criteria	Traditional QTO (2D Drawings)	Semi-Automated QTO (Revit Schedules)	Proposed Automated Workflow (Dynamo + Power BI)
Data Source	2D CAD drawings and printed plans	Revit BIM model (LOD 300)	Revit BIM model (LOD 350)
Method of Quantity Takeoff	Manual counting and measurement	Built-in Revit schedules with manual configuration	Automated extraction via Dynamo scripts
Validation and Traceability	Limited (subject to human error)	Moderate (element data linked but non-standardized)	Full traceability through element IDs and categories
Cost Estimation Method	Manual input in Excel	Manual mapping from schedules	Dynamic cost computation using linked Excel tables
Visualization of Results	Static Excel tables	Static Revit schedule export	Interactive dashboards (Power BI)
Update Flexibility	Requires manual recalculation	Requires rescheduling and export	Auto-updates with BIM model revisions
Suitability for CDE/ISO 19650	Not aligned	Partially aligned	Fully traceable and exportable for ISO workflows
Risk of Human Error	High	Moderate	Low
Time Efficiency	Time-consuming	Faster but partially manual	High speed (under 3 minute per run)
Scalability	Poor	Moderate – limited to scheduled categories	High – adaptable to other material types and buildings

3.4 Workflow Toolchain Diagram

A seamless and repeatable workflow is outlined within the proposed toolchain to facilitate automated rebar quantity takeoff and cost analysis of a BIM based construction project. It starts with model authoring in Autodesk Revit 2024, where both structural and detailing reinforcement components are defined with parametric attributes. Dynamo, a visual programming interface is utilized to retrieve the key parameters, such as the bar diameter extracted based on rule-based logic and unit conversion scripts. The data is exported to a structured Excel Template (.xlsm), that performs its post-processing functions (sorting by floor level, formatting, incorporating unit costs all via VBA macros. The structured form of data then gets imported to power BI, and visualized with dashboards. These dashboards provide an overview and allow instant analysis of rebar use by cost and structural component and building floor, supporting material optimization and procurement decision making.

This tool-chain integrates and improves data transparency, reduces manual errors, and leads to a traceable and data driven construction planning. It reflects a scalable solution applicable to mid- to large-scale structural engineering workflows. The overall workflow of the proposed automation system is illustrated in **Figure 18**, which demonstrates the integration of Revit, Dynamo, Excel, Power Automate Desktop, and Power BI for end-to-end BIM-based quantity takeoff and cost analysis.

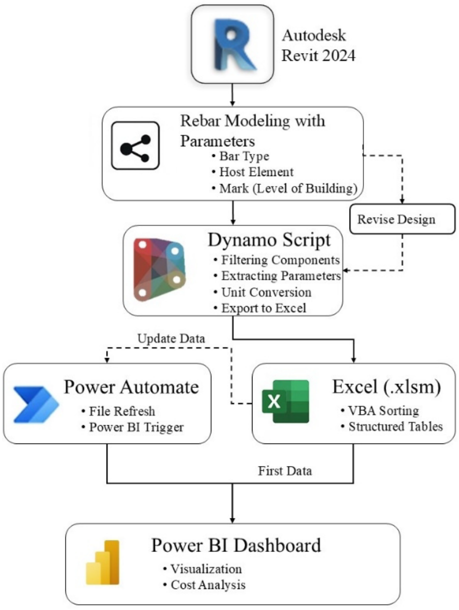

Figure 18 End-to-End BIM-Based Automation Toolchain for Rebar Takeoff and Cost Analysis

4. Results

Integrated Quantity and Cost Analysis of Reinforced Concrete Structures

This section presents the extended results of the integrated workflow for structural quantity takeoff and cost estimation, The framework incorporates both reinforcement (rebar) and cast-in-place concrete elements, enabling comprehensive assessment of construction resources across structural levels. All data were extracted from a Revit model using visual programming in Dynamo, exported as structured Excel sheets (.xlsm), and subsequently analyzed in Power BI.

