



## ADVANCING BIM-DRIVEN ELEMENTAL COST PLANNING – A STANDARDS-BASED REVIT PLUGIN FOR ACCURATE CONSTRUCTION ESTIMATION

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**Abstract:** While Elemental Cost Planning (ECP) is widely adopted in international construction, its integration with Building Information Modeling (BIM) remains underdeveloped in Sri Lanka. This study aims to address the absence of a standardised, automated, and NRM 01-compliant BIM-ECP solution by developing a functional Revit-based plugin capable of producing accurate, region-sensitive cost estimates. As the design methodology, this research adopts a mixed-method approach. Phase one involved developing a conceptual framework based on a literature review and validating it through surveys and expert interviews. In phase two, a plugin was developed using C# in Visual Studio, integrated with Autodesk Revit API, and tested through practical applications. The plugin automates quantity extraction, NRM-based categorisation, and cost calculations, including adjustments for time and location. The findings confirmed that Sri Lanka's construction sector lacks tools incorporating location-specific indices and internationally accepted standards, such as NRM 01. However, private sector stakeholders expressed readiness to adopt structured tools. The developed plugin demonstrated strong potential to bridge the gap between BIM and ECP. This research presents the first BIM-integrated, Revit-based ECP tool tailored to the Sri Lankan context. It offers a replicable model for improving early-stage cost planning accuracy while supporting broader adoption of digital construction practices aligned with global standards

**Index Terms:** Elemental Cost Plan (ECP), Building Information Modeling, New Rules of Measurements, Revit

### 1 INTRODUCTION

The construction industry stands as a cornerstone of any nation's economy, playing a significant role in economic development, job creation, and infrastructure growth [9]. Despite its profound importance, the sector is persistently challenged by issues such as cost overruns, budget discrepancies, and general inefficiencies [30]. These challenges are not merely confined to individual projects; their cumulative effect can undermine national economic stability, as inaccurate estimates lead to project failures, disputes, and a diminished contribution to the gross domestic product from the construction sector. Historically, construction cost estimation has been a labour-intensive process, heavily reliant on manual interpretation of two-dimensional (2D) drawings, repetitive calculations, and spreadsheet-based data management [18]. This

traditional approach is inherently time-consuming, often consuming between 50% to 80% of an estimator's time, and is highly susceptible to human error, leading to inconsistencies and inaccuracies [38].

The RICS New Rules of Measurement (NRM 1, “Order of cost estimating and elemental cost planning for capital building works”) provides a standardised framework for the Elemental Cost Plan (ECP) [26]. RM 1 offers “guidance on Order of cost estimating and cost planning” and specifically covers the preparation of order of cost estimates, elemental cost models, cost plans, cost analyses, and benchmark analyses [39]. It defines a hierarchical classification of building elements, systems, subsystems, and components, which are the basis for elemental cost breakdown. For example, NRM 1 includes a scheme where the highest level is the overall building (often measured in gross floor area or gross external area), beneath which are major elements (e.g., substructure, frame, external walls, internal walls, finishes, services, etc.) and further sub-elements. This structured classification ensures consistency in how costs are grouped and reported. Indeed, the Royal Institute of Chartered Surveyors (RICS) website notes that NRM “provides a standard set of measurement rules and essential guidance for the cost management of construction projects.” [25].

Linking ECP with Building Information Modeling (BIM) (i.e., automating an elemental cost plan from a BIM model) promises major benefits but also faces barriers. On the opportunity side, using BIM ensures cost data is consistent with the model geometry and updated with design changes [31]. Model-based ECP can also facilitate early cost advice and benchmarking, since elemental quantities can be rapidly computed from a conceptual model [40].

While NRM1 standardises the structure of cost plans, practitioners still need to supply quantities of work (e.g. areas of finishes, volumes of concrete) to apply rates. Traditionally, this required manual measurement or specialised estimating software, guided by SMM/NRM measurement rules [37]. The advent of BIM promises to automate quantity take-off, feeding directly into 5D cost models. Recent studies highlight that effective BIM workflows can dramatically speed up costing by linking BIM geometry to cost databases [21]. However, achieving this requires careful mapping between the model’s data schema and the cost coding scheme. In particular, common BIM classification systems like OmniClass or UniFormat (used in Revit and many tools) do not directly match the UK NRM breakdown [43].

Therefore, a key challenge is extracting the right data from a Revit model and aligning it with NRM categories. For example, Revit elements can provide properties such as volume, area, length, and custom parameters [2]. These must be filtered and aggregated according to NRM group/element. One approach is to use Revit shared parameters or schedules to assign an NRM code to each type of element; a recent case study [5] did exactly this, creating shared parameters in Revit for NRM1 codes and using schedules to generate an automated bill of quantities aligned with NRM. However, there still remains a gap between implementing NRM 01 rules properly with preliminary planning techniques, and the result of our research focuses on creating a model that accurately provides an elemental cost plan.

This research addresses the critical gap in accessible, NRM 01-compliant BIM-ECP tools by proposing the development of a user-friendly Revit plugin using C#, selected for its seamless integration with Revit’s API and superior performance over traditional desktop-based solutions. The study aims to develop a conceptual framework and automated workflow for Elemental Cost Planning (ECP) that leverages cloud-based APIs to integrate directly with Revit models. A core objective is to establish a robust methodology for extracting and mapping BIM quantities to NRM 01-defined elemental categories. The research further defines comprehensive ECP calculation formulas, incorporating preliminaries, overheads, profit, risk allowances, and inflation to ensure full compliance with RICS standards. In response to the current lack of web-enabled, standardised tools, the study proposes a practical model development strategy that demonstrates the tool’s accuracy and efficiency, particularly for private sector entities already aligned with NRM 01, thus

supporting broader industry adoption of structured, digital cost management practices.

