Construction Cost Estimate and Building Information Modeling in Renovation Projects Early Design Stages

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Abstract. The evaluation and control of building costs accompany real estate projects from the initial planning phase to the end of the construction stage. Each phase of project development is associated with distinct estimation methodologies, characterized by an increasing level of accuracy as the design progresses. Estimating construction costs during the early design stages is one of the most critical challenges in real estate and infrastructure investment planning. At these stages, detailed cost estimates based on bills of quantities are always unfeasible, as project information is typically limited to concise descriptions of functions and dimensions. Consequently, assessments rely on parametric methods, which involve identifying one or more reference buildings with similar characteristics to the planned one, using historical data on its costs as a basis for estimation. The cost of the reference buildings can be sourced from market monitors or specialized publications, such as building cost inventories. These inventories, in addition to providing construction costs divided by groups of work items, typically include key dimensional data, works brief description, and project excerpts. This study presents the results of BIM modeling for one of the buildings included in an inventory widely used in Italy, aiming to explore the potential of this technology to enhance cost estimate accuracy in the early design stages. The accuracy of parametric estimates based on data from the inventory and those derived from the BIM model is validated by comparison with a case study, for which the construction cost has been assessed through a bill of quantities.

Keywords: Building Information Modeling · Parametric construction cost estimate · Real estate investment planning

1 Introduction

The assessment and control of construction costs is an activity that involves the building process from the initial phases of investment planning to the conclusion of the construction and the commissioning of the property. In the architecture, engineering, and

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construction industry - and in the manufacturing sector, more generally - each phase of project development is paired with different cost estimation methodologies. The choice of the methodology to be used depends on the availability of information in each project phase and on the purpose of the assessment. The literature has provided various classifications of cost estimation methodologies with reference to the phases of product development [1, 2]. Regarding the construction industry, and based on a classification provided by [3], Aram et al. [4] have identified two categories related to the maturity level of project definition. The first one, suitable for use in the early design stages, comprises intuitive and analogical techniques, through which project costs are estimated based on historical data from similar projects. The second category, used in late design stages, includes analytical methods, which involve breaking down the construction to calculate its cost as the sum of the prices of its individual components or operations.

The accuracy of cost estimates is expected to increase as the project progresses: the more information is provided, the more precise the assessment becomes. AACE (Association for the Advancement of Cost Engineering) International [5] has developed a matrix that illustrates the general relationship between project development maturity, categorized into five classes based on the percentage of complete project definition, and the expected accuracy range of estimates for each phase. The relationship is shown in the following Fig. 1.

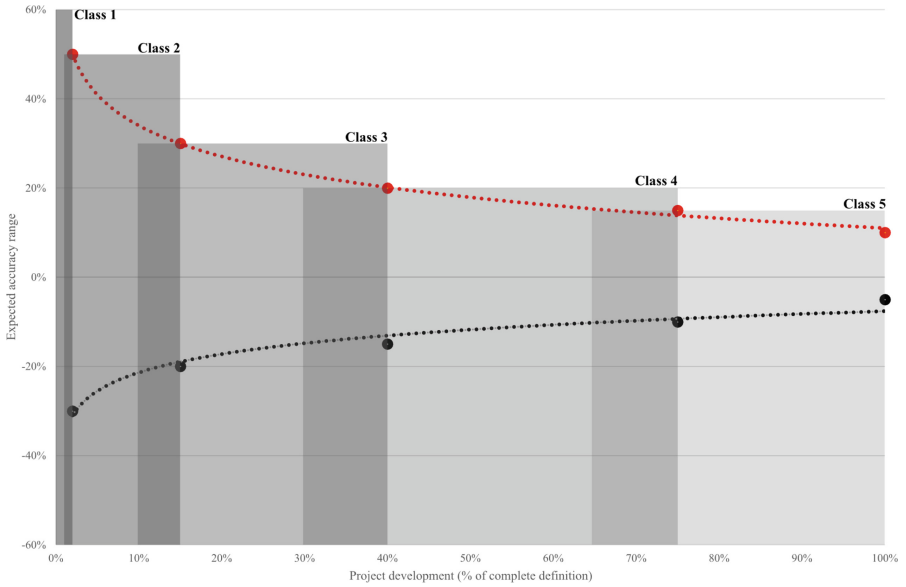


Fig. 1. Expected accuracy range based on maturity level of project definition (source: AACE International [5]).

Estimating construction costs during the early design stages is one of the most critical challenges in real estate investment planning [6–8]. Indeed, despite the limited design

information and unpredictable external factors [3], early estimates significantly influences a projects success or failure as 70%–80% of the total building costs are determined at this stage, leaving little room for adjustments in later phases [6, 7].