4.1 Data Acquisition and Structuring

Two key datasets were utilized to represent the structural components: (1) *STRUCTURAL REBAR QUANTITY LIST* and (2) *STRUCTURAL CONCRETE COLUMN QUANTITY LIST*. The first dataset comprises over 3,400 records categorized by level, rebar type (e.g., DB16, DB20, RB9), diameter, weight per instance, host count, and total rebar weight. The summarized results of rebar data extracted from the Revit model and processed through Dynamo are presented in **Table 5**. The second dataset records the volumetric properties of concrete columns (e.g., Pier C1 300 × 600 mm) across levels and element types. Both datasets are organized hierarchically by structural level, consistent with the building schema defined in the BIM model. **Table 6** presents the extracted concrete column quantity data.

Upon export, the Excel workbook was automatically processed by Power Automate Desktop. Macros were executed sequentially to clean, categorize, and summarize quantity data. Power BI Desktop then imported these curated sheets and performed further transformation using Power Query, including unit standardization, data typing, and table merging to form a star schema model. This ensured that all facts (e.g., volume, weight, unit cost) are normalized against dimensional attributes such as level, type, and material.

Table 5 Rebar data export from Dynamo

STRUCTURAL REBAR QUANTITY LIST						
Level	Type	Bar Type	Dia mm	W. kg	Host No.	Total W. kg
Footing Level	Foundation FS40-4	DB16	16	46.605	8	372.84
Footing Level	Foundation FS40-4	DB16	16	45.657	8	365.256
Footing Level	Foundation FS40-4	DB12	12	7.006	8	56.048
Footing Level	Foundation FS40-2	DB16	16	27.665	3	82.995

Table 6 Concrete column data export from Dynamo

STRUCTURAL CONC.COLUMN QUANTITY LIST			
Level	Type	Material	Concrete Volume (Cu.m)
Ground Level	Pier C1 300 × 600mm	Concrete, Cast-in-Place gray	0.27
Ground Level	Pier C1 300 × 600mm	Concrete, Cast-in-Place gray	0.27
Ground Level	Pier C1 300 × 600mm	Concrete, Cast-in-Place gray	0.27
Ground Level	Pier C1 300 × 600mm	Concrete, Cast-in-Place gray	0.27
Ground Level	Pier C1 300 × 600mm	Concrete, Cast-in-Place gray	0.27
Ground Level	Pier C1 300 × 600mm	Concrete, Cast-in-Place gray	0.27

4.2 Dashboard-Based Analytical Modeling

Power BI dashboards were developed to enable multi-perspective interrogation of material quantities and associated costs. Visual elements include matrix tables, pie charts, and clustered column charts. **Figure 19** shows the consolidated dashboard integrating all levels and material types, while **Figures 20–23** provide focused breakdowns for the footing level, 1st floor, and 6th floor respectively.

Total cost aggregation revealed that the concrete cost accounted for ฿2.41M, and rebar cost ฿2.12M, yielding a cumulative material cost of ฿4.52M. The bar charts indicate significant variations across levels, with the highest cost concentration observed on the rooftop and middle floors. Pie chart distributions showed that structural components such as beams and slabs dominate the rebar cost share, particularly in elevated levels.

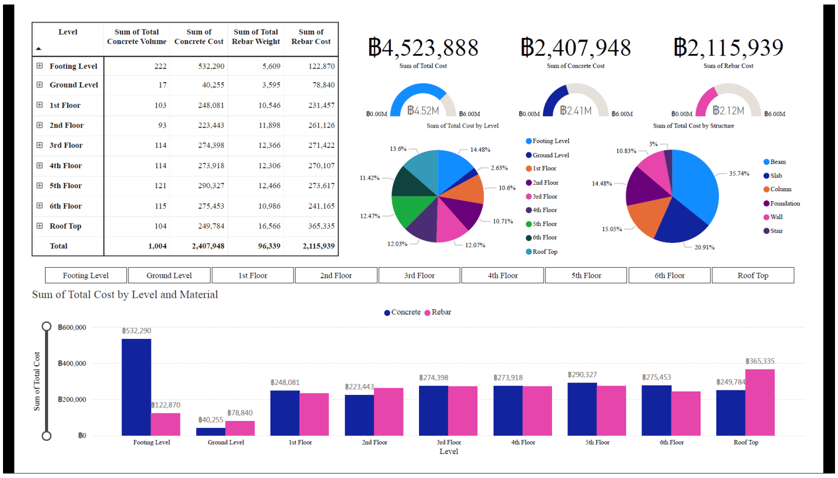

Figure 19 Overview dashboard showing aggregated material costs across building levels

