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A TOOL FOR DEVELOPING A PLAN FOR THE RENOVATION AND REMEDIATION OF CULTURAL HERITAGE BUILDINGS

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Abstract. Cultural heritage monuments are, to a large extent, public goods of collective consumption, and their preservation is in the public interest of the society as a whole. The benefits arising from the owner's investment and resulting from the existence and the use of a cultural heritage monument are usually not "consumed" solely by the owner, but, to a greater or lesser extent, by the whole society or a particular group. In the case of the renovation and remediation of cultural heritage buildings, the life-cycle costs are determined in the operational phase, before the intended renovation or remediation. They should be used to select an economically sustainable solution, with the maximum potential to preserve the cultural and historical value. The paper presents the application designed for the elaboration of plans for the renovation and remediation of cultural heritage monuments, developed in the form of a web interface. The application processes data at the level of individual structural elements. For faster and more comfortable users' work, a database of type objects is used, which combines primary data from the level of structural elements.

Keywords: Cultural heritage, remediation, renovation.

1. Introduction

More than CZK 7 billion was spent within the Ministry of Culture's subsidy programmes on heritage care in the Czech Republic in the years 2005–2016. The proposal for the years 2017–2020 amounted to CZK 727 million per year. According to the Ministry of Culture data from 2016, the conservation deficit of cultural monuments in the Czech Republic exceeded CZK 318 billion [1].

These are large amounts of money that should be spent efficiently. And not only in the form of renovation costs, but also in a long-term perspective – on the future costs of the operation, maintenance and further renovation of these buildings, i.e. on their economic sustainability throughout their whole life cycle.

The analysis of the life cycle cost performed on the basis of relevant input data on the technical parameters of the building, its structural elements and equipment, on the period of time when related costs originated serves as the tool for the assessment of the economic sustainability of an immovable cultural monument. In this way, the analysis becomes an important background factor for the owner's, designer's and future user's decision-making on the selection of the optimum alternative of the renovation technical solution respecting also the ecological aspects, the cultural and historical value and long-term economic consequences [2].

The Life Cycle Cost (LCC) is the total cost of an asset over its life cycle. When applied to the construction industry, it accounts for the costs associated with the acquisition of building and engineering structures, the costs of their maintenance and the renovation of the structures and equipment, the operating costs and the disposal costs at the end of an asset's life. In most cases, the evaluation covers the cost of the economic life of the building. When deciding on the choice of potential alternative options, it often happens that only the acquisition costs are incorrectly assessed, but the operating costs as well as the preventative maintenance and renovation costs are often neglected. It is, however, the costs incurred during the building's use phase that make up a significant portion of the building's life cycle cost [3].

2. Objectives of the research

The aim of the project was to create administration and management tools for the sustainable development of cultural heritage realty. The project provided tools for identification and optimization of technical and economic limits of such properties, with an emphasis on the specifics of cultural heritage.

Due to their monumental nature, the reconstruction and maintenance costs of historical buildings are often considerably higher than normal. Their value is predominantly of a non-utilitarian nature, which further increases the investor's financial burden. The research team designed specialized software with the purpose of passport, estimation and optimization of maintenance and renewal costs of realty.

Owners and managers of cultural heritage buildings often lack comprehensive maintenance plans that could be part of the money management. The research team prepared procedure of maintenance plan and proposal of conservation principles for cultural heritage structures, which lead to sustainability and maximum longevity of the building and will be in compliance with current trend in cultural heritage protection.

The developed tools are pilot-tested in the form of case studies of selected buildings. These studies include economically and technologically sustainable management model, which will also be sustainable in cultural and social terms. The main parts of studies contain a description of the current state and options of possible future operation. For each option, technological solution, costs, possible operational revenues and financial analysis with variant and risk assessment are proposed.

3. Life cycle costs of structural elements

The lifetime of the construction is limited not only by its technical but also its economic lifetime. With the technical lifetime the emphasis is put on material characteristics of a construction and the lifetime of the construction, which is dependent especially on the provision of building elements with a long-term viability. It concerns those structures of the construction which have, from the viewpoint of the technical lifetime, principal significance because with their damage (loss of performance of their function) the construction is not functional, threatens to collapse and any repairs become technically and economically extremely demanding.