If we assume that early design stages correspond to class five and four of the classification proposed by AACE, project information are often limited to location, building typology, functional space requirements, number of stories, preliminary room layouts, design criteria report, or technical memorandum by division of works, and the accuracy level of estimates can range from −30%/−20% to +30%/+50%, depending on the projects complexity, degree of definition, availability of reference data, and also including an appropriate contingency[1] definition.

The purpose of this research is to verify whether the adoption of BIM (Building Information Modeling) design can improve the accuracy of construction cost estimates in the early design stages, with particular reference to renovation projects. In fact, although some studies highlight the need to deepen the use of BIM for cost estimation – the so-called fifth dimension of BIM [9, 10] – in the early design stages [11–14], much of the literature has primarily focused on using this technology for detailed cost estimation in late design stages [15], including the analysis of costs related to alternative design scenarios [16], improving quantity take-off activities [17, 18], reducing errors when drafting bills of quantities [19], and monitoring project progression [20].

To assess the potential of using BIM to enhance the accuracy of estimates during early design stages, the case study of a dwelling renovation will be analyzed. The cost, estimated through a bill of quantities in the late design stages, will serve as the benchmark for comparing early estimates made using traditional methods and those based on BIM model.

The paper is organized as follows: Sect. 2 provides a description of the cost estimation methodology in early design stages; Sect. 3 presents the application of a BIM-based design for cost estimation in the early design stages; Sect. 4 describes the case study and the application of traditional and BIM-based approaches for cost estimate. In Sect. 5, results of the application are discussed. Finally, Sect. 6 draws conclusions and outlines further developments.

2 Cost Assessment in Early Design Stages

As introduced earlier, the methodologies most frequently used for cost estimation in early design stages can be categorized as analogical techniques, such as historical unit prices, functional space unit price [5], superficial area [21], and elemental [22] methods, to name a few. These methods, through the identification of a reference parameter that allows the linking of technical information to economic data by associating unit costs with physical characteristics [1, 2, 23], allow cost estimation by comparing historical cost data of similar buildings (comparables) to the one to be built (subject). In general, the application of analogical methodologies involves the following steps.

[1] "An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs. Typically estimated using statistical analysis or judgment based on past asset or project experience" [29 p. 31].

1. Identification of the comparable(s) with construction characteristics similar to the subject. The construction cost and the main dimensional, functional, and physical data of the comparable(s) must be known. Comparable(s) can be identified by consulting the technical and economic documentation of similar constructions, or through specialized publications, such as the inventories of building typologies and construction costs.
2. Selection of the parameter to be used for the estimation. The parameter is chosen based on the typology of the subject, such as gross floor area for residential buildings, the number of parking spaces for garages, or the number of rooms for hotels and other accommodation facilities.
3. Calculation of the unit cost, obtained by dividing the total cost of the comparables by the identified parameter quantity.
4. Estimation of the subject's construction cost, obtained by multiplying the parametric cost from step 3 by the parameter quantity of the subject.

The superficial area method, used in this research, assumes that the reference parameter is the surface area of the building (in this research, the gross floor area – GFA). Therefore, the construction cost of the subject is assessed by multiplying the parametric cost (€/m^2 of GFA) of the comparable by the GFA of the subject.

If adequate information on costs and construction characteristics of both the subject and the comparables are available, an alternative procedure known as the elemental method may be used. This method "considers the major elements of a building and provides an order of cost estimate based on an elemental breakdown of the building project" [22 p. 29].

This approach requires the buildings (subject and comparable) to be divided into their major elements, the dimensions of which must be known. Moreover, the unit cost of each element must also be known for the comparables. The construction cost of the subject is then assessed by summing the unit cost of each element multiplied by the corresponding quantity, according to the following equation:

$$Cc = \sum_{i=1}^{n} Eq_i \times Ec_i \tag{1}$$

where: Cc is the construction cost of the subject; Eq_i is the quantity of the i element of the subject; Ec_i is the unit construction cost of the i^{th} element of the comparable(s).

The cost of the reference buildings can be sourced from market monitors or specialized publications, such as building cost inventories. In Italy, the most widely used information sources for the parametric estimation of construction costs [24] is the Price list of building typology and related construction costs published by the Milan Board of Engineers and Architects [25]. The inventory provides, based on the actual costs of various types of works (new construction, renovation, maintenance, etc.) and different building types, a breakdown of construction costs by elements. Moreover, a description of the works, reference drawings, and the main dimensional data are provided. However, the dimensional data are limited to the key parameters typical of each specific building type: for residential buildings, the gross floor area and volume; for industrial buildings, the volume; for hotels, the number of rooms, and so on. The cost of all building

elements is then related to a single parameter – such as the gross floor area in residential buildings – which makes this information suitable for applying the superficial area method.

The application of the elemental method requires the costs of various elements be linked to their characteristic dimensions, as it is fundamentally a multi-parametric estimation approach. For instance, the parametric cost of windows and frames is not related to the gross floor area but rather to the surface area of the windows themselves, and the same principle applies to other elements. Consequently, detailed information on the dimensions of various elements is required for both the comparable(s) and the subject.

