Verification of Software for Planning Maintenance and Restoration of Historic Buildings in a Case Study

Daniel Macek[1[0000-0002-5535-3618]], Renata Schneiderova Heralova[1[0000-0003-3402-0686]] and Eduard Hromada[1[0000-0002-8336-8710]]

[1] Czech Technical University in Prague, Faculty of Civil Engineering, Thakurova 7, 166 29 Prague, Czech Republic
daniel.macek@fsv.cvut.cz

Abstract. The article deals with the issue of the valuation of construction works on historical buildings. This is a complicated matter because historical buildings are unique, they have a historical value that must be preserved for future generations, and they use many special technological and construction procedures. For this purpose, the research team developed methodological procedures and the software, which can draw up maintenance and restoration plans for historic buildings including the calculation of planned costs. The use of the software is shown on the case study of the general repair and construction modifications of the historical building of the Dobrovice Parish. The paper describes the original state of the historical building. Photos of the original condition are shown for illustration. The scope of the construction work carried out is also shown, including illustrative photos after the reconstruction. The paper ends with a demonstration of a sample calculation of the costs of reconstruction works in the software.

Keywords: Monument maintenance, valuation of reconstructions, parametric valuation, price analysis.

1 Introduction

Cultural monuments are to in a large extent public goods for collective consumption; their preservation is in the public interest of society as a whole. The benefits that arise from the investment of the owner and that flow from the existence and use of an immovable cultural monument are not usually "consumed" only by its owner, but to a greater or lesser extent by the entire society or a certain group thereof. Large amounts of funds are spent on the restoration of cultural monuments. Therefore, they should be spent efficiently. And not only in the form of renovation costs, but also with a long-term view - on the future costs of operation, maintenance and further renovation of these buildings, i.e. their economic sustainability throughout the life cycle [1, 2].

The tool for assessing the economic sustainability of a cultural monument is a life cycle cost (LCC) analysis performed on the basis of relevant input data on the technical parameters of the building, structural elements and equipment, the time period of the occurrence of costs related to them [3]. The analysis becomes an important basis for decision-making by the owner, designer and future user about the choice of the optimal variant of the technical solution for restoration, also with regard to ecological aspects, cultural and historical value and long-term economic consequences [4]. In the case of cultural monuments, the life cycle costs mainly include restoration costs. Restoration means the maintenance, repair, reconstruction, restoration or other modification of a cultural monument. In the case of cultural monuments, LCCs are determined in the operational phase, usually before the intended restoration. They should be used for the selection of an economically sustainable solution, with the maximum potential for preservation of historical and historical value.

The cost of restoration of cultural monuments cannot be universally estimated, they will always differ in the same way that buildings differ from one another [5, 6]. For their estimation, we can use data on comparable buildings to a very limited extent, i.e. comparable in terms of construction, scope, purpose of use, intensity of use. The uniqueness of historical building elements, during their revitalization, causes higher demands on the technologies used compared to classic (modern) building structures. And therefore, the calculation of the valuation itself is based on the analysis of market prices for construction works used for historical buildings in combination with traditional tools and methods of pricing [7]. This paper proposes a valuation procedure to comprehensively approach the solution of this problem using the MONUREV software, which is presented.

2 Principles of the estimation of construction costs

The proposed software MONURE is based on parametric calculation of construction costs.

Parametric valuation of buildings is a method based on the estimation of construction costs using selected input parameters of the building (usually dimensions, i.e. built-up area and height). In order for parametric valuation to be applied, the building must be divided into structural and technological units (structural elements). The unit of measurement is usually m^3 or m^2. (For example, 1 m^2 of internal plaster, smooth, unreinforced, 1 m^2 of exterior plaster, unreinforced). Construction elements are individually priced. Valuation can be done in two ways. It is either the use of databases of average unit prices, which are generally valid for drawing up the construction estimate. The second possibility is the use of market prices, that is, the prices that the construction company achieved during the realization of comparable buildings. The application of market prices is a more accurate method of valuation, but requires a uniform method of gathering cost information in relation to structural elements. It also requires an established system for trend monitoring and price development prediction.