## 2. LITERATURE REVIEW

### 2.1 Elemental Cost Planning Techniques

Elemental Cost Planning (ECP) is an indispensable tool in quantity surveying, specifically designed for estimating and managing construction project costs, particularly during the early design stages [30]. Its core methodology involves systematically breaking down a project's total cost into functional components or "elements," such as substructure, superstructure, finishes, and building services [42]. ECP offers several strategic advantages. It enables continuous monitoring of costs throughout the design development phase, ensuring that the final tender amount remains aligned with initial estimates and that financial resources are allocated deliberately and economically across various project components. This approach is often termed 'designing to a cost' or 'target cost planning,' as it establishes a cost limit for the scheme, guiding the design process to adhere to this financial target [41].

The efficacy of ECP is significantly bolstered by standardised classification systems, notably UNIFORMAT II (ASTM E1557) and the New Rules of Measurement (NRM) prevalent in the UK [6][30]. UNIFORMAT II, developed by the American Society for Testing and Materials (ASTM E1557), offers a hierarchical format for classifying building elements and related site work. It comprises multiple levels of detail, with Level 1 identifying major group elements such as "Substructure," "Shell," "Interiors," "Services," "Equipment and Furnishings," "Special Construction and Demolition," and "Building Site Work." [6].

In the United Kingdom, Elemental Cost Planning is closely aligned with the New Rules of Measurement (NRM), specifically NRM1: Order of Cost Estimating and Elemental Cost Planning [7,25]. NRM provides a comprehensive set of measurement rules, definitions, and guidelines for quantifying construction works, thereby promoting consistency, transparency, and accuracy in cost planning. NRM1 defines a series of group elements (numbered 0 to 14), which include categories such as "Facilitating Works," "Substructure," "Superstructure," and "Services," each further broken down into detailed sub-elements [34]. These systems provide consistent frameworks for classifying building elements and collecting historical cost data, which are fundamental to accurate and comparable cost analyses.

### 2.2 Building Information Modeling (BIM) Concept

The advent of Building Information Modeling (BIM) has marked a transformative development in the Architecture, Engineering, and Construction (AEC) industries [44]. BIM represents a digital model and data platform that integrates comprehensive information related to building design, construction, and operation [10]. The integration of cost information with the traditional 3D BIM model and the project schedule has given rise to the concept of 5D BIM [28]. 5D BIM integrates cost data into the 3D model, enabling automated quantity takeoff and dynamic cost updates [14], shows 5D-BIM greatly improves cost estimation accuracy and efficiency by automating quantities, enhancing visualisation, and accommodating design changes.

The state of BIM adoption in Sri Lanka is still nascent. One survey found Sri Lankan Quantity Surveying (QS) firms often use CostX, Cubicost, Revit, among other BIM tools for estimating [3]. Thus, usage is largely ad hoc. Further to the author, BIM software like CostX/Cubicost can link quantities to cost databases and unify BOQ codes, increasing the reliability of cost data. Nonetheless, many organisations remain at BIM Level 0–1 with low overall uptake [24]. A recent framework, Object-Oriented Evolutionary

Estimating (O2E2), was proposed to integrate cost estimation into BIM via IFC exchange and evolving Levels of Detail, but such approaches are still theoretical in Sri Lanka [12].

5D BIM represents a significant advancement in project management, defined by the integration of cost information (the fifth dimension) with the traditional 3D BIM model and the project schedule (the fourth dimension) [29]. This integration transforms the static building model into a dynamic, "live" cost estimation tool, where any changes made to the 3D design automatically trigger real-time updates to the associated project estimates and budgets [19]. While 5D BIM automates quantity take-off, its true value lies in

intelligently linking raw quantities to structured cost categories using dynamic rates, enabling real-time financial feedback on design decisions. This requires a sophisticated data model and rule-based logic to transform complex BIM data into meaningful cost insights aligned with Elemental Cost Planning, driving continuous value engineering and proactive budget control [11].

Many existing BIM-based tools, like Autodesk Revit (often enhanced with specialised plugins), Autodesk Navisworks, CostX, Nomitech, and CostOS, while capable of generating Bills of Quantities (BOQs), often lack the ability to independently analyse this data [34]. They frequently necessitate integration with other applications or external databases to transmit information between design and management models for comprehensive cost evaluations. This reliance on disparate systems can introduce inefficiencies and data transfer issues [33].

### **2.3 Review of BIM API Platforms – Revit API vs. Autodesk Forge (APS)**

The development of BIM-integrated tools heavily relies on the capabilities of available Application Programming Interfaces (APIs). Two primary platforms stand out for interacting with Autodesk Revit models: the Revit API and Autodesk Forge (now known as Autodesk Platform Services, APS) [4]. Understanding their differences is crucial for selecting the most suitable development approach. This API is a set of programming interfaces accessible through Microsoft .NET frameworks, such as Visual C# or Visual Basic.NET. It is primarily used to create external instructions and programs, commonly referred to as plugins or add-ins, that run directly within the Revit desktop application [2]. In contrast, Autodesk Forge is a cloud-based developer platform offering a comprehensive suite of APIs designed for interacting with various design files, including Revit models, within a web environment [45].

