NEW PERSPECTIVES OF RENOVATION AND MAINTENANCE

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Abstract

Maintenance and renewal costs for structural objects are a significant part of costs in the life-cycle of structures. Rational owners and construction service engineers try to minimize outlays on maintenance and renewal. However, at the same time it is necessary to respect a certain standard in the condition of a construction, to keep it above a fixed limit given from the type and demands on usage of the existing structural object.

The aim of the paper 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.

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.

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.

Keywords

Buildpass; LCC; maintenance; renovation

Introduction

The public sector manages an extensive amount of assets, mostly buildings, which are either occupied by public sector administration or are rented to tenant occupiers. The ongoing maintenance of these built assets requires a significant investment of public funds, which should be spent and managed effectively. In order to establish procedures and estimate preliminary operational expenditures generated by effective facility management – EN 15221-1 (2006), it is vital to use modern approaches and models, which are part of software tools designed to manage construction assets.

Asset management requires ongoing use of financial and engineering resources. Furthermore, ad-hoc asset management, implemented without any budgetary limits or calculated assessment of different possible solutions during the buildings life cycle, is not economical. Moreover, it offers only an average degree of building user satisfaction. The amount of expenditure designated for building operation, maintenance and modernization should be within a range of 0.2% to between 4 - 6% of the building's capital cost annually [1]. The scope of asset management covers areas including the rate of maintenance negligence in previous years, as well as variations to the main function of existing buildings. It initiates the topic of progressive construction, new technologies, new materials and overall conflicts of the technical progress. Pragmatic solutions are indeed feasible but they do not account for possible risks, uncertainty, incomplete information and expected progress trends in the 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 rents in the case of leasing the building to particular tenants in a rationally used building. [2] defines operational expenditure optimization as a Facility Management tool.

For each building there is a wide variety of known or easily accessible information about its technical and economic condition. This information is procured from different sources, has different weights, different accuracy and risks, and they change over a period of time, as [3] shows. It is difficult to make a proper and informed decision about building operational investments (especially about periodic maintenance and repairs) according to dispersed information over a specific period of time, because we do not know the inaccuracy which influences our decision making. The rational operation and Facility Management of several buildings based on dispersed information is almost impossible, due to the degree of information uncertainty. However, it is enhanced by different methodologies of information acquisition for each building, as stated by [4].

On the market there exist various instruments from the field of Facility Management, which deal with the problems of maintenance planning and structural objects renewal. Software processing and connection to graphic systems is usually very beneficial. The weakness of this system is an inadequately worked-out model of maintenance and renewal, which would realistically describe the ageing of structural objects at the level of individual construction components [5]. From this information there follows inaccurate outputs in the technical and economic data, which serve as a basis for user decision-making, on how to further dispose of the structural objects.

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

Methodology

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

Attributes of the IT solution do exist – the potential to work on various levels of the model's detail and the time exigency for obtaining information and tasks being solved. It is sometimes necessary to get data within a short timeframe, or alternative solutions to be analyzed, so it is key to focus only on the optimal solution identified, without wasting time exploring poor variants. The application must return 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 they want to dedicate to the task.

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

The requirements can be divided into the following main areas:

From a practical perspective:

- Passportization - capture the current state
- Determination of optimized maintenance cycles and restoration of objects
- Quantification of the costs per annum
- Determining the economic balance of the building

From a user perspective:

- Work with data in different details of specification
- Access to a wide range of users
- The possibility of taking into account the time needed for processing the outputs from the model

The points mentioned above define how the preliminary structure and content will look. Building passportization is very important and essential for planning the future of building renovations. Error in the building passportization can degrade techno-economic estimations. It is necessary to offer a solution, which enables the user to easily, and quickly assemble a model of their particular building. An average user must be able to generate a highly professional model in order to avoid major deviation from the project. The supporting databases, which form the basis for the model, must be precisely processed and the data must have a high professional accuracy in order to provide correct values for the model's processes.