In the case study, the first of the named options is used, that is, using a database of average unit prices of building structures and works. In the Czech Republic, these prices are provided by company ÚRS. The database of average unit prices is a set of information on construction and assembly works, materials and products containing a detailed description and unit of measure, method of measurement and other technical and price conditions for the possibility of compiling the calculation of the necessary costs and determining the unit price.

The average prices of building construction and work includes both direct costs (material costs, wages, machines, other direct costs), but also indirect costs (production and administrative overhead) and profit. The rates are calculated based on the determination of the quantity of individual needs (materials, wages, and machines). Individual needs are valued with prices, or rates that are obtained through sample surveys.

Average unit prices were aggregated into sub-estimate for defined structural elements. The final estimate of construction costs will be the sum of the partial awarded structural elements that are part of the selected historic building [8, 9].

The unit price that is assigned to the defined structural elements is based on the principle of the so-called sub-estimate. The sub-estimate consists of several items from the database of average unit prices, where the unit price of the structural element is the sum of the partial prices for all items of the sub-estimate. The calculation unit of the sub-estimate corresponds to the usual measuring unit of the structural element. Each sub-estimate contains typical items for the following activities:

- demolition of the existing structure (demolition of the structure, on-site movement of rubble, removal of rubble to the construction site dump, a fee for depositing rubble),
- creating a new structure (new construction including surcharges),
- internal & external scaffolding (according to the position of the structure),
- material transfer (transfer of materials from the construction site dump to the place where the structure is stored).

The advantage of parametric pricing lies in the quick determination of costs for construction work based on selected technical information about the construction object [10].

3 Basic description of the MONUREV software

The research team developed the MONUREV software to process maintenance and restoration plans for historic buildings. This software is designed in the form of a web interface and is thus accessible to a wide professional public. The software processes data at the level of individual structural elements. For faster and more comfortable work of users, it uses a database of type objects, which combines primary data from the level of structural elements.

The database of characteristic objects of historic buildings is used in the program processing of the software, which, however, practically enables the introduction of different types of classification of building objects conducted concurrently. It is not only the introduction of sorting of the same type with a change in content, but also a type of difference in the approach of generating object templates. In the software, only the approach was used to obtain proposals for the breakdown of structural parts

in a given type of object by entering measurement units, such as height, width, length of the object.
After selecting a reference construction object and entering its basic size data, the individual structural parts from which the reference object is created are uniquely assigned to this object. This assignment is made through a matrix of conversion formulas compiled for all objects and all structural parts. Each conversion formula contains the characteristic size parameters of the analyzed object and an empirically determined conversion coefficient, from which the quantity of the structural part in the object is derived. By summarization, a fictitious object is assembled, which differs from the actual analyzed object within the permissible tolerance.
The basic requirement for this database is the definition of all structural parts that occur in construction production and whose service life does not reach the limit service life of the entire object. The criteria for the breakdown of structural parts are the function of the part, its lifetime and the unit cost of renewing the part.
The use of the software MONUREV is shown on the case study of the general repair and construction modifications of the historical building of the Dobrovice Parish located in the district of Mlada Boleslav (Central Bohemian region).

4 General repair and construction modifications of the historical building of the Dobrovice Parish

The subject of the project was the general repair and building modifications of the Dobrovice Parish for the purpose of further use for the town's associational activities and for the Basic Art School. The project also included the construction of a gas connection, water supply, repair of the existing sewer connection, new fencing and partial landscaping.
The building is a former parsonage built at the beginning of the 18th century on the site of a former castle on the slope above the square, east of the church of St. Bartholomew in the wider center of the city of Dobrovice. The current form comes from the reconstruction in the second half of the 19th century. In the nineties of the 20th century, the last reconstruction of the resocialization center for youth was started, which was not completed. The work was stopped in the "rough construction" phase, after which the object was secured against the intrusion of unauthorized persons. Elements of the original fencing and some new unbuilt building fillings remained stored here. The building was abandoned.

