Automatic Estimate of Depreciated Reproduction Cost for Optimizing the Real Estate Management Through BIM

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Abstract. Building Information Modeling (BIM) can be defined synthetically as a digital model of a real estate that collects data from the different disciplines that contribute to its realization. In civil engineering, it represents an innovative approach to the construction and management of a building. Cost assessment is a fundamental activity both in the construction phase but especially in the economic management of real estate assets. The use of the BIM makes possible to carry out a rapid and precise estimate of the costs of production, reconstruction or maintenance during the entire life cycle of the building. This work aims to implement the depreciation of real estate assets within a BIM model in order to develop an easy tool to support the economic decisions of those involved in real estate asset management. In particular, the possibility of observing in real time the dynamics of depreciation of the building, placing it in relation, on the one hand, with the dynamics of the land rent and, on the other, with the costs of restoration, can become essential in the choices about times and ways of maintenance, building renovation or eventual razing. The first simulations well confirm the reasons for the research, which is placed in the same direction identified by relevant legislation aimed at the definition of the Real Estate Due Diligence and the digital dossier of the building.

Keywords: Building Information Modeling · Cost value · Depreciation · Economic management

1 Introduction

Building Information Modeling (BIM) represents the most important innovation within the AEC sector (Architectural, Engineering & Construction) [1]. The operators of this sector appreciate the effectiveness of a system that centralizes data and allows continuous and total sharing.

BIM offers the possibility of modeling and managing digital information describing a construction project, from its conception to the end of its life cycle. The BIM methodology, through the search for total sharing, collaboration and communication among all stakeholders, allows the creation of a virtual prototype of the object (whether

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it is still to be built or already built) in order to make the building process very efficient both in the implementation and management phases.

The advantages generated by the use of the BIM methodology can be summarized as follows:

- increased sharing, collaboration and communication among all stakeholders, from the client to the user, from technicians to workers and so on;
- possibility of creating a virtual prototype of the object designed before having built it;
- reduction of risks and contingencies on the construction site through the use of software that checks for interference between structural and architectural elements, and systems;
- making analyzes and simulations regarding, for example, the energy or seismic behavior of the building;
- reduction of costs and times;
- optimization of work management.

One of the potentials offered by BIM and on which research has been investing for a long time is to improve the sustainability of the project. Higher levels of sustainability - related to the aspects of structural integrity [2, 3], techniques, construction process and cost - are in fact achievable with the use of tools such as the BIM, which is able to support decisions in choosing the best design solutions or management models [4]. BIM can therefore be used to inform decisions from the earliest stages of building design or restructuring [5].

The integration of data relating to the life cycle cost (LCC) of building components in the BIM platform is fundamental for this purpose [6, 7].

For example, the BIM-integrated approach allows the identification of specific design hotspots that can be displayed on the building model for communicating LCA results and the visual design guide [8–10].

The evaluation of the most advantageous life cycle cost (LCCA Life Cycle Cost Analysis) is one of the support techniques for real estate investment decisions [11]. The analysis involves the comparison between different Life Cycle Costs (LCCs) related to different options regarding the construction and management of the building.

In general, property maintenance involves the enhancement of performance characteristics of the building system, thus an increase of the income capacity and the consequent increase in the property market value.

The convenience of maintenance is therefore a function of the final market value of the building which, in turn, depends on factors that act on urban rent [12]. These factors are characterized by a high uncertainty; we think of urban changes or any changes in the social or economic context, as well as innovations introduced by technological progress in the building production and the consequent new functional and aesthetic requirements. If, on the one hand, forecasting the dynamics of future property values is a complex and uncertain operation, on the other hand, the convenience of the maintenance intervention may also depend on its cost and optimal periodicity, the forecast of which is based on more certain elements.

There are in fact past experiences and databases deriving from the latter, which provide, albeit with some limitations, pointers on the probability of the respective measures.

With regard to the optimal periodicity of maintenance, emphasis must be placed on the concept of standard maintenance or acceptable current limit of the building or its subsystem and on the depreciation concept.

In fact, there is a very strong relationship between depreciation and maintenance. Well-maintained properties show much lower depreciation rates than properties that are subject to poor maintenance.

The graph in Fig. 1 reworks the one proposed by Neto and Bezelga [13]; it provides a useful representation of the difference between the various depreciation factors and their classification. Specially, it is clearly shown that maintenance and refurbishment activities are essential to extend the useful life of the building. In fact, it can be noted that, due to the continuous growth of quality standards (functional obsolescence), the initial quality level, even in the absence of income decay and physical wear, will be below the minimum acceptable one, which therefore defines the threshold of demolition. Even when the building is subject to regular maintenance (curve 1 of Fig. 1), in the absence of modernization interventions, the amount of incurable income decay and physical wear reduce the quality of the building over time and determine an anticipation of the exceeding the demolition threshold, thus producing a reduction in the useful life of the building.