Reference database of the construction production

One of the crucial requirements for practical and effective usage of the T-E analysis [6] is an unambiguously defined form and input data quantity which become a subject of summarization. The user will automatically insert missing data before the summarization begins.

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

- The characteristic representatives of construction output
- A database of typical components

The appropriate database assembly has created a system, which allows the non-technical user to acquire accurate practical outputs. The more components the database includes, the less output data will be misrepresented. The output data results from the allocation of objects to the construction components specified. If the number of components specified (reference examples) is too extensive; it will cause a chaotic and difficult data insertion [7].

Software processing of the building reference database

The software application uses a single database of construction components drawn from current industry specifications. The database allows the classification of different building objects to be maintained simultaneously. The database was adjusted so that modelling techniques can be inserted during the rendering of a construction section of a particular building. Presently, the database includes an expanding system, which generates examples based on building capital expenditures [8].

Model based on the basis of specific elements

When the referenced building has been chosen and all its main construction size attributes have been inserted, individual construction components are assigned to create a completed reference for the building. This mapping is carried out through the use of a 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 a real investigated building within tolerable deviation.

For the purposes of the T-E analysis, the existing production information is divided into 7 groups of type structures. Each group includes a specifically determined group of objects. These are defined by 102 structure types 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 the definition of all construction components which are present in the construction, and whose lifespan does not extend to the life of the whole building. The criteria for dividing the construction components are its functions, its lifespan and its expenses for component recovery per unit. Each construction component is labeled by a code and description. In order to maintain better transparency and to allow further components to be potentially added into the database, the construction components are sorted into groups labeled by letters and a binary number expressing the construction component class.

Model based on the overall building cost

This approach allows a file of construction components to be generated, and the amount for the given project to be quantified. The application of this approach is particularly suitable for new and recently constructed buildings. The reason is that the buildings capital cost can be expressed at current prices, which presents a challenge for historical buildings. If the user has the available budget for real construction costs they are able to predict the cost of the present buildings creating the possibility of reducing it. This approach based on the overall building cost could be the easiest method for determining a schedule of construction component volumes based on typical objects.

The model does not need to know the specific units due to the principle it is based on. A percentage allocation of the overall capital expenditure to particular construction components according to the percentage scheme is given beforehand, which is assembled according to the specific building type.

The system JKSO (Standard Classification of Construction Structures) [9] has been chosen as the most suitable catalogue for typical buildings, which represents a system of classification for the overall construction industry assembled in the Czechoslovakia in the 1970s. Part of the JKSO is a technical register and the main classification consists of seven numbers. The JKSO was created for statistical purposes and its codes are used for monitoring price trends and capturing and comparing typical characteristics for similar buildings.

Construction components Life Cycle Costs

The building life cycle analysis (Life Cycle Costs, LCC), which is described by [10], focuses on the empirical operational expenditure improvements over the total building life cycle. A building's lifespan is limited not only by its technical durability but also by its economic life. The technical lifespan is determined by the importance of material characteristics, which are dependent on construction components having been designed for a long life cycle. Construction components are of vital importance, because if damaged, the components cannot fulfil their main purpose. The result of which is that the whole building is not functional, total collapse could be a possibility, and potential repairs are both technically and economically demanding.

Considering the total cost for repairs it may 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 most buildings will lose their economical serviceability, which could be associated with permanent loss of net revenues due to high expenses, meaning that it would be more useful to remove the building and build new to return the site to profitability. The methods of decision making are described by [11].

The total LLC calculation includes relevant input data, which is defined by the technical parameters of the construction components and the time when the particular expenses have been generated. The LCC calculation should serve as an important basis for the decision making of the investor, designer and the future building end user when choosing the optimal technical solution with regards to the ecological aspects and long-term economic impacts. It is possible to divide [12] the expenses linked with the construction, operation and disposal of buildings into three main classes:

- Expenses linked with the buildings 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 facilities management – taxes, insurance, building management and the like

Therefore, based on the information above, it is possible to determine the basic relation of the building life cycle costs [13] as follows:

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

where C_n - the cost in year n,

i - the discount rate (time value of money) and

t_D - 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:

$$LCC = C_T + C_P + C_A \qquad (2)$$

where LCC - Life Cycle Costs,

C_T - costs associated with the technical characteristics of the building,

C_P - operating costs and

C_A - administrative costs.