To obtain information regarding the dimension of the various elements of the construction for the application of the elemental method, a BIM model was created based on the documentation of one of the cases included in the inventory. The modeling process is discussed in the next section.

3 BIM Design for Parametric Cost Assessment

3.1 Overview on BIM Potentialities for Cost Assessment

At every stage of a building design process, BIM technology enables the extraction of precise calculations of quantities and spatial data, which can be used for cost estimation [26]. In advanced project phases, BIM-based models serve as a reliable tool for obtaining detailed quantity data, allowing for accurate cost estimates. Patrick MacLeamy, one of the pioneers in the theoretical development of the BIM methodology, emphasized that its use has the greatest impact in the early design phases [26]. A key advantage of BIM in this decision-making process is its ability to adapt and parametrically modify the project while maximizing integration across different disciplines. This enhances the speed of development and ensures more effective cost estimation. The automation of precise quantity calculations in parametric 3D models - where parameters, both dimensional and non-dimensional, can be easily adjusted - has made BIM-based approaches among the most widely adopted [16]. In traditional 3D CAD systems, every geometric aspect of an element must be manually adjusted by the user. In contrast, parametric modeling allows the shape or geometry of a component to update automatically in response to contextual changes and predefined user settings. In this approach, geometry adjusts dynamically based on the rules governing its definition [26]. Another crucial aspect of this methodology is its ability to automatically generate a network of relationships between BIM objects. This enables the reciprocal association of specific attributes - e.g. length, area, and cost - between model elements, such as the wall-window, wall-room, or wall-floor relationships.

Current BIM design tools automatically incorporate these functionalities and adopt what is known as “object-based parametric modeling”. These features allow for precise and reliable quantity take-off in the more advanced design phases, as well as the generation of detailed as-built drawings. The process of extracting quantitative information relies on standard tools that query the model to obtain accurate geometric data. These tools often include dedicated quantity surveying functions within common BIM software, enabling the analysis of any model component - for instance, extracting all properties of a single wall layer. However, when performing quantity estimation in the

early design stages, standard BIM authoring tools may present limitations due to their lack of customization. If the built-in functionalities do not adequately meet specific requirements, Visual Programming Languages (VPLs) can be employed [27]. These tools, often integrated within BIM software, enhance their capabilities by combining geometric modeling functions with algorithm creation. Unlike traditional programming, VPLs allow users to develop scripts through graphical manipulation of elements rather than written code, making them accessible to professionals without coding expertise [28]. In this specific case, the need to associate building spaces with their corresponding architectural components - such as walls, doors, and windows - required the development of a custom script. This script, interacting automatically with the BIM environment, can extract the required geometric quantities.

3.2 The Use of BIM in This Study

The modeling process of the reference building was carried out in two distinct steps. The first involved creating the geometries using a well-established parametric modeling approach, while the second focused on developing a script to extract the required quantities and process them through algebraic operations. The modeling began by defining a lower and an upper level, which, in BIM practice, establish a typical parametric modeling space that can be easily updated. Next, walls - consisting of a single generic layer - were created between these two levels, along with the openings they accommodate. Doors and windows were inserted using a library of modifiable objects, which can be easily adjusted through dedicated parameters. Finally, rooms were placed within the model. These were automatically recognized by the software as enclosed spaces defined by walls. Each room was then assigned a unique number and name based on its function, enabling the extraction of key dimensional data for the interior spaces. The resulting building model allows for easy geometric updates by modifying parameters, facilitating the exploration of different design scenarios.

The developed script begins by automatically acquiring all rooms within the model. Through a sort list operation, it organizes and groups them into specific housing units while identifying all spatially related elements. This process enables the identification

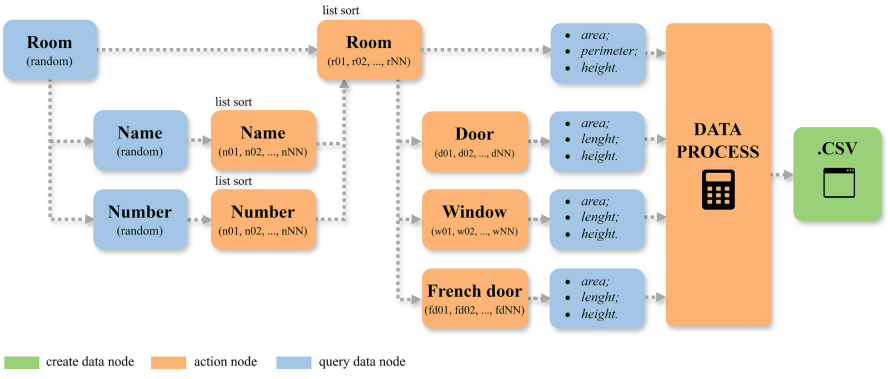


Fig. 2. Script workflow diagram.

and classification of all walls within the perimeter of each room, along with their associated openings. Once this operation is complete, the script extracts all relevant parameters linked to the architectural components - such as surface area, perimeter, height, and width - and combines them through algebraic operations with cost data to generate the required quantity estimates. Finally, all collected data is compiled into a CSV (Comma-Separated Values) file and exported in the common XLSX format (Fig. 2). The script runs automatically, ensuring that any updates to the model parameters are reflected real-time in the quantity calculations. This process represents a fully automated approach to quantity take-off for buildings modeled in a BIM environment.