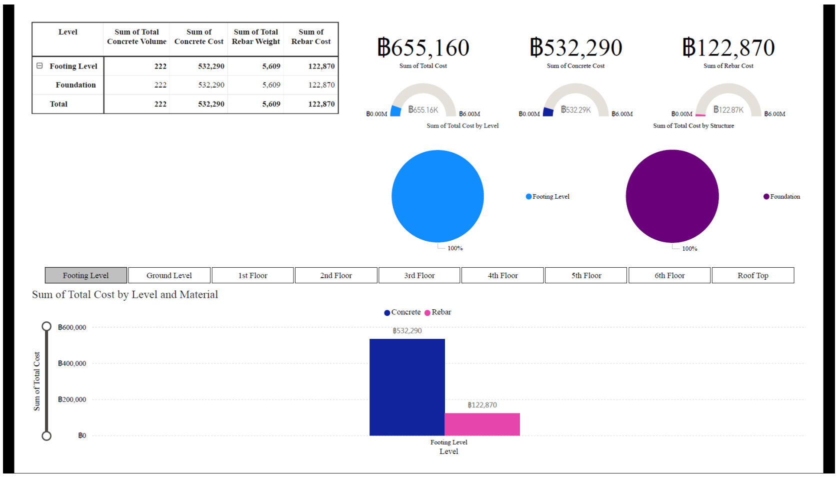

Figure 20 Cost breakdown at Footing Level by material and structural element

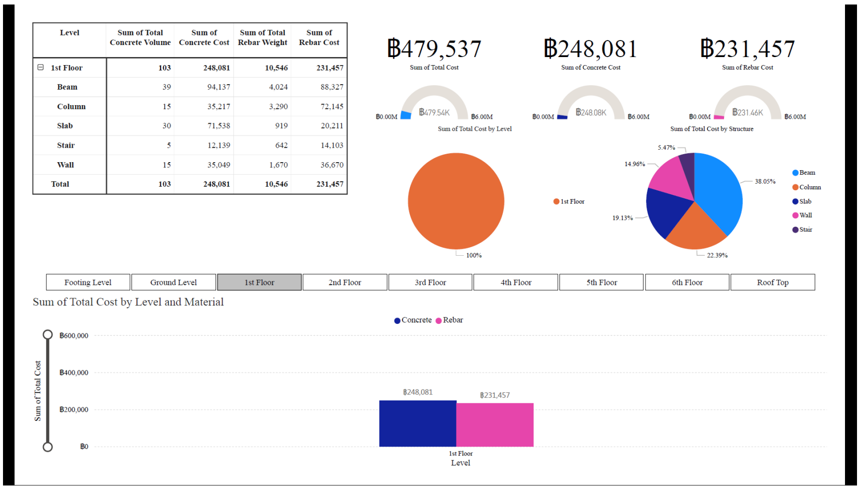

Figure 21 Cost breakdown at 1st Floor showing distribution among beam, column, slab, wall, and stair

