Abstract

The paper presents a model for maintenance and renovation of public sector buildings. The model creates the basis of the Buildpass application that allows users to use these methods through a web interface. The author researched innovative approaches in detail, in order to deal with the problems of maintenance and construction refurbishments indicated by companies dealing with software applications used for Facility Management.

Maintenance and renovation costs spent on buildings are a significant part of costs within the lifecycle of structures. Rational owners and facility managers try to minimize the outlays on maintenance and renovation. However, it is at the same time necessary to respect a certain standard condition of a building that must be maintained above the fixed limit given by the type and demands on usage of an existing building.

The model must be on such a level that the user, who is not a civil engineering specialist, would be able to use it without getting biased or misguided results. On the other hand, the aim is to create such an environment where the civil engineering expert can intervene in the primary inputs of a model and thus to use his/her own experience and knowledge.

Attributes of the information-technological solution do exist – the possibility to work on various levels of the model’s detail and the time exigency for gaining information outputs on tasks being solved. It is many times necessary to get data within a short time or more alternative solutions are analyzed and it is necessary to focus only on the potentially best solutions and not needlessly waste time on poor variants. The application must enable getting a result within a short time and at the same time not seriously bias the outputs. For a more in-depth analysis, the user then selects how much time wants to dedicate to the task.

Keywords: Maintenance; Renovation; Life Cycle Cost; Buildpass; Model.

1. Introduction

The public sector manages an extensive amount of assets, mostly buildings, which are seated by public sector administration or are rented. It is necessary to invest enormous amount of public expenditures which should be spent effectively. In order to establish procedures and estimate preliminary operational expenditures generated by effective facility management it is vital to use modern models and approaches which are part of software tools designated to manage construction assets.

Asset management requires ongoing use of financial and engineering resources. Furthermore, ad-hoc asset management which is managed without any conception or economical limits, without calculations and assessment of different possible solutions during the buildings life cycle, is not economical. Moreover, it offers only average degree of building user satisfaction. The amount of expenditures, designated for building operation, maintenance and modernization, should be within the range from 0.2% to 4 – 6% of the building capital cost annually (Bull, 1993). The subject of the asset management covers topics such as the rate of maintenance negligence in previous years or changing the type of the main function of existing buildings. It initiates the topic of progressive constructions, new technologies, new materials and overall conflicts of the technical progress. Pragmatic solutions are indeed feasible but they do not respect possible risks, uncertainty, incomplete information, expected progress trends in the uncertain informational future.

Terms such as building renovation and maintenance are inseparable from the term Facility Management which covers both. Facility Management is possible to define in a simplified way as a service which ensures the investment recoverability through economic operation thanks to the Life Cycle Costs or through the revenues from leasing of the building to particular tenants in a rationally used building. (Khojandi & Maillart & Prokopyev, 2007) defines operational expenditures optimization as a Facility Management tool.

* Corresponding author. Tel.: +420 224 354 529; fax: +420 224 354 521. E-mail address: daniel.macek@fsv.cvut.cz
For each building there is a wide variety of known or easily accessible technical information about its technical and economic condition. Those information are procured from different sources, have different weights, different accuracy, risks and they change over a period of time, as (Frangopol, 2001) shows. It is difficult to make a proper and responsible decision about building operational investments (especially about periodic maintenance and repairs) according dispersed information over a specific period of time because we do not know the inaccuracy which influence our decision making. Rational operation and Facility Management of several buildings based on dispersed information is not even possible and that is caused because the degree of information uncertainty is even enhanced by different methodologies of information acquisition for each building, as stated by (Seeley, 1987).

On the market there exist various instruments from the field of facility management, which deal with the problems of maintenance plan setting and structural objects renewal. Software processing and connection to graphic systems is usually very beneficial. The weak aspect of these systems is of course an insufficiently worked-out model of maintenance and renewal, which would realistically describe the ageing of a structural object at the level of individual construction components (Liu & Wu, 2013). From these there follow inaccurate outputs on the level of the technical and economic formations which serve as a basis for user decision-making as to how to further dispose of the structural object.