The owner of the building and most of the surrounding land is the city of Dobrovice. Only on the western side does the building adjoin land owned by the Roman Catholic parish in Dobrovice. The building is a free-standing, storeyed, partly basement, rectangular plan, covered with a hipped roof. The dimensions of the building in plan are 13.2 x 23.8 m, the height is approx. 15 m, the height of the rooms is 3 - 3.6 m.
The rooms on the ground floor are vaulted with cross and cloister vaults and are in good condition. In the central part there is an entrance hall with a wooden beamed ceiling, from which there is an accessible staircase. The rooms upstairs have flat ceil-

ings, now newly roofed with a steel structure and a reinforced concrete slab. The baroque wooden gable roof is covered by double-laid beaver tiles (area approx. 320m^2). Under the south-eastern part of the building is a barrel-vaulted cellar, from which a

buried stairwell outside the premises leads in a south-eastern direction.

Fig. 1. View of the Dobrovice Parish prior to the general repair and construction modifications.

Considering that this is an immovable cultural monument, the architectural and material solution was planned to be preserved without changes. The facades are preserved without changes, only the simple division of the northern facade is added. The facade is designed in shades of sand color. The hipped roof is covered with a new burnt roof, natural beavers for a scale covering, or grooves.

Fig. 2. View of the Dobrovice Parish after the general repair and construction modifications.

The internal layout is almost unchanged on the ground floor, sanitary facilities are added on the first floor, the attic and basement space are unused. The use of the building must respect the original layout scheme of the main room layout as much as possible. Modifications can only be accepted in the service area following the upcoming staircase and, on the floor, according to the already modified layout from 1992.
On the ground floor of the building, the load-bearing system remained unchanged, on the first floor the load-bearing walls were straightened and strengthened with facings and facings made of solid bricks or were re-bricked. The building is pulled down in the north-south direction by steel tie rods at the level of the ceiling structure above the 2nd floor. The new ties are at the level of the ceiling structure above the 1st floor.
A common problem is the dampness of the masonry in the basement and on the ground floor, which has degraded the interior and exterior plasters. Unfortunately, improper roof drainage also causes moisture. To improve the condition, it is immediately important to consistently divert surface water away from the perimeter of the building. As part of the project, measures were proposed to reduce the manifestations of humidity in the building (ventilation gaps, drainage, rehabilitation plasters).

5 Cost calculation using the software MONUREV

In order to verify the accuracy of the model generated from the MONUREV application, it was necessary to make a comparison with the actual restoration project of the monument. In this particular case, it is about the choice of a typical object of the rectory. The basic parameters of the object were entered into the MONUREV application, which is its height, length, width, height above ground, roof slope, number of floors and floor height.
Based on the choice of the type object and its measurement characteristics, a model of restoration of the tested object was generated. To evaluate the quality of the model, it is necessary to monitor and evaluate 3 basic parameters. The first is the agreement of the predicted structural elements generated in the model with the actual composition of elements on the monitored object. Another tested parameter is the agreement of the assumed dimensions of individual structural elements with reality. The third evaluated parameter is the comparison of the expected unit price of the renewal of structural elements with the actual prices. An example of a comparison is shown in Table 1.

Table 1. Example of comparing calculated and actual data.

Structural element	**Unit price (€)**	**Quantity**	**Actual unit price (€)**	**Actual quantity**
Basics - passport stone	353,8	137,6 m^3	355	144,8 m^3
Vertical non-load-bearing structure - partitions and load-bearing masonry without ceramic surface treatment	96,2	79,2 m^2	106	82,6 m^2
Surface treatment of vertical	32,2	1209,4 m^2	33	1125,7

structures - interior plaster without stucco reinforcement				m^2
Surface treatment of vertical structures - ceramic interior tiles	84,2	95,6 m^2	73	109,7 m^2
Compositions of horizontal constructions non-load bearing - embankment	59,9	368,6 m^2	67	321,6 m^2
Compositions of horizontal constructions non-load bearing - backlash	41,5	378,4 m^2	46	321,6 m^2

The deviations of the calculated data from the actual ones were calculated according to the following formula 1.

$$\textit{deviation} = (\textit{calculated data} - \textit{actual data}) / \textit{actual data} \tag{1}$$

Table 2 shows a summary statistical evaluation of the deviations of the observed parameters.

Table 2. Statistical evaluation of deviations of calculated and actual data.