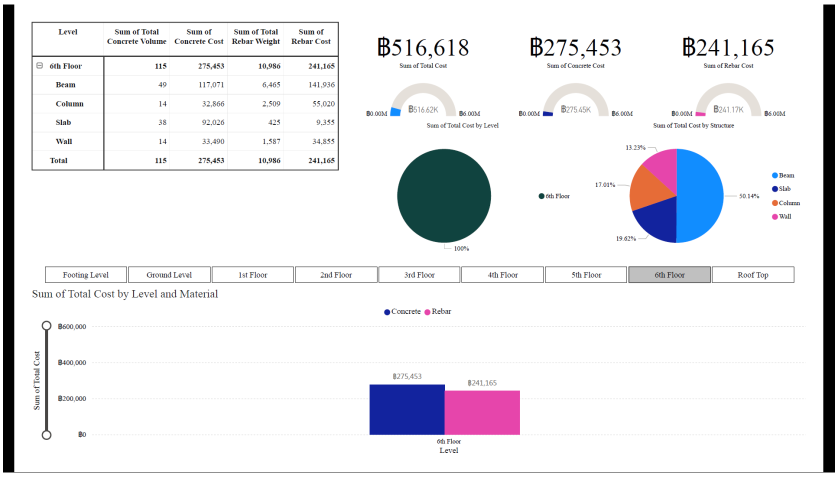

Figure 22 Cost analysis at 6th Floor with proportional rebar and concrete contributions

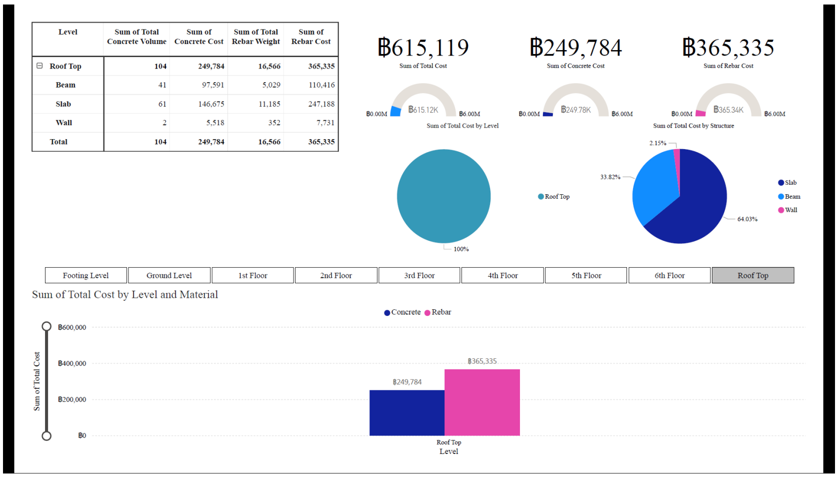

Figure 23 Material cost contribution at Roof Top Level, emphasizing rebar intensity in slab elements

4.3 Concrete Column Case Study

The analysis of concrete columns focused on volumetric estimation by level. For instance, at the ground level, all Pier C1 300 × 600 mm columns consistently registered a volume of 0.27 Cu.m per unit, resulting in more than 6 Cu.m total volume when summed across instances. First floor columns varied between 0.61 and 0.63 Cu.m, reflecting a design-driven variation in formwork dimensions. These quantities were multiplied by their respective material unit cost in the *Unit Price* table to yield level-specific concrete costs.

4.4 Rebar Analysis

In terms of reinforcement, the dashboard analysis revealed that DB16 and DB20 contributed the largest proportion of rebar weight and cost, especially in foundation and rooftop zones. At the footing level alone, DB16 constituted over 1,500 kg of reinforcement, while DB20 accounted for more than 1,800 kg. When examined at the Ground Level, Pier Column C1 with DB25 and RB9 bars showed aggregated totals exceeding 1,000 kg.

This mass distribution highlights the strategic use of bar types by structural function: DB25 and DB20 in columns and deep foundations for compressive resistance; DB12 and RB9 in stirrups and wall ties for shear and confinement. These insights not only inform procurement quantities but also scheduling and delivery logistics.

4.5 Implications for Planning and Procurement

The synchronized use of Power BI enabled the derivation of decision-support metrics, such as cost contribution by material type per level, and reinforcement density per structural zone. Figure 5 shows that on the 6th floor, beam elements alone contributed ฿141,936 in rebar cost, while slab elements accounted for ฿92,026. Similarly, the dashboard from the rooftop level indicates a rebar cost exceeding ฿365,000 , primarily concentrated in slab and beam components.

