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Heritage Regeneration and Sustainability

Awareness-Raising Campaigns and Tools

Cost Optimization for Renovation and Maintenance of Cultural Heritage Objects

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The paper deals with the issue of maintenance and renovation of cultural heritage objects. This is a very specialised area of cost optimization, for which there can still be used procedures and methods applied to more normal contemporary objects, but where there are many peculiarities and differences that need to be taken into consideration. In the initial phase, it is necessary to gather all relevant data about such objects. From data there can be obtained information that can be used to build the structure and correlations of the recovery and maintenance model. In the Heritage Catalogue there can be found basic information about cultural heritage objects. It provides basic description of the objects, but technical data which could be used for creating the recovery and maintenance model are missing. Only if based on a sufficiently large and properly structured database, is it possible to deduce the correlations and dependencies needed to create a system for the types of planning and optimization involved in recovery and maintenance. In order to establish the recovery and maintenance costs, it is necessary to complement the database for individual construction elements costs and the length of recovery and maintenance cycles.

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Abstract. The paper deals with the issue of maintenance and renovation of cultural heritage objects. This is a very specialised area of cost optimization, for which there can still be used procedures and methods applied to more normal contemporary objects, but where there are many peculiarities and differences that need to be taken into consideration. In the initial phase, it is necessary to gather all relevant data about such objects. From data there can be obtained information that can be used to build the structure and correlations of the recovery and maintenance model. In the Heritage Catalogue there can be found basic information about cultural heritage objects. It provides basic description of the objects, but technical data which could be used for creating the recovery and maintenance model are missing. Only if based on a sufficiently large and properly structured database, is it possible to deduce the correlations and dependencies needed to create a system for the types of planning and optimization involved in recovery and maintenance. In order to establish the recovery and maintenance costs, it is necessary to complement the database for individual construction elements costs and the length of recovery and maintenance cycles.

1. Introduction

The issue of sustainable management of cultural heritage objects has not yet been systematically addressed in the Czech Republic. There are some partial results from the current state of research related to financial issues of cultural heritage objects taken from the viewpoint of the non-profit sector, as well as case studies on the reconstruction of these objects. This issue is very topical. In 2011, there was a conference focused on the use of churches. In 2012, there was a conference entitled Restoration of Monuments and Historical Ecclesiastical Buildings. Both events were held under the aegis of The Institute for Monuments and Culture. There are also other events that can be used as inspiration for creating a strategy for sustainable management of cultural heritage objects. In order to find solutions in contemporary practice, there is available the source of foreign comparison. However, any such possible implementation in our national environment can be done only after a very thorough analysis.

When managing cultural heritage objects, it is necessary to keep in mind that they are of irreplaceable value and it is our duty as a society to preserve them for future generations. There are many publications dealing with preservation of cultural heritage objects, but they are not usually concerned with actual costs of managing and preserving these buildings [1, 2].

Cultural heritage objects are often in a very bad condition. They also require higher repair costs than ordinary buildings. Their value is predominantly not utilisable. This fact further increases the financial burden of an investor , because it does not promise a typical return on such investment [3, 4].

This paper introduces methods and procedures that are an essential part of sustainable property management. It takes into account the non-profitable value of cultural heritage objects and practical strategies to meet the social pressure to protect and preserve them. This means in synergy with the European landscape convention which identifies the landscape as a matter of public interest [5, 6, 7]. Based on a created original model, software for cost estimation of the maintenance, renovation and technical passport of the buildings will be developed. The software will work with the input values of the wear and tear of the technical state of the elements in both long-term and short-term lifetime. Recommended repair cycles will be available and the user will be able to adjust them. The output will be the cost of renewal and replacement of substructures during the life cycle of the building. The software will be designed with emphasis on the prioritization of the cultural and historical value of the shorter life elements, where the renovation is preferably solved by repair of the elements. Also, renewal costs will take into account a significant proportion of manual labour and the higher labour costs, unlike the case of conventional buildings [8].

2. Analysis of projects

In order to determine maintenance and renewal costs for individual structural elements of a historical building, it is necessary to obtain the broadest possible database on the bid and the actually realized construction work prices in the Czech Republic. In order to create this database, the project team gathered price information for a total of 55 construction orders that were completed between 2016 and 2018. The number of construction orders will be extended in subsequent stages of the project. Information on some construction contracts was obtained through these specialized web portals. They publish government contracts and information about individual procurements.