Model Derivative API is a cornerstone of Forge for data extraction from BIM models in the cloud. It facilitates the translation of source design files, such as Revit's native RVT format, into various derivative formats, including SVF/SVF2 for web viewing (*Model Derivative API | Autodesk Platform Services (APS)*, 2025). Crucially, during this translation process, it extracts comprehensive metadata, including the object hierarchy, properties, and geometries of the model elements. This API allows for fetching specific properties and quantities (e.g., "Area," "Volume," "Length" for linear elements, "Thickness" for layered elements, and "Quantity" for discrete components) from individual elements, which is fundamental for automated quantity take-off [46].

The Viewer API enables the display and interactive manipulation of the translated 3D models directly within a standard web browser. This API allows users to navigate the model, select individual elements, and retrieve their associated properties, providing a powerful visual interface for data validation and interactive exploration [47].

## 2.4 Automated BIM-ECP Conceptual Framework

Fig. 1 represents the BIM-ECP Conceptual Framework,

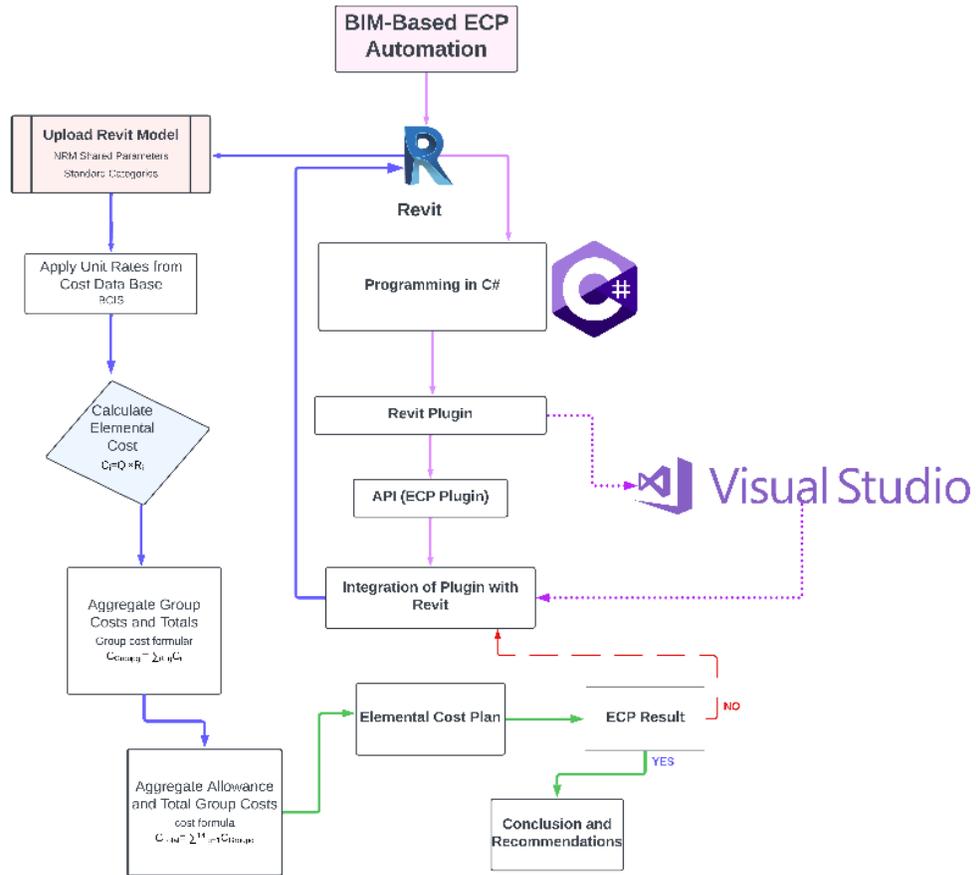


Fig. 1 - Conceptual Framework for Development of BIM-ECP Tool

## 3. METHODOLOGY

### 3.1 Research Approach

This research adopts a two-phased mixed-method approach to develop and validate a BIM-based Elemental Cost Planning (ECP) tool aligned with NRM 01. Phase One involves the creation of a conceptual framework based on a comprehensive literature review. This framework will be evaluated and refined through data collected from industry professionals using both surveys and semi-structured interviews. The survey aims to quantitatively assess the feasibility, current practices, and challenges of ECP implementation in the Sri Lankan construction industry, while interviews with selected professionals, each with a minimum of three years of industry experience, will provide qualitative insights to complement and enrich the findings. The conceptual framework will then be redeveloped based on this feedback to better reflect practical industry needs.

In Phase Two, the revised framework will serve as the basis for developing a functional web-based ECP tool integrated with Autodesk Revit via Visual Studio and C# Programming. This prototype will then be implemented and tested across three active residential and commercial construction projects in Sri Lanka. The second phase will assess the tool's real-world usability, accuracy, and performance, helping to validate and finalise the proposed solution. This approach ensures that the tool is grounded in both academic knowledge and practical industry experience, enhancing its relevance and applicability. Figure 2 elaborates

the research approach.