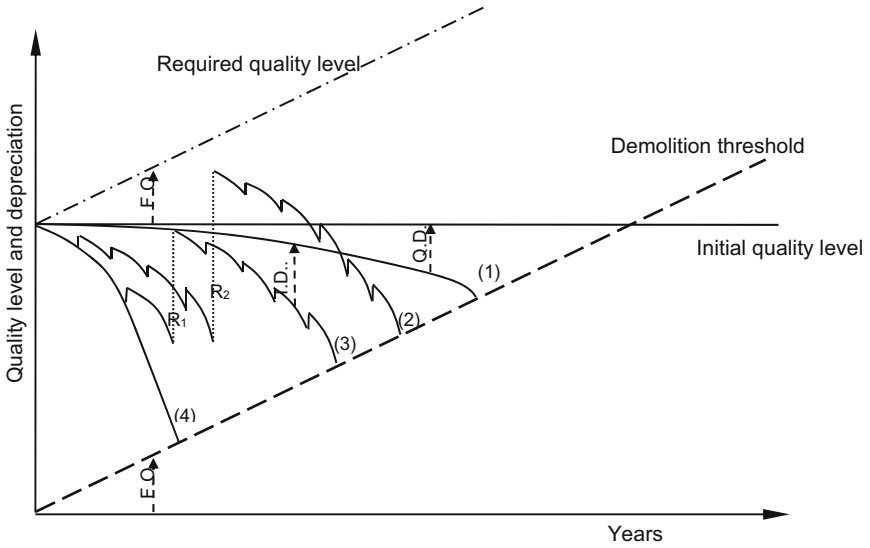
On these premises the research aimed to investigate the possibility of using the BIM methodology in estimating the depreciation of the construction cost, and then assessing the reliability and applicability of the BIM to build a support tool for those involved in asset management estate. The model and the software application that implements it can thus be used in order to evaluate the convenience and optimal periodicity of an extraordinary maintenance intervention on the building or on a part of it.

It should also be noted that the valuation of depreciation has growing importance in the fiscal sphere, when companies (public or private) have the need to enter the balance sheet value of their real estate asset.

2 Notes on Depreciation

In general, depreciation is the loss of value of an asset, caused by various factors all linked to the passage of time (physical wear, functional obsolescence, economic obsolescence). The distinction between economic depreciation and depreciation of the cost is fundamental and preliminary to the estimation approach: the first represents the loss of the market value of the property corresponding to the decrease in time of its utility; the second corresponds to the deduction to be made to the cost of construction or replacement of the building and therefore regardless of the real estate market and its fundamental determinants (supply and demand).

In this work we refer to the depreciation of the cost or to its economic result: the depreciated reproduction cost. The cost value, resulting from the sum of the expenses to be incurred for the production of a building, is in this case better specified as a "reproduction" cost. It is defined as the sum of the expenses to be incurred for the exact duplication of the property, hypothesizing that it should be rebuilt using the same materials and the same production techniques of the time in which it was built. When this is not possible, the value refers to the replacement cost, in other words the sum of



Key:
F.O. = Functional Obsolescence
I.D. = Incurable Income Decay
Q.D.= Quality Decay, due to incurable income decay and physical wear;
(1) = Evolution with very frequent maintenance;
(2) = Evolution with periodic maintenance with redevelopment and modernization (R2);
(3) = Evolution with periodic maintenance with redevelopment (R1) but without modernization;
(4) = Evolution with no maintenance.

Fig. 1. Depreciation evolution due to different factors and for different maintenance hypotheses.

the expenses to be incurred for the construction of a building similar to the existing one as far as possible, to be built with technical and functional characteristics similar to the reference one, using new materials and production techniques, which technological progress has made available.

This cost (new) must then be depreciated to take into account the time elapsed. If we talk about the cost of reproduction and not of construction, the value of the land on which the building stands must then be added to the value of what is built. Take into account that depreciation is a phenomenon that relates exclusively to the built, the value of the land is instead closely linked to the phenomenon of rent and therefore its variation over time is to be linked to the variables that generate the rent.

The estimate of the depreciation of the construction cost is dealt with by applying the model already illustrated in Manganelli [14].

This is an original approach based on the decomposition of the building in its essential functional elements and on the definition of parameters (such as, for example, the duration of life in service, the optimal periodicity and the cost of maintenance) that characterize these elements. The model addresses the estimative problem of depreciation in a rational manner and gives a complete analytical formulation, estimating the depreciation of the individual functional elements through the analytical examination of the factors that determine it.

In this work the depreciation model was implemented in a BIM approach, exploiting the ability of the methodology to manage data.