The aim of the inaugural dissertation is to offer an instrument which will generate a quality techno-economic solution to problems of planning and optimization in the renewal and maintenance of structural objects. The theoretical principles of the model come from the newest techno-economic knowledge and personal innovative reflections through practical acquaintance with the problems.

2. Input requirements

The application instrument must be on such a level that the user, who is not a civil engineering specialist, would be able to use it, without getting biased or bad results. On the other hand, the aim is to create such an environment where the civil engineering expert can intervene in the primary inputs of a model, and thus to use his/her own experience and knowledge.

With the possibility of working to a different degree of detail in a model there is also a connected time exigency for gaining information outputs on tasks being solved. Many times it is necessary to get data within a short time period or through analysis there emerges more variant solutions and it is necessary to focus only on the potentially best solutions and not to needlessly waste time on poor variants. Applications must enable getting a result in a short time horizon and at the same time not to bias outputs. For a more in-depth analysis the user then selects how much time wants to give to the task.

The application is elaborated by use of a modular system, which means that it is possible to add further instruments which will address and process further areas connected to the existing set of problems.

The requirements can be divided into the following main areas:

From a practical point of view it:

• passportization - capture the current state,
• determination of optimized maintenance cycles and restoration of objects,
• quantification of the costs in each year,
• determining the economic balance of the building.

From a user perspective, focusing on the following areas:

• work with data in different details of specification,
• user access to a wide range of users,
• the possibility of taking into account the time needed for processing the outputs from the model.

The mentioned points above define how the preliminary structure and content will look like. Building passportization is very important and essential for planning the future building renovations. Error in the building passportization can degrade the following technically-economic estimations. It is necessary to offer such a solution which enables the user to easily and quickly assemble a model of his building of interest. It means that even an average user must be able to generate a highly professional model in order not to create major deviation from the project basis. The supporting databases, which create the model basis, must be precisely processed and the data must have a high professional accuracy in order to provide correct values for the model processes.
3. Reference database of the construction production

One of the crucial requirements for practical and effective usage of the T-E analysis (Motawa & Almarshad, 2013) is an unambiguously defined form and input data quantity which become a subject of summarization. There will be automatically added missing data among the data required by the analysis and inserted by the user before the summarization begins.

The source of the supplement data will be two internal databases:

- the characteristic representatives of construction output,
- the database of typical components.

The appropriate database assembly has created a system, which allows the user without construction knowledge background acquires very accurate practical outputs. The more components the database will include the less the output data will be misrepresented. The output data result from allocation the objects to the chosen construction components representatives. On the other hand, if the number of the chosen representatives (reference examples) will be too extensive; it will cause chaotic and difficult data insertion (Voicu et al).

4. Software processing of the building reference database

The software application is physically using a single database of characteristic representatives of the present construction production. The database allows inserting different simultaneously maintained types of building object classification. The database was adjusted as such that allows inserting more modeling techniques during the rendering of the example scheme of construction parts of a particular building. Presently, the database includes an expanding system which generating examples based on building capital expenditures (Lim et al, 2005).

4.1. 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 and create the complete reference building. This mapping is carried out through the use of matrix of conversion formulas assembled for all buildings and all construction components. Each conversion formula includes characteristic size parameters of the analyzed building and an empirically determined conversion coefficient which defines the amount of construction components in the building. A fictive building is created by summarizing all the components and differentiates from the real investigated building in tolerable deviation.

For purposes of the T-E analysis, the existing construction production is divided into 7 systems. Each system includes a more specifically determined group of objects. There are defined 102 representatives of construction production in total in the database. Each object is labeled by a four digit code (first two digits represent the system; second two digits represent the building) and by a description.