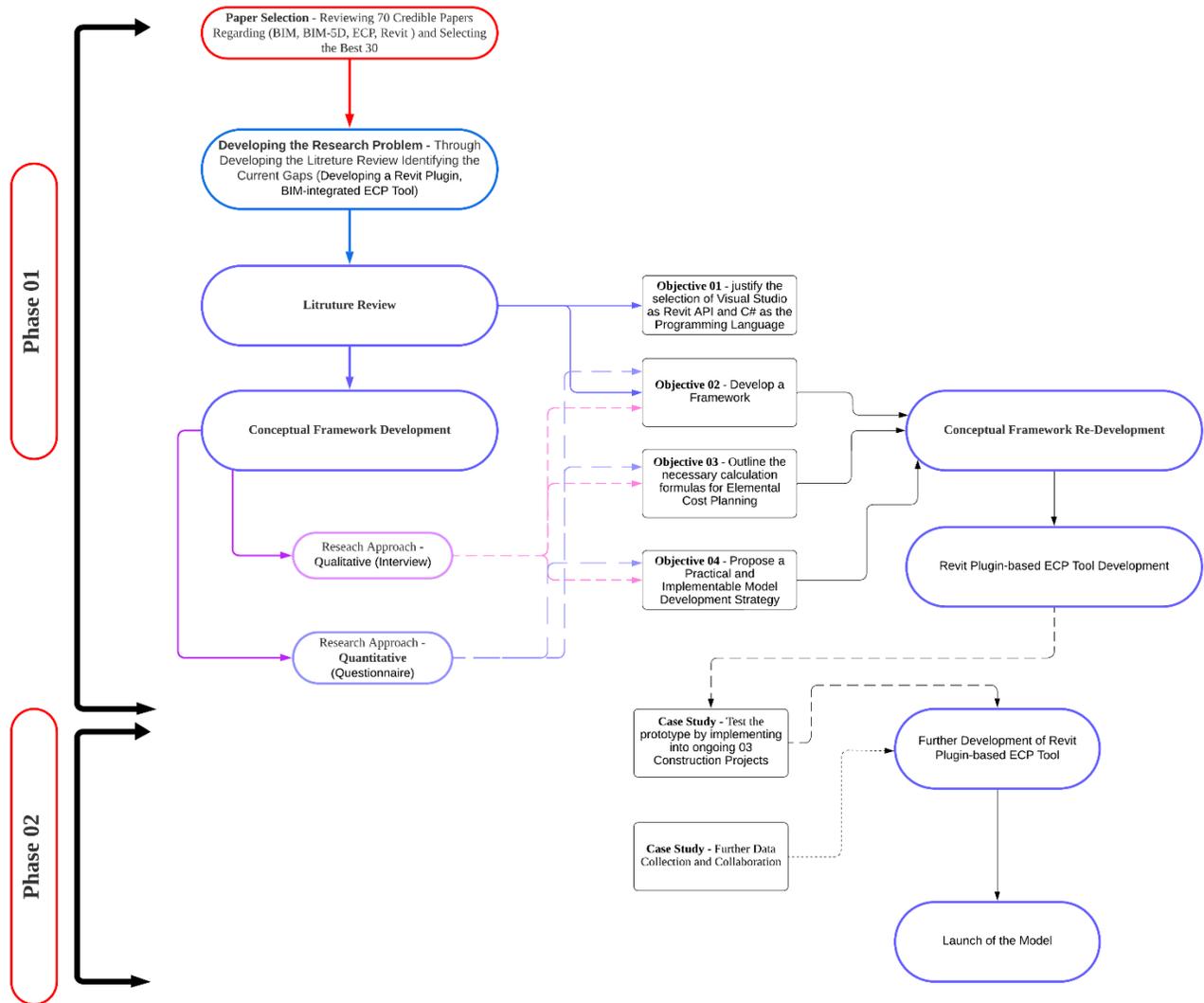


Fig. 2 - Research Process

### 3.2 Data Analysis Methods

For this research on developing a justified algorithm for Elemental Cost Planning (ECP) using NRM 01 with time and location adjustment factors, data analysis primarily focused on interpreting technical inputs from literature, BIM datasets, and Revit API integration processes. A mixed-method approach was used, combining structured content analysis of documentation and prototype evaluations with quantitative assessments derived from plugin test runs. Descriptive statistics were applied to BIM-extracted quantities (area, volume) to calculate cost outputs, while parametric adjustment factors (inflation rates, regional indices) were integrated for scenario testing.

Thematic coding was employed to identify recurring development patterns, plugin functionality gaps, and stakeholder-relevant criteria. Visual analysis was conducted through Excel-based charts and Power BI dashboards to present cost variations and performance metrics. Code validation and logic verification were achieved using sample models within Autodesk Revit, ensuring computational accuracy. This multi-layered approach ensured that both algorithmic and implementation insights were critically examined and aligned with the study’s objectives of automating and contextualising ECP in digital construction environments.

### 3.3 Revit Data Extraction Methods

Extracting BIM Data and Mapping to NRM Categories Revit Data Extraction Methods Revit models contain a wealth of information (families, parameters, geometry) that can drive quantity take off. To extract this data programmatically, one typically uses the Revit API or related tools. In a web context, Autodesk Forge offers two main options, which are the Model Derivative API and Design Automation for Revit. Regardless of the method, the extracted data must include quantities (e.g. lengths, areas, volumes, counts) and identifiers (e.g. category or type) to enable classification. For instance, one could extract all walls and sum their parameter to get Area external wall area, or extract volumes of structural elements. Advanced extraction can combine geometry computation (e.g. volumes) with parameter readout (material types, dimensions).

### 3.4 Mapping to NRM Elemental Categories

Once raw data is available, the next step is to map each quantity to an NRM element code. Since Revit does not natively use NRM codes, some mapping strategy is required. Possible and most suitable approach is to Shared Parameter (Custom NRM Code), which is a more direct approach is to attach an NRM element code to each Revit type or instance via a shared parameter [37] defined shared parameters corresponding to NRM1’s levels and categories and manually assigned the appropriate NRM code (e.g., “2.6.1” for external windows) to each element type during modeling or scheduling. The tool then reads this shared parameter and uses it to bucket quantities. This method ensures an exact mapping but requires extra work setting up the Revit model.