From the viewpoint of the cost level for repairs it is more effective to remove the construction and build a new one. In the case of the economic lifetime this concerns the period in which it is appropriate to use the building economically. It is usually shorter than the technical. Very often it concerns the loss of economic usefulness which can be connected with the permanent loss of net income with reference to disproportionately high costs and it would seem preferable to remove the building and replace it by a new building and thus re-evaluate the land.

The resulting LCC calculation of the relevant inputs which concern the technical parameters of structural elements and the time period for incurring costs related to them should be an important basis for the decision of an investor, a designer and any future user in choosing an optimum variant of a technical solution for a construction and also looking to ecological aspects and long-term economic consequences. Costs connected with the implementation, use and disposal of a building are divided into 3 basic groups [4]:

- costs directly related with the technical parameters of a construction – investment costs, repair and maintenance of a building costs, reconstruction costs, costs relating to modernization and disposal of a building,
- operating costs of a building – energy, cleaning, depreciation etc.,
- administrative costs related to property management – taxes, insurance, administration of a building etc.

4. Life cycle cost of cultural heritage

In the case of immovable cultural monuments, the life cycle cost mainly includes the renovation costs. Renovation in the sense of the Act on State Heritage Care refers to the maintenance, repair, rehabilitation, restoration or other modifications of a cultural monument. The term "maintenance" can generally be understood as the removal of undesirable changes to a cultural monument that have occurred as a result of its use (e.g., a new coating on the facade of a house). The term "repair" can be defined as the elimination of the consequences of damage to a cultural monument or the effects of its wear (e.g., adding part of the roofing). The term "rehabilitation" can either denote such structural and technological interventions in a cultural monument which have either changed its technical parameters or its function or purpose (e.g., the conversion of an industrial building into an exhibition space), or restored the cultural monument to the previous, historically documented or presumed state, designed on the basis of professionally substantiated assumptions (e.g., the construction of a new roof truss after a fire).

"Restoration" is understood as a set of specific artistic, craftwork and technical activities respecting the technical and artistic structure of the original – works of fine arts or handicraft. "Another modification" is not any modification of a cultural monument, but only the modernization of a converted building with a changed function, as well as the extension and addition to a building. "Modernization of a building with an unchanged function" is such a modification of a cultural monument in which its parts are replaced by more modern parts, its amenities are upgraded or its usability is extended, without changing its function (e.g., the installation of central heating instead of local heating by a stove). Here, the objective of the renovation is to extend the technical life of buildings and, at the same time, preserve their historical and cultural value [5].

Operating costs come up to high amounts. These are the costs incurred throughout the entire technical life of a building, which is very long in the case of immovable cultural heritage.

LCC is usually calculated in the pre-investment phase of the life cycle of a construction project, and can thus be used to select effective alternative solutions. The LCC indicator is a cost criterion, its lower value being more beneficial for the investor. The information on the cost development in individual phases and the possibilities and ways of affecting them, as well as the information on the service life of structures and equipment, is the key information relevant for the LCC modelling.

In the case of immovable cultural monuments, LCC is calculated in the operational phase, usually before the intended renovation. It should be used to select an economically sustainable solution, with the maximum potential to preserve the heritage and historical value of the monument [6].

The investors engaged in the rehabilitation of immovable cultural monuments funded from public budgets can profit from the optimized construction life cycle costs: they contribute to following the 3E principles (economy, efficiency, effectiveness), which are key to public contracts. In the currently valid wording of the Public Procurement Act, the life cycle cost is listed as one of the options for the application of the basic indicator for the selection of a public procurement contractor, as the "economic efficiency of the tender".

The private investors engaged in the renovation projects of immovable cultural monuments profit from using the optimized construction life cycle costs as well: they contribute to achieving higher value for money (Value for Money) and a shorter payback period.

The evaluation of the life cycle cost of buildings can also be viewed from a broader perspective to include, in addition to the costs related to the rehabilitation, remodelling, renovation and operation of an immovable cultural heritage building (i.e. LCC), also externalities and social (community) benefits and costs arising in connection with construction activities and the building operation in its surroundings. The construction costs defined in this way are denoted as the lifetime costs of a building [7].

5. Evaluation applying life cycle cost

The methodology of sustainable acquisition of buildings by public contracting authorities has been designed for newly built, mostly public buildings, but after a modification, it can also be used for the renovation of immovable cultural monuments. The application of the methodology can be split into several steps:

- determination of the LCC analysis objective,
- determination of the LCC analysis scope,
- definition of key parameters,
- identification of alternative options for the analysis,
- data collection on evaluated alternative options,
- economic assessment of the alternatives, including risk and sensitivity analysis,
- final report.