- https://smlouvy.gov.cz/
- https://www.vhodne-uverejneni.cz/
- https://www.hlidacstatu.cz/

These web portals also contain a contracts register designed to increase the transparency of the contracting authority's work. The register contains documents which the contracting authority wishes to make available to the public. In some cases, it is also possible to find related work contracts on the official websites of individual municipalities that are owners of historic buildings.

However, for some construction orders on these web portals, the full price information was not provided. The contracting authority has published a works contract, but has not yet published appendices to the works contract. These appendices included the itemized building budget that the project team needs for research work. Therefore, the project team had to choose other approaches for data collection. Law No. 106/1999 Coll., on free access to information, was used. Applications for the provision of the bid budget for construction contracts from the winning bidder for these public contracts have been submitted.

All requested statutory parties responded positively to our request and provided the project team with the required price information. The project team currently has a large number of building budgets for historical buildings, including tender documentation. This data is statistically processed to create current prices for developing the software for property owners and administrators.

It is necessary to create a database for the basic dimensions of each type of building object, in order to ensure the relevant software outputs. To this end, the project team collects project documentation (floor plans, sections, views) for the widest possible set of historical buildings. At this stage of the project, the project team focused on the category – Burgher house. The project team addressed the owners and administrators of selected historic buildings (burghers' houses) and asked them to provide a copy of the basic project documentation. The owners and administrators of these properties were addressed:

- Měšťanský dům, Husovo nám. 88/16, Beroun
- Veigertovský dům, Karlovo nám. 8, Kolín
- Červinkovský dům, Brandlova 27, Kolín
- Měšťanský dům, Masarykovo náměstí 98, Brandýs nad Labem – Stará Boleslav
- Měšťanský dům, Náměstí Přemyslovců 165/18, Nymburk
- Dům U Tří bubnů, Nám. Franze Kafky 14/8, Praha
- Dům U Červeného jelena, Malostranské nám. 265/6, Praha
- Dům U Bílé řepy, Nerudova 237/39, Praha
- Dům U Černého orla, Nerudova 205/2, Praha
- Dům U Černého beránka, Valdštejnská 150/4, Praha
- Dům U Bílého orla, Malostranské nám. 4/27, Praha
- Dům u Zlatého bažanta, U radnice 10/2, Praha
- Dům U Tří lip, Malé nám. 7/7, Praha
- Dům U Tří kominíčků, Malé nám. 9/5, Praha
- Dům U Bílého jelínka, Nám. Franze Kafky 18/6, Praha
- Dům U Tří špačků, Nám. Franze Kafky 17/7, Praha
- Dům U Anděla na kohoutě, Karlova 145/25, Praha
- Buchalovský dům, Havlíčkova 1025/4, Praha
- Dům U Ambrožů, Školská 687/13, Praha
- Dům Na Korábě, Václavské nám. 824/29, Praha

This list of historical buildings will be continuously expanded in the next phase of the project. Since owners and property managers are not by law required to provide project documentation, the project team does not have the consent of all the owners and administrators of these properties at the moment. Some owners have asked the project team for a more detailed explanation of the need to provide project documentation. The project team has then tried to provide relevant justification. In cases where owners agreed to share the documentation, the project team representative contacted the relevant building archive and obtained a copy of the project documentation for further research.

3. Classification of buildings

The basic pillar of the generated model is a breakdown of types of cultural monuments. This structure of object types must contain a sufficiently clear and balanced database capable of capturing a wide range of cultural monuments [9].

The Monument Catalogue, which is new system of monument listing, was chosen as a relevant source of information about cultural heritage objects in the Czech Republic. It contains comprehensive information about these buildings including basic description, photographs, location and other matters.

Based on such data, statistics on the occurrence of types of buildings were created in combination with the building styles, which is also one of the important factors for creating a suitable maintenance and recovery plan [10, 11, 12].