### 3.5 Formulas and NRM Cost Calculation Methodology

The elemental cost plan is underpinned by simple formulas. The fundamental relationship is: Elemental Cost = Measured Quantity × Element Unit Rate. In notation:

$$C_i = Q_i \times R_i,$$

Where,

- $C_i$  is the cost of element  $i$  (e.g., “Roof” element),
- $Q_i$  is the extracted *element quantity* (e.g., roof area in m<sup>2</sup>),
- $R_i$  is the *element unit rate* (e.g. £/m<sup>2</sup> for roof).

This follows NRM1 guidance – element unit quantities (EUQs) are measured and then priced with suitable element unit rates (EURs) to form a cost target for that element. If detailed quantities for a particular element are not available at an early stage, NRM suggests using a proxy (e.g., Gross Internal Floor Area) as the EUQ until refined.

Once each element cost  $C_i$  is computed, costs are aggregated by element group as follows:

$$\text{Group cost (for group } g) = \sum_{i \in g} C_i.$$

For example, if Group 2 (Superstructure) has elements 2.1 (Frame), 2.2 (Floors), 2.3 (Roof), etc., then  $C_{\text{Group}2} = C_{2.1} + C_{2.2} + C_{2.3} + \dots$ . The *Total Building Cost* (sum of group 1–8) is the sum of all such group totals.

Separately, allowances like Main Contractor’s Preliminaries (Group 9), Overheads/Profit (Group 10), Fees (Group 11), Other Costs (Group 12), Risks (Group 13), and Inflation (Group 14) are computed per NRM rules. For example, preliminaries may be entered as fixed items (9.1.1 Site accommodation, etc.) or as

a percentage. Overheads (10.1) and profit (10.2) are often a percentage markup on substructure + superstructure (groups 1–8). Risk allowances (group 13) are typically contingency sums. Inflation (14.1, 14.2) covers pre-tender and construction period inflation, as defined in NRM In formula terms, one might express:

- $C_{Group10} = \alpha \times (C_{Sub-structure} + C_{Superstructure} + \dots + C_{External Works})$ , where  $\alpha$  is the main contractor's overhead rate (e.g., 5%).
- $C_{Total} = \sum_{g=0}^{14} C_{Group\ g}$

All these calculations can be clearly codified in the tool's backend logic. Table 2.2 of NRM1 defines measurement rules for elemental quantities, which our tool follows when interpreting BIM data. The linking of extracted BIM quantities (e.g., Revit "Length", "Area", "Volume" parameters) to NRM EUQs must respect these rules (for instance, measuring concrete volume in situ vs. formwork area). For our purposes, we ensure each Revit property used corresponds to the correct NRM basis.

In summary, the cost engine applies per-element formulas (cost = quantity  $\times$  rate) and summations. The user may optionally review or override unit rates. Formulas are transparent, as required for a professional cost plan. For example, an internal wall finish element might be calculated as

$$\text{Cost}_{3.1} = (\text{Total wall finish area from BIM}) \times (\text{rate } \text{£}/\text{m}^2 \text{ for wall finish})$$

and this element cost would feed into the internal finishes total. By coding these formulas into the tool, we can regenerate the ECP with any updated BIM data or cost library.

### 3.6 ECP Algorithm

At its core, the methodology utilizes the standardized elemental breakdown of NRM 01 to organize cost data and link it directly to quantities extracted from BIM models. By integrating shared parameters within Revit to tag each element with a corresponding NRM code, the algorithm ensures seamless classification and alignment of model data with the cost planning structure, facilitating real-time updates and consistent cost tracking as the design evolves.

Once BIM elements are mapped to their NRM categories, quantities such as area, volume, or length are extracted using the Model Derivative API. These raw quantities are then combined with Element Unit Rates (EURs) sourced from cost databases or historical benchmarks to calculate the elemental cost using the standard formula  $C_i = Q_i \times R_i$ , where  $C_i$  represents the cost of element  $i$ ,  $Q_i$  is the extracted quantity, and  $R_i$  is the adjusted unit rate. This fundamental calculation forms the basis of the cost plan, which is then aggregated by elemental groups as defined in NRM 01.

To ensure the relevance and accuracy of the estimates in varying temporal and geographic contexts, the algorithm incorporates both time and location adjustment factors. Time adjustment is handled through inflation indices such as the Tender Price Index (TPI), which modifies base rates to reflect current market conditions. Simultaneously, a Location Adjustment Factor (LAF) accounts for regional construction cost variances, ensuring that rates are localized for specific project settings. These adjustments are embedded into the cost computation pipeline, with final rates calculated as,

$$R_{adj} = R_{base} \times \frac{(1 + \Delta TPI)}{TPI_{base}} \times LAF$$

The final output is a dynamic elemental cost breakdown that not only aligns with professional standards but is also responsive to design changes, cost escalations, and geographical factors. By codifying the NRM 01 cost logic within a Visual Studio environment using C# as the programming language, the approach facilitates broader accessibility, interoperability, and ease of use for quantity surveyors and cost planners. This framework enhances transparency, accuracy, and efficiency in early-stage cost planning while supporting the ongoing shift toward digital transformation in the construction industry.

NRM Element	Quantity	Base Rate	Adjusted Rate (w/ 6% inflation, 1.1 LAF)	Element Cost
2.2.1 Upper Floors	120 m <sup>2</sup>	£120/m <sup>2</sup>	£120 × 1.06 × 1.1 = £140.16/m <sup>2</sup>	£16,819.20

Fig.3 - Justified ECP Algorithm Using NRM 01 with Time and Location Adjustment Factors

### 3.7 ECP Plugin Development

The development of an Elemental Cost Planning (ECP) plugin within Autodesk Revit is a highly technical yet powerful process that allows for the automation of cost estimation using BIM data. This development is executed using the C# programming language within the Microsoft Visual Studio environment, and it leverages the Revit API—specifically the RevitAPI.dll and RevitAPIUI.dll libraries, to access and manipulate BIM data. These libraries enable developers to interact programmatically with Revit model elements, user interface components, and project data, forming the backbone of any Revit-based plugin.