The methodology of sustainable acquisition of buildings by public contracting authorities is more specific; the costs are structured at individual levels of the LCC analysis respecting the practices of pricing strategies in the construction industry in the Czech Republic, the recommended methods and background materials for their compilation available for pricing in the Czech Republic. The methodology contains a list of common risks impacting on the building's life cycle cost value. It also highlights the specifics of the methodology use by public contracting authorities. The methodology is supplemented by the templates of clear forms that can facilitate its application [8].

The aim is to encompass the complete process of the application of the life cycle cost analysis for immovable cultural monuments. The workflow of the modified methodology application is defined for three levels:

- preliminary LCC analysis for the decision on the project implementation,
- detailed LCC analysis for designed alternative options of the immovable cultural monument renovation,
- detailed LCC analysis for alternative options of key structures, systems and installations.

The public sector is aware of the importance of evaluating buildings in terms of their life cycle cost. In the Public Procurement Act currently in force, the life cycle cost is listed as one of the options for applying the basic indicator for selecting a public procurement contractor, as "the economic benefits of a tender". In this case, the life cycle costs must include the bid price (in terms of LCC, it is part of the acquisition costs, in public construction projects it is equivalent to construction costs) and may include:

- costs incurred by the contracting authority or other users during the life cycle of the public contract subject, which may, in particular, refer to
  - ▷ other acquisition costs,
  - ▷ costs related to the use of the public contract subject,
  - ▷ maintenance costs, or
  - ▷ disposal costs at the end of the service life, or
- costs caused by the environmental impacts associated with the public contract subject at any time during its life cycle, provided that their monetary value can be quantified; these may, in particular, refer to the cost of emissions of greenhouse gases or other pollutants or other costs of the climate change mitigation.

Another option for the evaluation of the economic efficiency of projects involving immovable cultural monuments that should be mentioned uses the Cost-Benefit Analysis (CBA), based on the utility theory. It is an analytical tool used to evaluate investment decisions to assess how they contribute to changing the level of a society's well-being. The CBA method serves primarily to evaluate projects from the public sector, comparing the benefits, which express any positive effects (Benefits), with costs in the broadest sense (Costs), or negative effects of the investment. The method is based on the analysis of the impacts of the investment on the affected entities, the quantification of the identified effects and, finally, the conversion to a common numerical (ideally monetary) unit [9].

6. Pricing of construction works on immovable cultural monuments

The pricing of construction works on immovable cultural monuments studies methodologically how to approach the pricing of construction activities related to historic buildings. The uniqueness of historical building elements sets higher demands for the technologies used during their revitalization compared to classic (modern) building structures. Therefore, the pricing concept itself is based on the analysis of construction work market prices used for historic buildings in combination with traditional tools and pricing methods [10].

The designed methodology is based on ten pillars:

- CS ÚRS and RTS DATA price systems for buildings.
- Principles of parametric pricing of buildings and classification of structural elements respecting the needs of immovable cultural monuments.
- Budgetary principles according to the TSKP classifier (classification of building structures and works).
- Technological handling of rubble.
- Measurement method of structures.
- Examples of rehabilitation and repair pricing.
- Individual calculations of items using a standard calculation formula.
- Hourly billing rates.
- Micro budgets referring to defined structural elements.
- Analysis of market prices of construction works used for historic buildings.

The pricing of renovation projects of historic buildings is generally considered problematic due to the type of work and some degree of uncertainty in estimating its amount. The aim of the guide price analysis was to find out whether they actually corresponded to the prices on the construction market. In this context, it must be realized that if the works in the building are regulated by the restoration regime and can only be performed by a conservator with a valid certificate, it is necessary to price these works individually, as guide prices do not take restoration repairs into consideration. Furthermore, a relatively large scope of works can be needed during renovations that are not listed in the budgeting programmes and are priced individually in the bids. This mostly refers to carpentry and locksmith structures and artistic elements [11].

7. MONUREV

The MONUREV software application, designed as a web-based interface, has been developed for the elaboration of maintenance and renovation plans of cultural monuments. The application processes data at the level of individual structural elements. For faster and more comfortable users' work, it uses a database of type objects, which combines primary data from the level of structural elements.