3 The Model

This research has developed an algorithm implemented in a software capable of developing analysis and estimation of depreciation within a BIM model.

The BIM model of the test building was built with Autodesk Revit software, while the depreciation estimation module was developed through the Dynamo application (Autodesk Inc.) that uses a simple visual programming language.

Dynamo can work as independent software or as a plug-in. Here it was used as a plug-in for Revit.

Dynamo's architecture is based on only two elements: nodes and wires (Fig. 2).

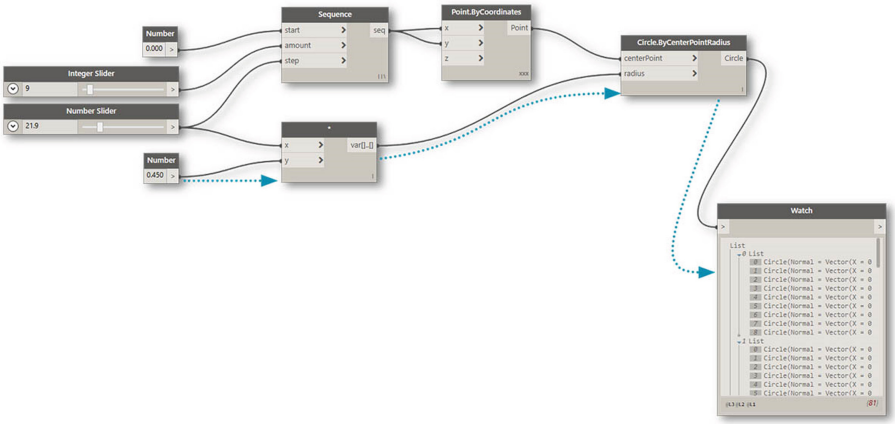


Fig. 2. Sequence of nodes and wires in Dynamo.

Visual programming allows the designer to pay attention only to the information flow even without specific knowledge of the programming language. It is based on the concepts of boxes (nodes) and arrows (wires), where the former are conceived as elements that perform a function and are interconnected by the seconds representing their relations.

In order to automate the estimation of depreciation, the flow of the phases was constructed; in practice the different steps of the estimate are defined in logical sequences then implemented in the packet (Fig. 3).

The input consists of a series of information, partly contained in the BIM model of the building and partly provided as new data.

The BIM model of the building allows the identification of all the workings of the construction process. The measurement obtained using the appropriate scale (surface, volume, weight, etc.) must be connected to each of these items. This data is clearly present in the BIM model and can easily be extracted from it. Through external input,

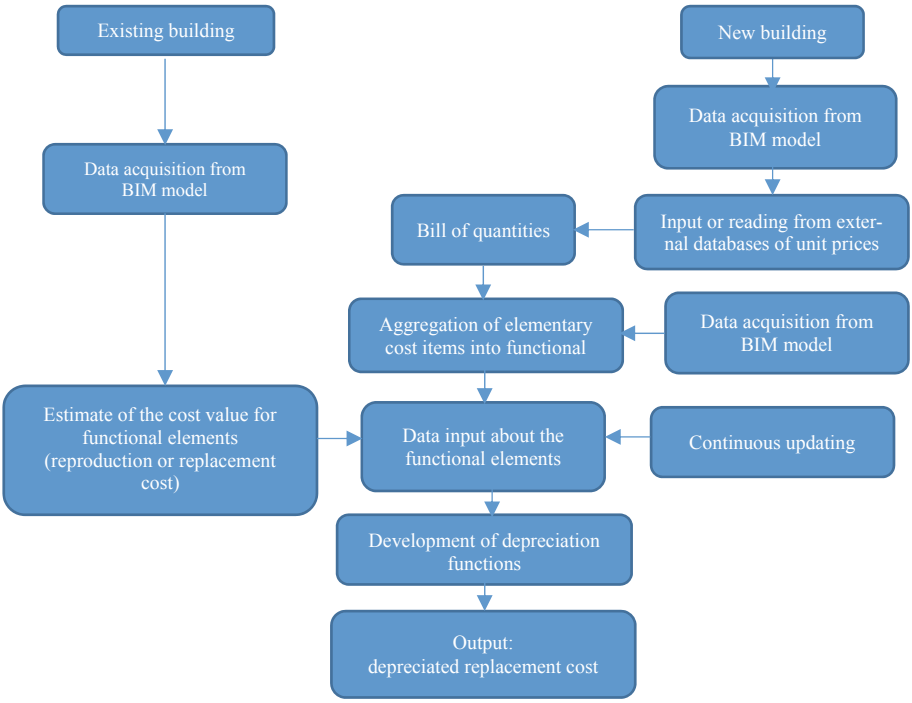


Fig. 3. Flow of operations implemented in the software application.

the unit price, selected by an appropriate database (for example the price list of the Region in which the building is located) is therefore associated with each individual item. The bill of quantities can automatically be generated and obtained the cost value.