From a planning standpoint, such visual disaggregation allows stakeholders to forecast critical procurement phases and align supply chain logistics with construction sequencing. It also supports cost control by pinpointing cost-intensive components for value engineering.

5. Discussion

The revised approach demonstrates the feasibility and benefits of extending automated quantity takeoff to integrate concrete and reinforcement materials. Beyond graphical modeling, the analytical dimension achieved through Power BI transforms static quantity data into dynamic, actionable intelligence. While the computational workflow from Dynamo to Power BI remains technically complex, its repeatability and compatibility with industry-standard file formats (IFC, XLSM, PBIX) render it scalable for multi-project implementation.

The current workflow, though focused on reinforced concrete structures, provides a flexible foundation for expansion to other domains of building information modeling. Future developments will extend automation to encompass additional building systems, including architectural elements, mechanical, electrical, and plumbing (MEP) systems. These systems, when integrated, will enhance the holistic capabilities of BIM-based quantity takeoff and cost estimation across interdisciplinary domains.

To validate the scalability of the proposed workflow, further implementation on large-scale and high-complexity projects—such as high-rise buildings, infrastructure facilities, or industrial plants—is planned. Such projects will provide an opportunity to assess performance in terms of processing time, schema compatibility, and visualization responsiveness under higher data volume and structural complexity.

Moreover, the integration of analytical results with cloud-based platforms such as Autodesk Construction Cloud or Microsoft Power Platform represents a promising direction. These collaborative environments allow for real-time data synchronization across design, engineering, procurement, and site management teams. By embedding dynamic Power BI dashboards within these platforms, stakeholders can perform live cost diagnostics, monitor deviations from budget baselines, and support decision-making processes in line with ISO 19650-compliant CDE practices.

These enhancements aim not only to scale the technical framework but also to align with broader digital construction goals such as transparency, auditability, and sustainable cost management throughout the project lifecycle.

6. Conclusion

This research presents the development of an automated workflow for reinforced concrete structural quantity takeoff and cost estimation by leveraging Building Information Modeling (BIM) technologies in conjunction with Dynamo visual programming, Excel VBA, and Power BI analytics. The integrated workflow proposed in this study significantly enhances the conventional practices of rebar quantity estimation in terms of accuracy, efficiency, and data traceability.

By extracting rebar data directly from the BIM model via Dynamo, the proposed method enables the automated classification of structural elements, floor-level grouping, and material type categorization. The subsequent data processing in Excel utilizes VBA macros to clean, sort, and aggregate quantities, which are then visualized through interactive dashboards in Power BI. This approach eliminates the need for manual calculations and repetitive data handling, reducing human errors and enabling real-time cost monitoring.

Experimental results demonstrate that the automated workflow not only reduces processing time compared to traditional BIM-based quantity takeoff methods in Revit but also provides a more scalable and reproducible solution. The use of DAX formulas in Power BI further supports dynamic filtering, comparison across building floors, and cost summaries by material type, thereby facilitating procurement planning and investment decision-making.

This study contributes a structured and reproducible method that aligns with digital construction and data-driven cost management principles. Furthermore, it demonstrates the practical integration of BIM data with business intelligence platforms, offering a transferable framework that can be extended to other disciplines within the AEC industry.

7. Acknowledgments

The researcher expresses sincere appreciation to Assoc. Prof. Dr. Suradet Tantrairatn, principal advisor, and Dr. Aphai Chaphirom, co-advisor, for their invaluable academic supervision, insightful feedback, and consistent encouragement throughout the research process. The authors also wish to acknowledge the School of Engineering, Suranaree University of Technology, for providing the technical infrastructure and collaborative research environment essential to the successful completion of this study.

This research received no external funding. The authors declare no conflicts of interest.

8. References

[1] Y. Cepni, A. Akcamete and L. Klein, "Automated BIM-based formwork quantity take-off," in *Proc. 20th Int. Conf. Construction Applications of Virtual Reality (CONVR)*, Middlesbrough, UK, Sep. 30–2, 2020, pp. 220–227.