4 Case Study

To verify whether the additional information obtained from the BIM model of a reference building actually results in more accurate cost estimates during the early design stages of renovation projects, a case study is developed. The process includes the following stages (Fig. 3). Firstly, a detailed cost estimate of a residential renovation project, used as the subject, is carried out through the preparation of a bill of quantities. The second phase involves identifying a reference building to be used as comparable from the aforementioned price list. Then, cost estimates are carried out using the superficial area method, and, after creating the BIM model of the comparable, the elemental method is applied. Finally, the accuracy of the parametric estimates is evaluated using the results of the bill of quantities as benchmark.

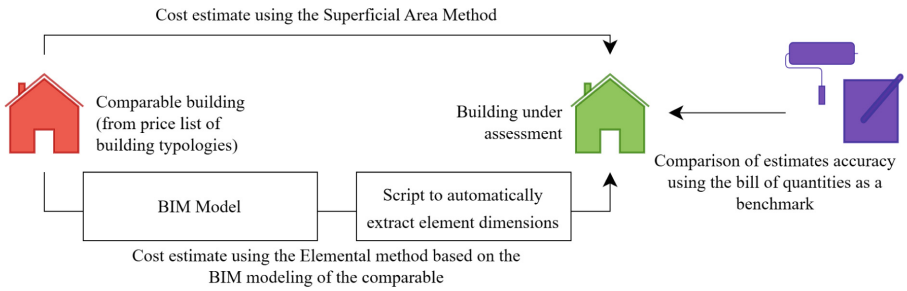


Fig. 3. Methodology workflow diagram.

4.1 Description and Cost Benchmark

The case study concerns the renovation of a flat located on the mezzanine floor of a condominium with ten residential units, built in 1927. For the purposes of this study, it is assumed that it is located on the outskirts of a medium-sized city in the Veneto region, northeast Italy, in an area characterized by good accessibility. The apartment consists of one living room, a kitchen, two bedrooms, one bathroom, and a small corridor. The gross floor area is 79 m^2, while the net floor area is 62.5 m^2. Fig. 4 shows the floor plan of the flat.

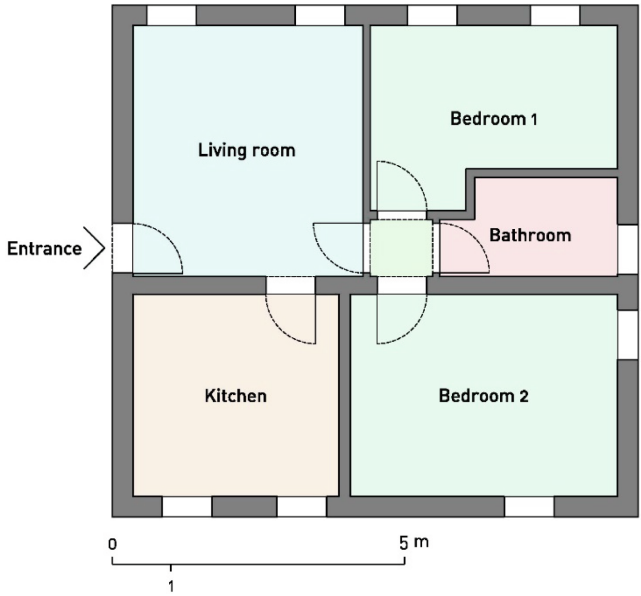


Fig. 4. Floor plan of the case study.

The renovation includes the following work: laying of internal wall and ceiling plaster; construction of screeds and installation of floors, with wooden flooring in the bedrooms and the small hallway, and tiled flooring in the other rooms; installation of tile cladding on the kitchen and bathroom walls; painting of internal walls; replacement of windows and doors. For the purposes of this study, costs related to demolition and the installation of heating, water, and electrical systems were not included. In order to identify the renovation cost to be used as a benchmark, a bill of quantities for the works was prepared, using the Public Works Price List of the Veneto Region, 2024 edition, as a reference. Table 1 provides a summary of work items, quantities, unit prices, and cost estimate obtained through the bill of quantities. The total renovation cost thus obtained is 42,166.59 €.