The following periods have emerged as key building styles:

- Romanesque
- Gothic
- Renaissance
- Baroque
- Classical
- 2nd half of the 19th century

It was suitable to divide buildings into two levels. The first level was the range of objects and the second level was a typology of objects. The breakdown that was compiled for the generated model is as follows:

- Building for crafts, workshop
  - water mill, smithy.
- Agricultural construction
  - farm building, stables, vineyard house.
- Church and sacred buildings
  - chapel, church, round, vicarage, bishop/dean, canonical house, bell tower, monastery, synagogue.
- Residential buildings
  - burgher / town house, country house, apartment house, monks house, lock, palace, fortress, summerhouse.
- Buildings for culture and social events
  - community house, library, theater, museum.
- Buildings for business and services
  - salt storage house, store, butcher shop, pub, hotel.
- Buildings for sports
  - riding school, Sokol house, ballgames house.
- Buildings for education and training
  - school, dormitory.
- Health and social buildings
  - house for disabled, pharmacy, poorhouse, hospital.
- Production structures
  - ceramic factory, spinning mill, tannery, glassworks, printing house.

4. Framework of structural elements

The next step in creating a recovery and maintenance model of historical buildings is to determine the construction elements from which the standardized buildings are composed. For the most accurate estimation of actual costs, renovation and maintenance activities were divided into the following categories [13, 14]:

- Preparatory work
  - exploratory, geodetic and project work, site preparation and equipment, engineering activities.
- Structural and static construction parts
  - insulation (against water, moisture, gas etc.), vertical structures (including interior surface treatment), exterior surface treatment, staircases and ramps, ceilings, floors, roof, windows, doors, remediation.
- Restoration work
  - stonework, exterior surface treatment, interior surface treatment, staircases and ramps, ceilings, floors, roof, windows, doors.
- Functional proficiency
  - central heating, technological equipment (ventilation), sanitary installation (water supply, sewerage), wiring.

The building elements are then divided into a third kind of classification but it should be noted that the inventory is not part of our contribution. The specificities of the historical buildings are based mainly on sanitation works which are not used in the contemporary construction practice. At the same time, the structure of the components is expanded by information on what technology will be deployed. A special chapter would relate to the renovation of historical artefacts, but these too are not addressed in this work. In these cases an individual costing is required, which is very costly, and indeed an estimation is problematic even to an order of magnitude involving a monetary value of millions [15].

5. Structural components of Life Cycle Costs

The building life cycle analysis (Life Cycle Costs, i.e. LCC), which is described by [8, 12] focuses on the empirical operational expenditure improvements over the total building life cycle. Building lifespan is limited not only by technical durability but also by economic life. Technical lifespan is determined by the importance of material characteristics and building lifespan, which especially depends on designing construction components over a long life cycle. Those construction components are of vital importance because when they are damaged (the components cannot serve their main purpose) the whole building is not functional, a total collapse may be imminent and potential repairs are extremely demanding technically and economically.

Considering the total cost of repairs it would be more effective to completely demolish the building and build a new one. Economical lifespan defines the period of time over which it is economic to operate the building. Usually, the economic lifespan is shorter than the technical lifespan. It is very probable that the building will lose its economical serviceability, which could be associated with permanent loss of net revenues due to high expenses and it appears that it would be more useful to remove the building, then build afresh permitting the site to return to profitability. The methods of decision making are described by [7].

The total LLC calculation includes relevant input data, which are defined by the technical parameters of the construction components and by the time when the particular expenses were generated. The LCC calculation should serve as an important basis for decision making by the investor, designer and the future building end user in choosing the most optimal technical solution with regards to the ecological aspects and long-term economic impacts.

5.1. Lifetime of structural components

For estimation of the recovery cycle, it is necessary to know the average life of the individual components. The main decisive factor is the environment in which the material or structure is located and what traffic is present in a given environment. In general, all building materials have a high service life (to an extent of hundreds of years) when they are in a protected environment and are not adversely affected by heavy traffic (e.g. dynamic loads, chemical products). The aging of most materials does not occur, for example if the moisture content of wood does not exceed 18%, the humidity of masonry is 7% and there is no dew point on the surface of the structures. These conditions are usual in residential buildings, but it is difficult to maintain them in uninhabited buildings [16].

A different situation applies for materials and structures exposed to the external environment. Table 1 shows the lifetime of structures based on exposure to the environment.