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

4.2. Model based on the overall building cost

This approach allows generating a file of construction components and its amount for the given object type based only on entering the overall building cost. The application of this approach is possible especially for processing the newly built buildings or buildings built in recent decades. The reason is that the building capital cost must be expressed in the present prices which could be a problem for historical buildings. If the user has available building budget for real construction costs or he is able to discount the cost of the present buildings, the approach based on the overall building cost could be the easiest method how to determine the proposal of schedule of construction components volumes based on typical object.
The model does not need to know the specific units at all because the principle is based on a percentage allocation the overall capital expenditure to particular construction components according the percentage scheme given beforehand, which is assembled according the specific building type.

The system JKSO (Standard Classification of Construction Structures) (Veselý et al., 2013) has been chosen as the most suitable catalogue of the typical buildings, which represents a system of classification of the overall construction industry production assembled in the Czechoslovakia in the 70s of the 20th century. Part of the JKSO is a technical register and the main classification consist 7 numbers. The JKSO was created for statistical purposes and its codes are used for monitoring the price trends and for creating typical characteristics of a similar building.

5. Construction components Life Cycle Costs

The building life cycle analysis (Life Cycle Costs, LCC), which is described by (Schneiderová, 2007) is focusing on the empirical operational expenditures improvements over the total building life cycle. Building lifespan is limited not only by its technical durability but also by the economic life. Technical lifespan is determined by the importance of material characteristics and building lifespan, which especially depends on designing construction components of long life cycle. Those construction components are of vital importance because when they are damaged (the components cannot serve to their main purpose) the whole building is not functional, the total collapse is imminent and potential repairs are extremely technically and economically demanding.

Considering the total cost for 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 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 losing the net revenues due to high expenses and it appears that it would be more useful to remove the building, build a new building which will return the site its profitability. The methods of decision making are described by (Macek & Měšťanová, 2007).

The total LLC calculation includes relevant input data, which are defined by technical parameters of the construction components and by the time when the particular expenses have been generated. The LCC calculation should serve as an important basis for decision making of the investor, designer and the future building end user for choosing the most optimal technical solution with regards to the ecological aspects and long-term economic impacts. It is possible to divide (Liu & Li, 2011) the expenses linked with the construction, operation and building disposal into three main classes:

- expenses linked with the building technical parameters – capital costs, repair costs, reconstruction costs, modernization costs and removal costs,
- operational costs – utilities, cleaning, amortizations and the like,
- administration expenses linked with the facility management – taxes, insurance, building management and the like.

Therefore, based on the mentioned overview, it is possible to determine the basic relation of the building life cycle costs (Kiviluoma & Korhonen, 2012) as follows:

$$LCC = \sum_{n=0}^{t_D} \frac{C_n}{(1+i)^n}$$

where $C_n$ is the cost in year $n$,
- $i$ is the discount rate (time value of money) and
- $t_D$ is the length of the evaluation period (the life of the building).

The issue focuses on the costs associated with the technical parameters of the building. Life cycle costs can simply be written as the sum of the groups listed above costs:

$$LCC = C_T + C_P + C_A$$

where $LCC$ Life Cycle Costs,
- $C_T$ costs associated with the technical characteristics of the building,
Costs associated with the technical characteristics of the building \((C_T)\) can be written by the following formula:

\[
C_T = \sum_{n=0}^{t} \sum_{j=0}^{p} C_{T_j} \left( \frac{1}{1+i} \right)^n
\]

where \(T_j\) above j-th category of costs associated with the technical characteristics of the building, 
\(n\) the year of assessment, 
\(t\) life cycle of buildings (lifetime), 
\(p\) the number of categories of costs associated with the technical characteristics of the building, 
\(i\) the discount rate.

In terms of time sorting LCC cost object can be classified as follows:

- investment in phase (implementation) is an investment cost (purchase price),
- in the operating phase, it is the cost of the repair and maintenance of the building, modernization and reconstruction,
- in Phase liquidation is a cost for disposal of buildings.

6. Buildpass application

Previously mentioned models and techniques were processed by the software tools and the resulting application is called Buildpass. The application is using a web interface for its operation. Users can input their data on the webpage http://www.buildpass.eu with their login and password. The advantages are easy access of individual users and easy access of the reference databases stored on a server. Further advantages are actualization of individual user interfaces and adding more tools and exporting formats.