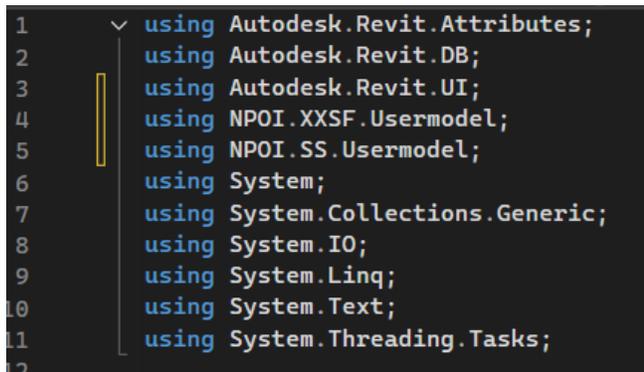
At the core of the ECP plugin is its ability to extract and process building element quantities such as area, volume, and length. The plugin uses the FilteredElementCollector class to iterate through Revit model elements by category (e.g., walls, floors, roofs), and accesses geometric and parametric data using the Parameter class. These raw quantities are then converted from Revit’s internal units (Imperial) to metric units (such as square meters) using the UnitUtils class. Each element is also mapped to a standardized classification using NRM 01 codes, which can be embedded into the BIM model via shared parameters.

Once the quantities are extracted, the plugin calculates the cost for each element using a formula that incorporates base unit rates and adjustment factors. Specifically, the cost is calculated as the product of the element’s quantity and its adjusted rate, where the rate is adjusted for both time (e.g., inflation) and location (e.g., regional cost indices). This dynamic pricing model as example Figure 3 ensures that the cost estimates produced are context-sensitive and reflect real-world conditions. For example, a base rate of £120/m<sup>2</sup> could be adjusted using a time inflation factor of 1.06 and a location adjustment factor of 1.10, resulting in an effective unit rate of £140.16/m<sup>2</sup>.

The plugin also includes an automated reporting module using the NPOI library as represented in Figure 4, which allows developers to generate and manipulate Excel files programmatically. Thus, to extract data from Revit and to make Excel Sheets we need “NPOI.XSSF” and “NOPI. SS” specifically. This module creates a structured spreadsheet that includes each element’s name, NRM code, quantity, base and adjusted rates, and total cost. This spreadsheet is automatically exported to the user's desktop, making the process

seamless and user-friendly. The use of Excel ensures that cost data is accessible and can be further analyzed or integrated into other cost management systems without requiring additional software.

To make the tool accessible within Revit, a custom user interface is created, typically in the form of a new ribbon tab with a command button that launches the ECP tool. When clicked, the plugin runs its command class, collects the model data, performs calculations, and exports the final cost plan. This integration eliminates the need for external cost estimation tools or manual data entry, streamlining workflows and improving accuracy.



```

1  using Autodesk.Revit.Attributes;
2  using Autodesk.Revit.DB;
3  using Autodesk.Revit.UI;
4  using NPOI.XSSF.UserModel;
5  using NPOI.SS.UserModel;
6  using System;
7  using System.Collections.Generic;
8  using System.IO;
9  using System.Linq;
10 using System.Text;
11 using System.Threading.Tasks;
12

```

Fig. 4 - Implementing NPOI in Visual Studio for Program the Data Sheets

### 3.8 ECP-BIM plugin for Revit using Visual Studio and C#

In this research, the development and integration of the ECP-BIM plugin were executed through a systematic six-step process using Visual Studio and Autodesk Revit's API. Initially, a Class Library project was created in Visual Studio with .NET Framework 4.8 to support Revit's plugin architecture. RevitAPI.dll and RevitAPIUI.dll were then referenced to enable interaction with Revit's model elements and user interface. The core logic was developed in C# by implementing the IExternalCommand interface, allowing the extraction of element data such as area and volume for cost calculations aligned with NRM 01 standards.

A .addin manifest file was configured and placed in Revit's Add-ins folder to register the plugin. The compiled DLL was generated through the Release build and deployed into Revit's plugin directory. Functional testing was conducted within Revit to validate data extraction and automated cost computation. This structured plugin development approach enabled seamless integration of real-time cost planning within the BIM environment, supporting the research. The above process is represented by Figure 5 and 6.

## 4. RESULTS AND DISCUSSION

Based on the analysis of both quantitative survey data and qualitative expert interviews, several critical insights emerged that will directly inform the refinement of the conceptual framework and the development of the initial BIM-based Elemental Cost Planning (ECP) model. A key outcome of the research was the strong consensus among industry professionals on the necessity of incorporating **time and location adjustment factors** into the cost planning algorithm. This emphasis aligns with the industry's demand for context-sensitive modelling that reflects economic fluctuations and regional pricing disparities. These factors were deemed essential preconditions that should be embedded at the conceptual stage, before full model development, to ensure both realism and applicability.