These values apply to constructions that are newly built or renewed. They are derived from the age of existing buildings. In most cases the age of the buildings are many times greater. These kinds of lifetimes are subject to regular maintenance.

Table 1. Approximated lifetime of construction elements

Construction	Lifetime (years)	Maintenance
facade masonry in external exposure		
of bricks	100–500	necessary repair of gaps and replacement of individual bricks
sandstone blocks	100–500	necessary repair of gaps
granite, crystalline slate	100–500	necessary repair of gaps
marlstone, sandstone	100–500	must be protected by plaster
concrete (in external exposure)	100	
reinforced concrete	50–100	necessary repair of reinforcement
timbered and half-timbered buildings	100–200	necessary replacement of the sick wood
steel structures (in external exposure)	100–200	reapplication of coatings
fired roofing	70	repairs
slate roofing		
copper nails	100	repairs
iron nails	50	
sheet metal roofing (copper, lead)	300–400	repairs
sheet metal roofing (galvanized)	100	reapplication of coatings every 10–15 years
shingle roofing	30	without reapplication of coatings
	70	reapplication of coatings every 8–10 years, shingle repairs
lime plasters with hydraulic binder	30–70	repair damaged areas in time
cement plasters	70–100	repair damaged areas in time
restoration of plasters, stone elements	10–30	must be monitored
Windows	100–200	reapplication of coatings every 4–6 years

6. Processing of the building reference database

The application uses a single database of characteristics representative of the physical historical construction production. The database allows for inserting different simultaneously maintained types of building object classification. The database was adjusted such that allows inserting more modelling techniques during the rendering of an exemplary scheme of construction parts of a particular building. At present, the database includes an expansive system generating examples based on building capital expenditures.

6.1. A Model based on the basis of specific elements

When the reference building has been chosen and all its main construction size attributes have been inserted, individual construction components are assigned to create a complete reference building. This mapping is carried out through the use of a matrix of conversion formulae assembled for all buildings and all construction components. Each conversion formula includes characteristic size parameters of the analysed building and an empirically determined conversion coefficient which defines the amount of construction components in the building. A notional building is created by summarizing all the components and is differentiated from the real investigated building by a tolerable deviation.

For purposes of the T-E analysis, the existing construction production is divided into 10 systems. Each system includes a more specifically determined group of objects. There are defined 180 representatives of the construction production in total in the database. Each object is labelled by a four digit code (first two digits represent the system; the second two digits represent the building) and by a description.

The main requirement for this database is a definition of all construction components which are present in the construction production, and whose lifespan does not attain the lifespan limit of the whole building. The criteria for dividing the construction components are its functions, its lifespan and the expense for component recovery per unit. Each construction component is labelled by a code and description. In order to maintain better transparency and the possibility to insert more components into the database, the construction components are included into groups labelled by letters and a binary number expressing the construction component class.

6.2. Software solution

The project solution will be based on software modules which are linked with the main database system. The database initiates the main foundation which interlinks the separate software tools. The user chooses which areas will be used and what the level of detail will be. The system is solved in such a manner that during the processing of the fundamental operations it is possible to generate the software outputs without unnecessary pressure on the user to insert details about his building.

The application has been upgraded not only in terms of the calculation and optimization procedures but also in terms of visual interface. Furthermore, a user interface has been added allowing easy output processing with the table interface . In order to be able to examine the application preview it is possible to use the login demo and password demo. The preview login allows an examination of the created examples, and a look at all options and settings which are included in the application.

7. Conclusions

The paper summarizes the platform (theoretical and modelled) for the preparation of a software application that will be an appropriate tool for planning maintenance and restoration of cultural heritage objects.

Historic buildings have various specificities and cannot be treated as contemporary buildings. The difference lies in another approach to the renovation and maintenance of these buildings and not only in the design solution that corresponds with the time of construction. Cultural heritage objects have a number of maintenance constraints that differ in the materials used for their construction and in the technologies that will be deployed to restore them. A special chapter is required for sanitation works that have been identified as an independent part of restoration works.

Consideration must also be given to the fact that historical objects often consist of parts from different historical periods. Thus, the resulting model must reflect that as well.

The software application will have a form of web interface in order to be accessible to entities that deal with recovery and maintenance issues of historic buildings. Launch of the web portal is scheduled for the second half of 2019.

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