The project solution is based on the basis of software modules, which are linked with the main database system. The database creates 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 exports 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, the 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 login demo and password demo. The preview login allows examining created examples, look at all options and settings, which are included in the application.

7. Conclusions

The application Design builder offers a tool which is useful not only to industry professionals but also to users who are oriented on the economic aspects. The module structure of the software model (Macek, 2011) allows the individual adjustments and specification of the algorithmically generated schemes. The user is allowed to utilize his specialization within the industry or add specification based on consultation with other professionals. The overall calculating time intensity of the analysis depends on individual user requirements and the type of export data. Nevertheless, it is possible to process the majority of the building components within a few minutes.

The application has been developed on the modular system basis. It is possible to add other tools, which will be able to process additional areas linked with the particular building construction problems. The software export provides the application users with practical instructions for managing building repairs and refurbishments. Linkage with the technical standards is a partial application outcome. However, the technical database contribution and elaboration of the facility management expenses is crucial.
Acknowledgement

This paper originated as a part of a Czech Technical University in Prague, Faculty of Civil Engineering research project SGS14/013/OHK1/1T/11.

References

Bull, J.W. (1993). Life Cycle Costing for Construction (1st ed.). London : Taylor & Francis, 172, 20.
Khojandi, A.; Maillart, L. M.; Prokopyev, O. A.(2014). Optimal planning of life-depleting maintenance activities. IIE Transactions. Vol. 46, iss. 7, 636-652.
Frangopol, D.M. (2001). Life-cycle Cost Analysis and Design of Civil Infrastructure Systems (1st ed.). Honolulu : ASCE Publications, 323, 10-15.
Seeley, I.H. (1987). Building Maintenance (2nd ed.). London : Macmillan Education, 452, 112-118.
Liu, H.; Wu, W. (2013). Computer Integrated Construction and Facility Management. 3rd International Conference on Civil Engineering, Architecture and Building Materials (vol. 357-360, pp. 2865-2868). Zurich : Trans Tech Publications Ltd.
Motawa, I.; Almarshad, A. (2013). A knowledge-based BIM system for building maintenance. Automation in Construction. Vol. 29, 173-182.
Voicu, M.C.; Banciu, A.; Dragota, M.; et al. (2009). Study on Residential Assemblies. Database and Algorithms. MICBE ’09: Proceedings of THE 10th WSEAS International Conference on Mathematics and Computers in Business and Economics (pp. 159-164), Athens: World Scientific and Engineering Acad and Soc.
Lim, C.; Cho, S.; Lee, Y.; et al. (2005). Basic construction of intelligent expert system for riser design using database system and optimisation tools. 6th Pacific Rim International Conference on Modeling of Casting and Solidification Process (vol. 18, pp. 195-201). Leeds: Maney Publishing.
Vesely, J., Miks, L., et al. (2013). Technical requirements for construction. Prague : Verlag Dashöfer, 2290, 120-155.
Schniederová, R. (2007). The Building’s Value Assessment using the Utility and the LCC. Central Europe towards Sustainbale Building 07 Prague (pp. 126-131). Prague : CTU in Prague.
Macek, D., & MŠťanová, D. (2009). Multi-criteria Evaluation of Crash Barrier System Types. The Baltic Journal of Road and Bridge Engineering. Vol. 4, no. 3, 108-114.
Liu, C.; Li, Q. (2011). Study on Life-Cycle Cost Control of Green Building. Proceedings of 2011 International Conference on Construction and Real Estate Management (pp. 411-414). Beijing: China Architecture & Building Press.
Kiviluoma, R.; Korhonen, P. (2012). Guidelines for calculating the life cycle costs. 6th International Conference on Bridge Maintenance, Safety and Management (pp. 2057-2063). Boca Raton : CRC Press Taylor & Francis Group.
Macek, D. (2011). Renovation and Maitenance Planning for Buildings. VI International Eurasian Symposium (pp. 63-68). Ekaterinburg: Ural University Publisher.