[2] M. Valinejadshoubi, O. Moselhi, I. Iordanova, F. Valdivieso and A. Bagchi, "Automated system for high-accuracy quantity takeoff using BIM," *Automation in Construction*, vol. 157, 2024, Art. no. 105155, 2024 doi: 10.1016/j.autcon.2023.105155

[3] X. Huang, "Application of BIM Big Data in Construction Engineering Cost," *Journal of Physics: Conference Series*, vol. 1865, no. 3, 2021, Art. no. 032016, doi: 10.1088/1742-6596/1865/3/032016.

[4] G. Digregorio, "Real-Time Data and BIM: Automated Protocol for Management and Visualisation of Data in Real Time," M.S. thesis, Dept. Struct., Geotech. and Build. Eng., Politecnico di Torino, Turin, Italy, 2020. [Online]. Available: https://webthesis.biblio.polito.it/19447/

[5] K. Zawada, K. Rybak-Niedziółka, M. Donderewicz and A. Starzyk, "Digitization of AEC Industries Based on BIM and 4.0 Technologies," *Buildings*, vol. 14, no. 5, 2024, Art. no. 1350, doi: 10.3390/buildings14051350.

[6] *BIM Overlay to the RIBA Outline Plan of Work*, Royal Institute of British Architects (RIBA), London, U.K. 2012, pp. 1–17.

[7] B. Succar, "Building information modelling framework: A research and delivery foundation for industry stakeholders," *Automation in Construction*, vol. 18, no. 3, pp. 357–375, 2009. doi: 10.1016/j.autcon.2008.10.003.

[8] *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling*, ISO 19650-1:2018, International Organization for Standardization, Geneva, Switzerland, Dec. 2018.

[9] *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling*, ISO 19650-2:2018, International Organization for Standardization, Geneva, Switzerland, Dec. 2018.

[10] *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling*, ISO 19650-3:2020, International Organization for Standardization, Geneva, Switzerland, Jul. 2020.

[11] *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling*, ISO 19650-4:2022, International Organization for Standardization, Geneva, Switzerland, Aug. 2022.

[12] E. Çekin and S. Seyis, "BIM Execution Plan based on BS EN ISO 19650-1 and BS EN ISO 19650-2 Standards," in *6th International Project and Construction Management Conference*, Istanbul, Turkey, Nov. 12–14, 2020, pp. 1–9.

[13] T. Pimchanok, S. Tiyanan and T. Thanatcha, "The Apply of Using Building Information Modeling (BIM) to Present Material Takeoff: Case Study Educational Building," *The Journal of Architecture, Design and Construction (JADC)*, vol. 3, no. 1, pp. 57–68, 2021.

[14] K. L. O'Shea and D. Lamon, "A Critical Analysis of the Application of Visual Programming to Increase Efficiency in BIM Object Metadata Delivery Workflows During the Delivery Phase of an Asset," Technological University Dublin , Dublin, Ireland, Rep. 1, 2021. [Online]. Available: https://doi.org/10.21427/W73K-9531

[15] C. M. Olszak, "Business Intelligence Systems for Innovative Development of Organizations," *Procedia Computer Science*, vol. 207, pp. 1754–1762, 2022. doi: 10.1016/j.procs.2022.09.233.

[16] M. Djerdjouri, "Data and Business Intelligence Systems for Competitive Advantage: prospects, challenges, and real-world applications," *Mercados y Negocios*, no. 41, pp. 5–18, 2020. doi: 10.32870/MYN.V0I41.7537.

[17] M. Golestanizadeh, H. Sarvari, D. W. M. Chan, N. Banaitienė, and A. Banaitis, "MANAGERIAL OPPORTUNITIES IN APPLICATION OF BUSINESS INTELLIGENCE IN CONSTRUCTION COMPANIES," *Journal of Civil Engineering and Management*, vol. 29, no. 6, pp. 487–500, 2023. doi: 10.3846/jcem.2023.19533.