4.2 Superficial Area Method Based on Cost Inventory Data

The cost estimation using the superficial area method first requires identifying a suitable comparable within the mentioned price list of building typologies. Comparable A.8, renovation of a penthouse in a downtown area, was selected as it shares similar characteristics to those expected for the subject in terms of the breakdown of the work. Indeed, the costs of the comparable are broken down into a series of work categories that group together typical bill-measured items.

Table 1. Summary of the estimate from the bill of quantities.

Work	Quantity	Rate (€/UoM)	Total (€)
Providing and laying in position of two-coat interior plaster, applied at any height on vertical, horizontal, with an average total thickness of 20 mm. The area measured is the internal net surface area of walls (excluding doors and windows) and ceilings. (m^2)	269.76	27.08	7,305.10
Painting with washable paint for interior walls. The area measured is the internal net surface area of walls (excluding doors and windows) and ceilings. The area of bathroom and kitchen walls with tile cladding is also excluded. (m^2)	226.36	11.99	2,714.06
Reinforced concrete screed 10 cm thick. The area measured is the net area of floors. (m^2)	62.40	44.77	2,793.65
Providing and laying in position of first-choice ceramic floor tiles in the bathroom and the kitchen. The area measured is the net area of floors. (m^2)	16.90	50.49	853.28
Providing and laying in position of first-choice ceramic floor tiles in the living room. The area measured is the net area of floors. (m^2)	17.00	96.29	1,636.93
Providing and laying in position of oak wood flooring in bedrooms and the corridor. The area measured is the net area of floors. (m^2)	28.50	201.01	5,728.79
Providing and laying in position of oak wood skirting board in bedrooms and the corridor. The length measured is the perimeter of the room excluding doors. (m)	29.90	22.01	658.10
Providing and laying in position of first-choice ceramic skirting board in the living room. The length measured is the perimeter of the room excluding doors. (m)	13.95	50.12	699.17
Providing and laying in position of first-choice ceramic cladding tiles in the bathroom and the kitchen. The area measured is the internal net surface area of all walls cladded with ceramic tiles (excluding doors and windows). (m^2)	40.34	50.49	2,036.77
Providing and laying in position of aluminum windows with double glazing, including all the necessary components. The area measured is the net area of windows. (m^2)	13.01	653.70	8,501.35
Providing and laying in position of aluminum shutters. The area measured is the net area of windows. (m^2)	13.01	452.80	5,888.66
Providing and laying in position of internal wood doors including all the necessary components. The area measured is the net area of doors. (m^2)	10.71	312.86	3,350.73
TOTAL			42,166.59

Table 2 shows the comparable cost distribution across the various works categories and the unit cost referred to the gross floor area. Works categories considered for the subject cost estimation are highlighted using bold font and refer to the renovation works listed in Sect. 4.1.

Table 2. Construction costs of the comparable.

n.	Work category	Cost (€)	Unit Cost (€/m^2 GFA)
1	Scaffolding	1,49,641	
2	Demolitions and removals	27,370	
3	Reinforced concrete works and load-bearing masonry	1,26,978	
4	Roof	59,433	
5	Internal walls and insulation	37,822	
6	**Plaster**	**36,220**	**69.65**
7	Plasterboards suspended ceilings	4,377	
8	**Ceramic floors (in living area)**	**40,382**	**77.66**
9	**Wood floors (in sleeping area)**	**21,784**	**41.89**
10	**Traditional ceramic floors (in bathrooms and kitchens)**	**4,443**	**8.54**
11	**Ceramic cladding in bathrooms and kitchens**	**12,728**	**24.48**
12	**Painting**	**15,364**	**29.55**
13	**Doors**	**24,760**	**47.62**
14	Skylights	24,657	
15	**Windows**	**50,440**	**97.00**
16	Heating and cooling system	1,90,272	
17	Bricklayer support to heating and cooling system inst.	40,790	
18	Water system	57,021	
19	Bricklayer support to water system inst.	18,321	
20	Electrical system	75,515	
21	Bricklayer support to elettrical system inst.	37,216	
22	Lifts extension	1,23,784	
23	Bricklayer support to lifts extension	34,932	
TOTAL (€)		1,214,250	
GFA (m^2)		520	
Total Unit Cost (€/m^2)		2,335	
Total Unit Cost of works considered for estimation (€/m^2)			396.39

The selected comparable, in fact, included additional works not relevant to the case study, such as roof reconstruction, installation of lifts, changes to the internal room layout, and so on. For the identified work categories, the unit cost has been calculated by dividing the total cost by the gross floor area of the comparable.

Table 3. Superficial area method cost estimate.