Costs associated with the technical characteristics of the building (CT) can be calculated using the following formula:

$$C_T = \sum_{n=0}^{t} \frac{\sum_{j=0}^{p} C_{T_j}}{(1+i)^n} \tag{3}$$

where T_j- the 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 objects 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 the liquidation phase it is the cost for disposal of buildings

Results

Previously mentioned models and techniques were processed by the software tools and the resulting application is called Buildpass. The application uses 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 for individual users and easy access of the reference databases stored on the server. Further advantages are actualization of individual user interfaces and the addition of more tools and exporting formats.

Buildpass application

The project solution is based on software modules, which are linked with the main database system. The database creates the main foundation which interlinks to the separate software tools. The user chooses which areas will be used and at what level of detail. The system is designed in such a manner that during the processing of the fundamental operations it is possible to generate the software exports without placing unnecessary pressure on the user to insert details about their 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. Users are able to examine the application using a preview function accessible using a demo login and password. The preview allows examples to be reviewed, looking at all the options and settings, which are included in the application. The main web page settings are depicted in figure 1.

The application offers several pre-set export settings, which can be further edited using the Buildpass application with a spreadsheet editor. In this way the end-user is able to create the model in their desired format. In order to track the spatial units or functional units it is possible to merge several buildings into a group of buildings, which is provided with its own export configurations. figure 2 provides a visual example of the Buildpass web interface.

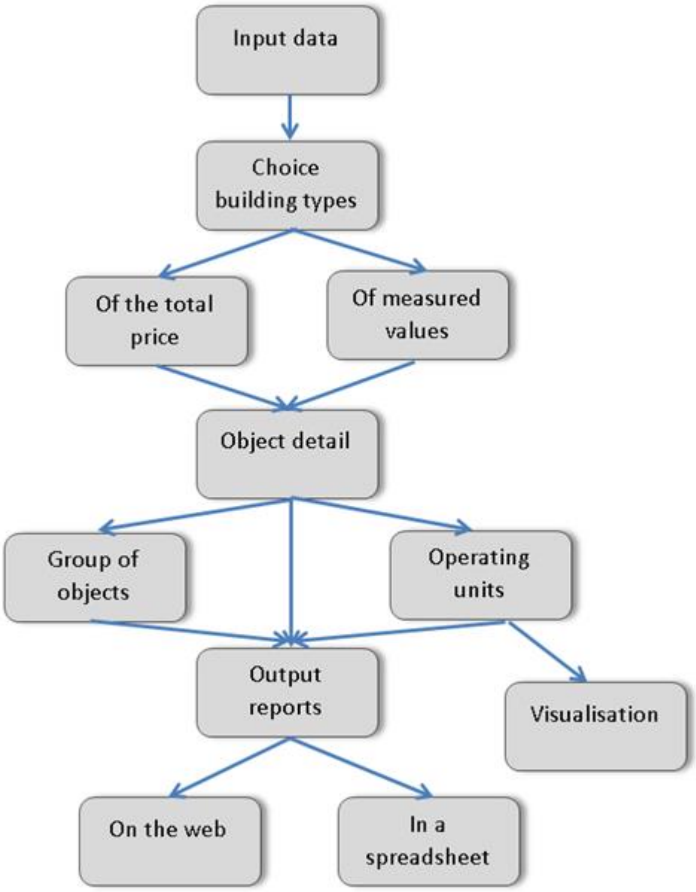

Figure 1: Web page setting

After selecting a sample type, a list of building construction elements can be generated. The list contains all anticipated construction elements for the chosen type of building and also includes volumes of the anticipated elements. The aim is to choose the most accurate type of building to best reflect the new construction. If the wrong building template is chosen at the start then the Buildpass application will provide the user with inexact results and the process of model adjustments will be more complicated. Subsequent data processing and construction elements modification do not depend on a type of generative model. However, the actual cost of construction elements renewal influences the calculations results, and the building dimensions serve only as descriptive values.