The individual items of the bill of quantities must be classified and organized into functional elements. This classification, which is obviously of a higher order than that based on materials and workmanship, groups the latter into elements that perform technologically compatible functions necessary to obtain pre-established services. For example, structures, systems and finishes are macro-categories of this classification; in turn, these can be divided into further and more detailed categories of functional elements (e.g. water system, electrical system, etc.).

This classification is fundamental for estimating the depreciated reproduction cost. The depreciation functions are in fact distinct for each identifiable functional element [15]. Although the equations describing the different depreciation factors are the same in form, they assume different configurations for each functional element in relation to the inputs that characterize them [16, 17]. It is in fact required that the following additional information (second phase) be specified for each functional element:

- age at the time of estimation = estimate year -year of construction (n);
- year of the replacement intervention (if carried out);
- year of the extraordinary maintenance intervention (if carried out);
- optimal frequency of maintenance (s);

- maintenance costs (m), expressed as a percentage of the construction cost as new (Co);
- useful life of the element - service life (v);
- recovery value at the end of the useful life (Vr);
- interest rate (i).

The estimate of depreciation involves the separate analysis of the three main factors:

– *Pure age*: it is determined by the progressive reduction of the life in service of the asset.
– *Income decay*: it is related to the lower utility of an asset already in use, compared to the corresponding new one; it is therefore consequent to the expenses to be incurred for extraordinary maintenance interventions capable of restoring its initial efficiency.
– *Functional obsolescence*: it is related to potential variations that occur in the design system, in the materials used or to the poor compliance with new quality standards, but also simply to the introduction of innovative technological systems that have lower operating costs and/or greater efficiency.

Pure age and income decay are two aspects of a single phenomenon: physical wear. The calculation of depreciation due to these two factors (respectively$\Delta Cage$ and $\Delta Cincome$) is developed with the following functions:

$$\Delta C_{age} = (C_0 - V_r)\frac{(1-i)^n - 1}{(1-i)^v - 1} \tag{1}$$

$$\Delta C_{income} = C_0 \cdot m\frac{(1-i)^n - 1}{(1-i)^s - 1} \tag{2}$$

As regards functional obsolescence, given the difficulties generated by the numerous variables involved in the calculation, we proceed to its evaluation in an empirical way. In practice, its effects can be considered by introducing the concept of useful economic life, understood as the period in which that element is used because it constitutes the least expensive solution with respect to its intended use. Therefore, functional obsolescence involves the zeroing of the economic value of the element before the end of its service life. This determines, for the calculation of depreciation by physical wear, the use of the useful economic life (estimated on the basis of experience) instead of useful service life. For most of the elements that make up buildings, functional obsolescence is negligible; it assumes particular importance only for the systems.

Once the depreciation is determined, by subtracting it from the costnew the accumulated depreciation or the final output of the application is determined.

4 The Software

Two versions of the application have been created:

1. extended version, called "*depreciation gb*" (glass box);
2. compact version, called "*depreciation bb*" (black box).

The extended version consists of 131 nodes and 192 arrows; the nodes are collected in 24 groups:

- 6 input groups (with 21 nodes);
- 14 processing groups (with 88 nodes);
- 3 partial outputs groups (with 18 nodes);
- 1 final output group (with 4 nodes).

This version allows precise and punctual control over the operation of the application as it is possible to view and identify any errors.

The compact version was designed for a more practical use, as it is less dispersive than the extended one, presenting a number of nodes reduced to the essential (or better, hidden to the user). In practice there are 23 knots and 23 arrows; the nodes are collected in 8 groups:

- 6 input groups (with 21 nodes);
- 1 partial output group (with 1 custom node);
- 1 final output group (with 1 custom node).

To build it, custom nodes have been used, which allow to enclose within them all the desired nodes, in this specific case the processing and output nodes, leaving visible only the nodes that require user input.

5 Conclusions

BIM allows the collection, sharing and management of information and at the same time their integration in the virtual model of the building. The information is fundamental and necessary to conduct a set of analyses: for example, to simulate the behavior of the building in the design phase, to improve its safety in the construction phase and to allow a deeper knowledge in the management phase.

This research has shown the possibility, starting from the information present in the model and using appropriate tools, to carry out the estimation of the depreciation of the construction or reconstruction cost and automate it to make it dynamically updatable. The automatic estimation of depreciation is possible thanks to the development of a software module that extracts the information associated with each functional element of the work, processes it and returns the depreciated cost, reporting this information in the BIM model. The application was created using visual programming and Dynamo open source software.

The application performs very well the function for which it was designed, but it needs a greater implementation and experimentation; on these operations the future development of the research will concentrate.

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