While ECP is already practised in the Sri Lankan construction industry, findings confirm that **5D BIM**

**integration**, which combines cost with design data, remains a relatively new concept within the local AEC sector. Experts highlighted that the adoption of a BIM-based ECP tool would fill a critical technological gap. Furthermore, the decision to embed **NRM 01** published by the Royal Institution of Chartered Surveyors (RICS), rather than the Sri Lankan SLS573, was heavily endorsed due to its international recognition and wider applicability. NRM 01 and BCIS standards provide structured measurement rules and elemental breakdowns that are not only methodologically sound but also globally accepted, enhancing the clarity and reliability of the model. In contrast, SLS573 was noted to be more restrictive and complex in implementation [15].

Consequently, these insights will be foundational in redeveloping the conceptual framework and structuring the BIM-ECP integration logic. They validate the need for a standards-driven, globally compatible model that addresses local project realities while also positioning the tool for potential international scalability and professional relevance.

#### 4.1 ECP Practice in Sri Lanka

The following table 1 illustrates a typical elemental cost breakdown in Sri Lankan construction, reflecting the average percentage contribution of major cost elements to the total project cost. This provides a quantitative overview of how costs are commonly distributed across different components.

Table 1 - Elemental Cost Breakdown in Sri Lankan Construction

Element Category	Average Percentage Contribution to Total Cost	Example Sub-Elements/Components
Material	40%	Concrete, Steel, Bricks, Timber, Finishes (e.g., flooring, wall finishes, ceilings, joinery, painting)
Labour	24%	Site labour, skilled and unskilled labour for various trades (e.g., masonry, concrete, finishing, roofing)
Plant & Equipment	9%	Machinery, tools, and equipment used on-site
Preliminaries	10%	Project management, site setup, temporary works, insurances, and general conditions
Overheads & Profit	17%	Contractor's establishment costs, supervision, taxes, and reasonable profit margins
<b>Total</b>	<b>100%</b>	

*Note – This breakdown represents average contributions based on the respective data collection survey done and can vary based on project type, size, complexity, and specific market conditions.*



Fig. 5 - BIM-ECP Plugin Development in Visual Studio

```

37
38 // Sample unit rates per NRM 01 codes (can be loaded from external DB in advanced version)
39 Dictionary<string, double> unitRates = new Dictionary<string, double>
40 {
41     {"2.1.1", 120}, // External Walls - £/m2
42     {"2.2.1", 110}, // Upper Floors - £/m2
43     {"2.3.1", 130}, // Roof - £/m2
44 };
45
46 // Create Excel workbook
47 IWorkbook workbook = new XSSFWorkbook();
48 ISheet sheet = workbook.CreateSheet("ECP Cost Plan");
49
50 // Header
51 IRow header = sheet.CreateRow(0);
52 header.CreateCell(0).SetCellValue("Element ID");
53 header.CreateCell(1).SetCellValue("Element Name");
54 header.CreateCell(2).SetCellValue("NRM Code");
55 header.CreateCell(3).SetCellValue("Quantity (m²)");
56 header.CreateCell(4).SetCellValue("Base Rate");
57 header.CreateCell(5).SetCellValue("Adj. Rate");
58 header.CreateCell(6).SetCellValue("Element Cost");
59
60 int rowIndex = 1;
61 double totalCost = 0.0;
62
63 // Process each relevant category
64 ProcessElements(doc, BuiltInCategory.OST_Walls, "2.1.1", unitRates, inflationRate, locationFactor, sheet, ref rowIndex, ref t
65 ProcessElements(doc, BuiltInCategory.OST_Floors, "2.2.1", unitRates, inflationRate, locationFactor, sheet, ref rowIndex, ref t
66 ProcessElements(doc, BuiltInCategory.OST_Roofs, "2.3.1", unitRates, inflationRate, locationFactor, sheet, ref rowIndex, ref t
67
68 // Total row
69 IRow totalRow = sheet.CreateRow(rowIndex);
70 totalRow.CreateCell(5).SetCellValue("Total Cost:");
71 totalRow.CreateCell(6).SetCellValue(Math.Round(totalCost, 2));
72
73 // Save Excel file
74 string path = Environment.GetFolderPath(Environment.SpecialFolder.Desktop) + "/ECP_CostPlan.xlsx";

```

Fig. 6 - Codding for Generating Data Rows and Cells and implementing ECP Formula

The analysis confirms that location adjustment factors are critical for achieving accurate and context-sensitive construction cost estimates in Sri Lanka. Despite this, current practices largely neglect formal location indices, relying instead on a generalized cost index that primarily reflects time-based changes. This oversight introduces significant risk, particularly given the considerable regional variations in labour costs, material availability, market rates, and logistical challenges [23]. The absence of standardized location-based data, as highlighted by the limitations of the Construction Industry Development Authority (CIDA) bulletin, further exacerbates this issue, leaving practitioners to rely on ad-hoc or inconsistent adjustments. Key variables influencing regional cost disparities include proximity to Colombo (the capital and economic hub), site conditions, project complexity, and local regulatory and climatic conditions. Urban projects tend to be more expensive due to higher wages, logistical constraints, and increased site management needs. These findings underscore the importance of integrating dynamic, data-driven location adjustment mechanisms into the proposed BIM-ECP framework. Doing so would ensure greater accuracy, budget reliability, and regional applicability, addressing a significant gap in current Sri Lankan construction cost planning methodologies.

The analysis highlights that protectionist tariffs on key construction materials, such as cement, steel, and tiles, are a major driver of elevated construction costs in Sri Lanka, estimated to be 40% higher than in regional counterparts. These tariffs, alongside limited market competition and high energy costs, inflate material prices, reduce affordability, and contribute to regional cost disparities. Import restrictions, despite existing Free Trade Agreements, limit access to competitively priced materials, forcing reliance on costlier local production. Additionally, economic and infrastructure development remain disproportionately concentrated in the Western Province, leading to inaccurate cost estimations when applying a uniform national index.