Work category	Unit cost (€/m^2 GFA)	Cost (€/m^2)
Plaster	69.65	5,502.35
Ceramic floors (in living area)	77.66	6,135.14
Wood floors (in sleeping area)	41.89	3,309.31
Traditional ceramic floors (in bathrooms and kitchens)	8.54	674.66
Ceramic cladding in bathrooms and kitchens	24.48	1,933.92
Painting	29.55	2,334.45
Doors	47.62	3,761.98
Windows	97.00	7,663.00
TOTAL	396.39	31,314.81

The cost estimation was then carried out by applying the unit costs thus obtained to the subject gross floor area. As a result, the total renovation cost of the building under assessment using the superficial area method amounts to 31,314.81 €, derived from the product of the sum of the unit costs of the various work categories (396.39 €/m^2) and its gross floor area (79 m^2). Table 3 presents the results of the parametric estimation using the superficial area method.

4.3 Elemental Method Based on the BIM Modeling of the Comparable

Using dimensional information and technical drawings provided by the price list, a BIM model of the comparable was created. Figs. 5 and 6 show a sample view of the BIM model and the floor plan as issued in the price list.

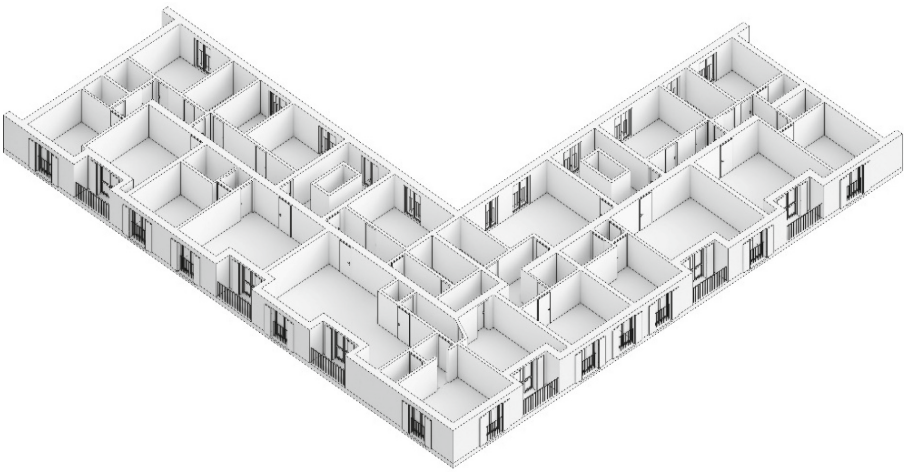


Fig. 5. BIM model of the comparable building.

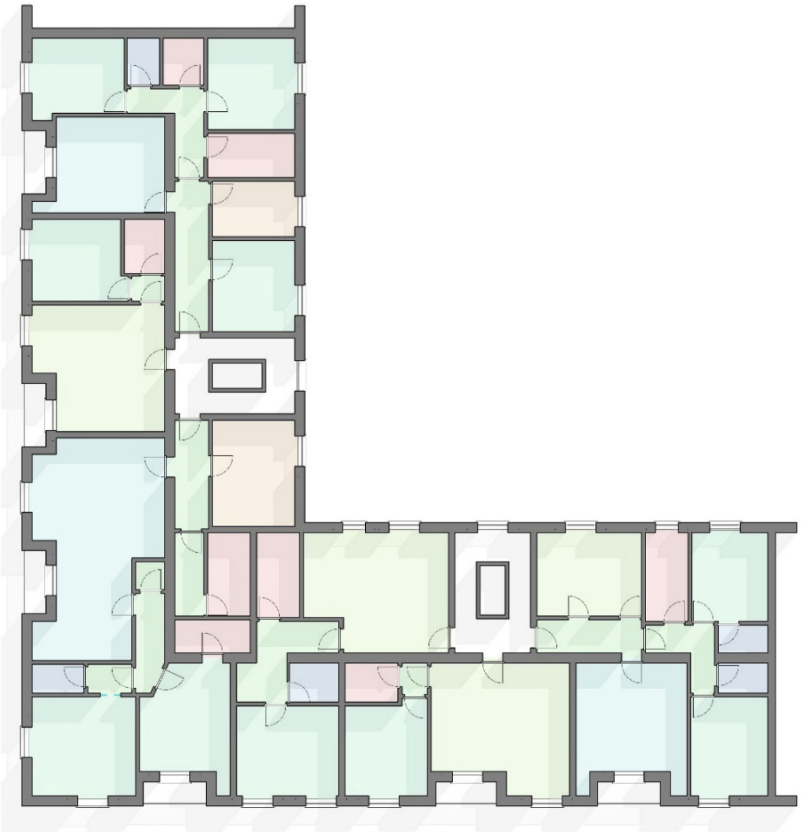


Fig. 6. Floor plan of the comparable building.

Then, by means of the script described in Sect. 3, it was possible to extract the dimensional details of the individual elements of the construction, in order to apply the elemental method for the cost estimate. The information extracted through the script, divided for each individual room of the reference building, is presented in an aggregated form in Table 4.