One of the conditions necessary for a practical and full use of the T-E analysis model is an unambiguously defined form and amount of input data, which will be the subject of the summarization. The obligatory data that must be entered by the analysis maker are automatically complemented by the remaining data necessary for the processing of the analysis before the summarization. The sources of these additional data are two internal databases:

- database of characteristic representatives of cultural monuments,
- database of typical structural components.

By a suitable compilation of the databases, a system has been created which enables the analysis maker who has no professional construction qualifications to obtain the best practically usable outputs. The more elements the database will contain, the lower the distortion of the output information caused by assigning the analysed buildings to the selected representatives of buildings and structural components. A too wide range of selected representatives (reference models), on the other hand, would lead to a complicated and confusing entering process.

One database of characteristic representatives of cultural monuments has been physically used in the application programme processing, which, however, practically enables the introduction of different types of classification of buildings running in parallel. This not only involves the introduction of the classification of the same type with a change in the content, but also a type difference in the approach to the generation of the templates of buildings. The only approach used in the application for obtaining the options for the distribution of structural components in the respective type of building is by entering the units of measure, such as the height, width, length of the building.

After selecting the reference building and entering its basic size data, individual structural components which the reference building is composed of are unambiguously assigned to this building. This assignment is made through a matrix of conversion formulas compiled for all buildings and all components. Each conversion formula contains the characteristic size parameters of the analysed building and an empirically identified conversion coefficient from which the number of structural components in the building is derived. By the summarization, a fictitious building is created differing from the actual analysed building within acceptable tolerance limits.

The basic requirement for this database is to define all structural components existing in the building construction production whose service life does not reach the limit service life of the entire building. The criteria for the classification of structural components are the component's function, its service life and the unit cost of the component's renovation.

The life cycle of an element expresses in what time cycles and at what costs the renovation of the respective structural element will be necessary to maintain its standard use and, at the same time, not to renovate it unnecessarily prematurely when its potential for use has not been exhausted yet.

A characteristic feature of the T-E analysis model is the collection and arrangement of all relevant data on the technical and economic condition of the analysed building valid as of the selected date into a uniform input data scheme.

The application runs on the server of the Faculty of Civil Engineering, CTU in Prague and is available at `https://monurev.fsv.cvut.cz/`. The users will log into the application with the assigned user password and name.

8. Conclusion

The Monurev application is intended primarily for owners (administrators) of listed buildings. The tool is focused on qualified planning of renovation and maintenance of buildings. The project solution is based on reference databases of objects and structural elements, which will allow users who are not experts in this field to obtain results quickly. On the other hand, the tools allow you to go into details and modify the designed models according to your own specifications. The user chooses which areas to use and how deep the detail he goes into processing the data.

The developed methodology and tools for the administration and management of the sustainable development of immovable cultural heritage are pilot-tested in the form of a feasibility study for a selected listed building. The feasibility study includes an economically and construction-technologically sustainable model of further operation of the historic building in the long term. The study includes a description of the current state (building certification), evaluation of the current wear rate of the building and design of variants of further operation of the building (zero variant – only maintenance work, partial reconstruction, complex reconstruction, design of innovative technologies related to environmental protection, etc.). For all variants, the organizational implementation, the implementation schedule, the planned construction-technological solution are described, the investment and operating costs and possible revenues from the operation of the historic building are quantified, and a financial analysis, including economic evaluation, is prepared. All assessed variants and risks. The owner will be able to use the outputs of the feasibility study for further strategic decisions on the operation of the historic building.

The life cycle costing and analysis are primarily a tool for informed decision making. As a rule, they involve the evaluation of several investment scenarios in the pre-investment phase, the selection between alternative options in the investment phase, and the choice of alternative structures and equipment with acceptable parameters in the investment phase and in the use phase. The life cycle cost analysis is also a valuable tool to estimate the future costs incurred by the building owner or to evaluate an ex-ante investment decision.

The analysis of the life cycle cost of a building should be part of the decision making on the renovation of immovable cultural heritage. The experience from construction practice indicates that the choice of alternative options, structures or equipment of buildings on the basis of the lowest acquisition costs (lowest bid price) only is wrong. The investors should aim at the acquisition of an economically sustainable building, i.e. a building with the lowest life cycle cost. This can be achieved by the incorporation of the life cycle cost analysis into the design of buildings.

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