Statistic	Unit price	Quantity	Structural compliance
Average	-0,0869	0,0670	0,0496
Variance	0,0096	0,0091	0,0123
Standard deviation	0,0982	0,0954	0,1107
Median	-0,0653	0,0566	0,0325
Lower quartile	-0,1012	-0,0476	-0,0236
Upper quartile	-0,0110	0,1282	0,1025

From the values shown in Table 2, it is evident that the accuracy of the generated model is around 90%, which is greater than the expected limit of 80%, which the authors of the project set internally. However, there may be cases when the object will be more diverse in layout and then the deviations from the model may increase. However, it must be taken into account that this is an initial design of the model, which the user can continue to refine according to his own project, so the actual results will be at a higher level of reliability than 90%.

6 Conclusions

Buildings of cultural heritage, due to their historic nature, require higher costs for rehabilitation and maintenance than ordinary buildings. Their value is mainly of a useless nature, which increases the financial burden of the investor, i.e., it does not promise a typical return on investment. The authors developed methodological procedures and created software MONUREV for determining an optimized cost plan for the restoration and maintenance of real estate with an emphasis on respecting cultural

and historical value, which aims to help owners and managers of historic buildings in their complex task of facility management.
Owners and managers of historic buildings currently lack comprehensive plans for maintenance activities that could subsequently be included in the economic framework of building management. The authors developed methodological procedures for creating a plan of maintenance activities that will lead to ensuring a long-term sustainable condition, to the maximum extension of the vitality of the historical building, and at the same time will be in line with current trends in historic preservation.

Acknowledgement

This contribution was instigated and undertaken at the Czech Technical University in Prague, Faculty of Civil Engineering. It was supported by the Program for the Support of Applied Research and Experimental Development of National and Cultural Identity for the Years 2019 to 2022 (NAKI II - DG18P02OVV012) funded by the Ministry of Culture of the Czech Republic.

References

1. Eklová, K., Kupec, J., Schneiderová Heralová, R., Dlask, P., Prostějovská, Z.: Evaluation Criteria of Sustainable Solutions in Buildings based on the Three Pillars of Sustainability. Business & IT 02(02), 2-9 (2021).
2. Eklová, K.: Sustainability of buildings: Environmental, Economic and Social Pilars. Business & IT 02(02), 2-11 (2020).
3. Hromada, E., Vitásek, S., Holcman, J., Schneiderová Heralová, R., Krulický, T.: Residential Construction with a Focus on Evaluation of the Life Cycle of Buildings. Buildings (2021).
4. Schneiderová Heralová, R.: Life Cycle Costing of Public Construction Projects. In: Central Europe towards Sustainable Building (CESB19). Bristol: IOP Publishing Ltd, IOP Conference Series:Earth and Environmental Science. vol. 290 (2019).
5. Brožová, L., Střelcová, I., Vitásek, S., Tomek, R., Krulický, T.: Valuation of construction work on architectural heritage and its influence on project implementation decision. In: New Trends in Business and Corporate Finance in COVID-19 Era. vol. 132, České Budějovice, The Institute of Technology and Business in České Budějovice (2022).
6. Macek, D., Schneiderová Heralová, R., Hromada, E., Střelcová, I., Brožová, L., Vitásek, S., Pojar, J., Bouška, R.: Cost Optimization for Renovation and Maintenance of Cultural Heritage Objects. In: Central Europe towards Sustainable Building (CESB19). Bristol: IOP Publishing Ltd. IOP Conference Series:Earth and Environmental Science. vol. 290 (2019).
7. Vitásek, S., Žák, J.: BIM for cost estimation. In: Advances and Trends in Engineering Sciences and Technologies III. London: Taylor & Francis, p. 543-549 (2019).
8. Nadkarni, R. R., & Puthuvayi, B.: A comprehensive literature review of multi-criteria decision making methods in Heritage Buildings. Journal of Building Engineering, 32 (2020).
9. Antuña, J.: Construction history: Tool to improve maintenance and intervention in built heritage. Reconstruction and Restoration of Architectural Heritage, 3–7 (2021).
10. Nowogońska, B.: Consequences of abandoning renovation: Case study—neglected industrial heritage building. Sustainability, 12(16) (2020).