The costs of the reference building elements can therefore be related to the actual dimensions of the elements themselves. For example, the cost of plastering is divided by the sum of the Net walls surface area and Floors and ceilings surface area, the cost of painting is divided by the sum of the Painted net walls surface area and Floors and ceilings surface area, and so on. This allows for the calculation of their unit cost, as shown on the left side of Table 5. The parametric costs thus obtained are then applied to the dimensions of the elements of the building under assessment to obtain the estimate shown in the right part of the same table. Therefore, using the elemental method based on the BIM Modeling, the total renovation cost of the subject amounts to 44,838.83 €.

Table 4. Extraction of dimensions from the reference building elements.

Information	Description	Dimension
A - Room	Room identification code	–
B - Use	Room intended use	–
C - Room perimeter	Gross perimeter of the rooms (m)	535.17
D - Average height	Rooms average height (m)	2,2
E - Gross walls surface area	Total gross walls surface area (m^2)	1,177.37
F - Doors	Total number of doors (nr.)	82.00
G - Doors surface area	Total net surface area of doors (m^2)	137.76
H - Windows	Total number of windows (nr.)	20.00
I - Windows surface area	Total net surface area of windows (m^2)	44.46
L - French doors	Total number of French doors (nr.)	6.00
M - French doors surface area	Total net surface area of French doors (m^2)	15.12
N - Net walls surface area*	Total net walls surface area (m^2)	980.03
O - Tile cladding	Total surface area of walls cladded with tiles (m^2)	190.33
P - Painted net walls surface area**	Total painted net walls surface area (m^2)	789.70
Q - Floors and ceilings surface area	Total floor surface area of rooms (m^2)	410.37
R - Ceramic floors surface area	Total surface area of rooms with ceramic floor (m^2)	57.65
S - Non-ceramic floors surface area	Total surface area of rooms with non-ceramic floor (m^2)	352.72

* The surface area of doors, windows, and French doors is excluded (used, for example, to quantify plastering).
** The surface area of doors, windows, and French doors and that of tile cladding is excluded (used to quantify paintings).

Table 5. Unit costs of reference building elements.

	Comparable			Subject	
Work category (The letters refer to the elements described in Table 4)	Cost (€)	El. Dim. (m^2)	Unit Cost (€/m^2)	El. Dim. (m^2)	Cost (€)
Plaster - N + Q	36,220	1,421.06	25.49	269.76	6,876.18
Ceramic floors - R	40,382	226.41	178.36	17.00	3,032.12
Wood floors - S	21,784	126.31	172.46	28.50	4,915.11
Traditional ceramic floors - R	4,443	57.65	77.07	16.90	1,302.48
Ceramic cladding - O	12,728	261.36	48.70	40.34	1,964.56

(*continued*)

Table 5. (*continued*)

	Comparable			Subject	
Work category (The letters refer to the elements described in Table 4)	Cost (€)	El. Dim. (m^2)	Unit Cost (€/m^2)	El. Dim. (m^2)	Cost (€)
Painting - P + Q	15,364	1,247.71	12.31	226.36	2,786.49
Doors – G	24,760	75.60	327.51	10.71	3,507.63
Windows - I + M	50,440	64.14	786.40	26.01	20,454.26
	TOTAL				44,838.83

5 Discussion

The tables below compare the results of the estimates obtained through the application of the three methods. The cost items in the bill of quantities have been grouped to align with the work categories identified for the reference building. Using the values from the bill of quantities as a benchmark, Table 6 shows the deviations for the superficial area method, while Table 7 presents those for the elemental method, both in absolute values and percentage terms. The following Fig. 7 shows the comparison of the percentage deviation from the benchmark of the two methods estimates.

Table 6. Comparison between bill of quantities and superficial area method estimates.

Work category	Cost benchmark (€)	Cost Sup. area meth. (€)	Absolute deviation (€)	% deviation
Plaster	7,305.10	5,502.35	-1,802.75	−24.68%
Ceramic floors	3,097.19	6,135.14	3,037.95	98.09%
Wood floors	7,662.83	3,309.31	−4,353.52	−56.81%
Traditional ceramic floors	1,609.89	674.66	−935.23	−58.09%
Ceramic cladding in bathrooms and kitchens	2,036.77	1,933.92	−102.85	−5.05%
Painting	2,714.06	2,334.45	−379.61	−13.99%
Doors	3,350.73	3,761.98	411.25	12.27%
Windows	14,390.02	7,663.00	−6,727.02	−46.75%
TOTAL	42,166.59	31,314.81	−10,851.78	−25.74%

Table 7. Comparison between bill of quantities and elemental method estimates.