The absence of a formal location index exacerbates this issue, as regional variances in labour, materials, and logistics are not adequately captured, particularly outside the Colombo Megalopolis. This reliance on professional judgment for location-based adjustments is inconsistent and unsustainable. The findings underscore an urgent need for policy reform and the implementation of standardized, data-driven regional cost indices by authorities like CIDA to enhance cost accuracy, promote equitable development, and support more efficient, evidence-based construction planning across Sri Lanka [48].

#### 4.2 Impact of Location Factors on Construction Cost Elements in Sri Lanka

The following table 02 illustrates the identified impact of various location factors on different construction cost elements in Sri Lanka, based on available research.

Table 2 - Impact of Various Location Factors on Different Construction Cost Elements in Sri Lanka

Location Factor	Impact on Material Cost	Impact on Labour Cost	Impact on Plant & Equipment Cost	Impact on Preliminary Cost	Impact on Overheads & Profits Cost
Distance from Colombo	Moderate (0.071)	Moderate (0.077)	Moderate (0.085)	Not specified	Not specified
Local Market Condition	High (0.140)	High (0.130)	High (0.204)	Moderate (0.057)	High (0.276)
Availability and Price of Labour	Not specified	High (0.255)	Moderate (0.032)	Moderate (0.035)	Moderate (0.075)
Legal Issues	High (0.120)	High (0.109)	High (0.196)	High (0.162)	High (0.124)
Ground Condition	Not specified	High (0.123)	Very High (0.357)	Very High (0.301)	High (0.230)
Climate	Moderate (0.105)	Very High (0.383)	Moderate (0.059)	High (0.229)	High (0.239)

*Note – Numerical values in parentheses represent relative importance or impact scores from Data Collection, where higher values indicate a greater impact. "Not specified" indicates the impact was not explicitly quantified for that combination in the provided material. Generally, urban areas tend to be more expensive due to higher wages, access constraints, and security requirements.*

#### 4.3 ECP-BIM-Based Revit Plugin Development

### 5. RESEARCH LIMITATIONS

This research identifies a critical limitation in Sri Lanka’s construction cost management: the absence of granular, region-specific data for accurate cost estimation. Although multiple data sources exist, such as CIDA, CBSL, and DCS, they operate in isolation, offering fragmented and incomplete insights. The prevailing reliance on a single, time-based cost index, without accompanying location indices, undermines the ability to reflect regional price fluctuations. The CIDA bulletin, while regularly publishing national indices, omits location-specific factors, compelling practitioners to rely on subjective professional judgment when estimating regional costs. This introduces inconsistency and weakens the reliability of cost

forecasts, particularly for projects outside the Western Province, where most economic data is concentrated. Moreover, protectionist tariffs and variable local material costs further intensify regional disparities, which cannot be objectively captured without disaggregated data.

The lack of integrated, standardised datasets inhibits the adoption of structured frameworks like NRM, which require detailed elemental and location-based inputs. This results in persistent cost overruns and inaccurate budgeting across diverse project locations. The findings highlight the urgent need for a centralised, comprehensive construction cost database, led by institutions such as CIDA or IQSSL, that systematically integrates material, labour, plant, and overhead costs by region [27]. Such a database would significantly enhance the accuracy of Elemental Cost Plans, support the effective application of NRM standards, enable robust benchmarking, and contribute to more equitable infrastructure development and investment planning across Sri Lanka's regions. Developing a fully localised Revit plugin for Sri Lanka is challenged by the lack of a standardised national cost database, regional indices, and digital measurement rules. In contrast, using NRM 01 offers a structured, internationally recognised framework that enhances accuracy, benchmarking, and transparency in early-stage cost planning. While it may not fully capture local nuances, it supports global best practices. Given that some private sector entities already apply NRM 01, the developed model is well-suited for validation in future case studies.

## **6. FUTURE DIRECTION**

As a continuation of this research, future studies can focus on conducting real-world case studies to validate the developed BIM-ECP plugin within selected construction projects in Sri Lanka. These studies can assess the model's accuracy, efficiency, and adaptability in practical settings, particularly in organisations already aligned with NRM 01. Further research may also explore integrating local cost databases, developing formal regional cost indices, and expanding the plugin's capabilities to support lifecycle costing (LCC) and sustainability metrics. Additionally, the incorporation of cloud-based collaboration features and user interface enhancements could be investigated to improve usability and broader industry adoption.

## **7. CONCLUSION**

This study has demonstrated the development of an automated Elemental Cost Planning (ECP) tool integrated into Autodesk Revit software, specifically designed to align with NRM 01 standards. The research identified the persistent gap in structured, BIM-based cost planning tools within the Sri Lankan construction industry, particularly tools that incorporate both time and location adjustment factors. While BIM is increasingly adopted for design and coordination purposes, its integration with standardised cost planning, especially at the conceptual stage, remains underdeveloped locally. Thus, the main objective of this study was to develop a plugin using C# within Visual Studio, capable of extracting quantities directly from BIM objects and systematically mapping them to NRM-defined elemental categories.

By leveraging the Revit API, this plugin automates cost calculations, including provisions for preliminaries, overheads, profit, inflation, and regional factors. The findings from expert consultations revealed that some private sector stakeholders already recognise and apply NRM 01, suggesting strong relevance and adoption potential for the developed tool. Therefore, this research has successfully culminated in the development of a functional Revit-based BIM-ECP plugin, presenting a structured, globally informed yet locally tailored solution to enhance early-stage cost management practices within the Sri Lankan AEC context.

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