Work category	Cost benchmark (€)	Cost element meth (€)	Absolute deviation (€)	% deviation
Plaster	7,305.10	6,876.18	−428.92	−5.87%
Ceramic floors	3,097.19	3,032.12	−65.07	−2.10%
Wood floors	7,662.83	4,915.11	−2,747.72	−35.86%
Traditional ceramic floors	1,609.89	1,302.48	−307.41	−19.10%
Ceramic cladding in bathrooms and kitchens	2,036.77	1,964.56	−72.21	−3.55%
Painting	2,714.06	2,786.49	72.43	2.67%
Doors	3,350.73	3,507.63	156.90	4.68%
Windows	14,390.02	20,454.26	6,064.24	42.14%
TOTAL	42,166.59	44,838.83	2,672.24	6.34%

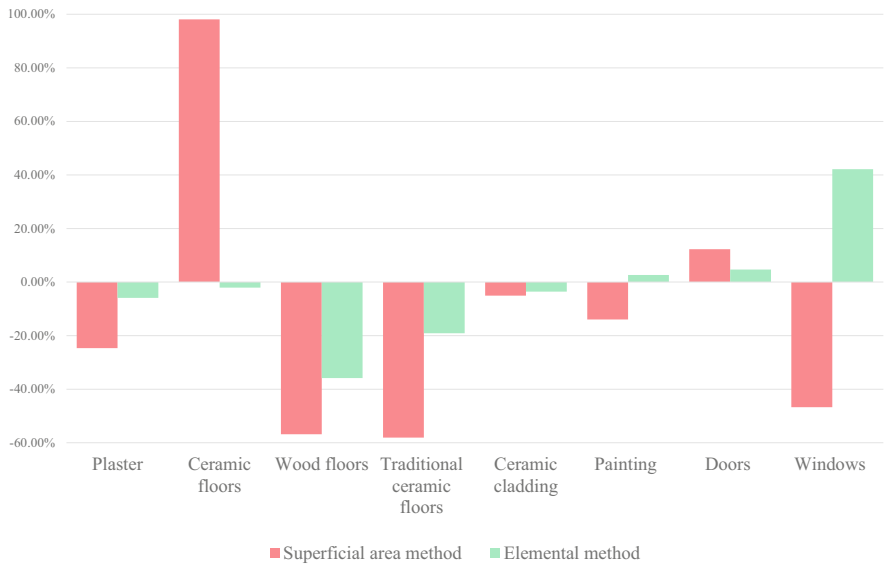


Fig. 7. Comparison of the percentage deviation from the benchmark of the two methods estimates.

Regarding the superficial area method, the cost categories with the largest deviations are those related to flooring, all of which are more than 50% higher than the benchmark (with ceramic flooring in the living area showing a percentage difference of +98.09%), and the external windows and doors category (−46.75%). The latter also shows a significant deviation in the elemental method estimate, although with opposite sign (+42.14%). This result may be due to the fact that the costs of the reference building, although updated annually, refer to a building constructed in 2004, and thus to technologies, particularly for windows and insulation, whose performance may no longer be applicable given the evolution of energy efficiency regulations. As for flooring, the elemental method yields more accurate results, especially for ceramic flooring, while for wooden floors it shows a greater underestimation (though smaller than that of the superficial area method), likely due to issues related to the quality of finishes (even though the same type of wood – oak – was chosen for both the subject and the comparable building). The best elemental method estimates are obtained for all the work related to walls (plastering, painting, and cladding), and for internal doors, for which the deviation from the benchmark is below 5%. As for the total cost, the elemental method estimate shows an overall deviation from the benchmark of 6.34%, which is a quarter of the absolute deviation of the superficial area method (−25.74%). From a timing perspective, the development of the BIM model required approximately two hours of work by an expert in modeling. The creation of the script took about four hours. The replication of the method requires only the development of additional BIM models, while the script operates independently and data processing is performed instantaneously.

Therefore, the elemental method based on BIM modeling seems to have significant potential for improving the accuracy of building renovation cost estimates in the early design stages.

6 Conclusions and Further Development

The research compared two methods for parametric construction cost estimate in early design stages. Starting from one of the most commonly used information sources in Italy for early design cost assessment, a BIM model and a script were developed to extract a larger amount of information on dimensions of the elements composing a construction identified as comparable. This allowed to assess the renovation costs of a sample property using both the superficial area method and the elemental method. By comparing the results of the two methods with the cost estimate carried out through the preparation of a detailed bill of quantities, it was concluded that the elemental method allows for a more accurate estimate, deviating by +6.34% from the expected costs, whereas the estimate performed with the superficial area method showed a significantly larger deviation of −25.75%. The latter aligns with the tolerances identified in the literature regarding the accuracy of estimates in the early design stages, while the former approaches the accuracy expected in late design stages. The results may be due to the choice of the case study: the renovation works (where the dimensions of the subject's elements are known beforehand and are only partially defined during the design phase, whereas in new constructions the dimensions of some elements in the early design stages may be entirely unknown), as well as the relative simplicity of the analyzed renovation project.

Future developments of the research aim, on one hand, to extend these analyses to more complex cases of building rehabilitation and new construction, and on the other hand, to test the creation of BIM models for comparables that include cost information, leveraging parametric modeling to allow for the inclusion of cost information and support more accurate estimates in early design stages.

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