The tab named "Building Details" contains a list of all added construction elements for the chosen building and generated data according the specific building type is included. The user can further edit the construction elements added by modification of the chosen elements, or by adding (or deleting) new elements, which better define the projected building. It is possible to edit the recommended technical and economical linkages between elements, which will have an impact on building renewal, and maintenance.

The Buildpass application is significant as it processes information on predicted revenues from the building operation, which can be divided according to individual building units or the whole building. For example, the building unit could be a dwelling unit, but it is also possible to use non-residential or commercial premises for the total building operation costs.

The results are accessible from the main menu under a tab “Export Series”. There are 4 main export settings:

- Building Balance
- Plan of Construction Elements Renewal
- Renewals for the Chosen Time Period
- Renewals for the Chosen Time Period – Time Schedule

It is possible to create user series, named “Client Series”. These are user-defined export settings which are specific to the user and include special requirements which may not be appropriate for others users or applications.

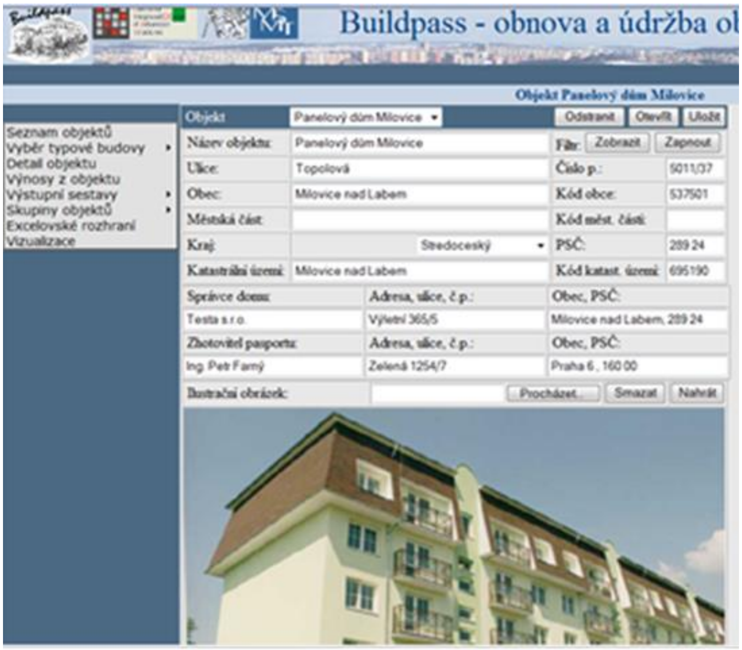

Figure 2: Buildpass application

In order to determine the overall cost of renewal for a group of buildings, there is a menu named “Group of Buildings” which defines the buildings included in a particular group. Subsequently, based on the definition of the group of buildings, it is possible to create an export series for the whole group. The menu also allows building sections to be merged with a different construction type. At first, it is necessary to create a separate building from each section and then merge the created buildings into a group.

The Buildpass user can examine and review all separate export series or they can print out the series directly from the web environment. Nevertheless, users differ in their expectations of the export series and a lot of them need further export data adjustments. This could mean usage of different plugins or a data preview in a different graphical layout. The most common tool for data processing is MS Excel. In this software the users can extend their calculations or insert the exported Buildpass data into another calculation. The majority of the recent applications allow the series to be exported into MS Excel format. The Buildpass application contains an interface for web data to be imported into a spreadsheet data processor.

The output is captured in an Excel sheet, which can be downloaded from the Buildpass web interface and afterward the user can track the export series created by the web application online using the spreadsheet data processor. The file is downloadable in the “Excel Interface” tab in the main menu. The downloaded data can be further processed as normal Excel sheets (figure 3).

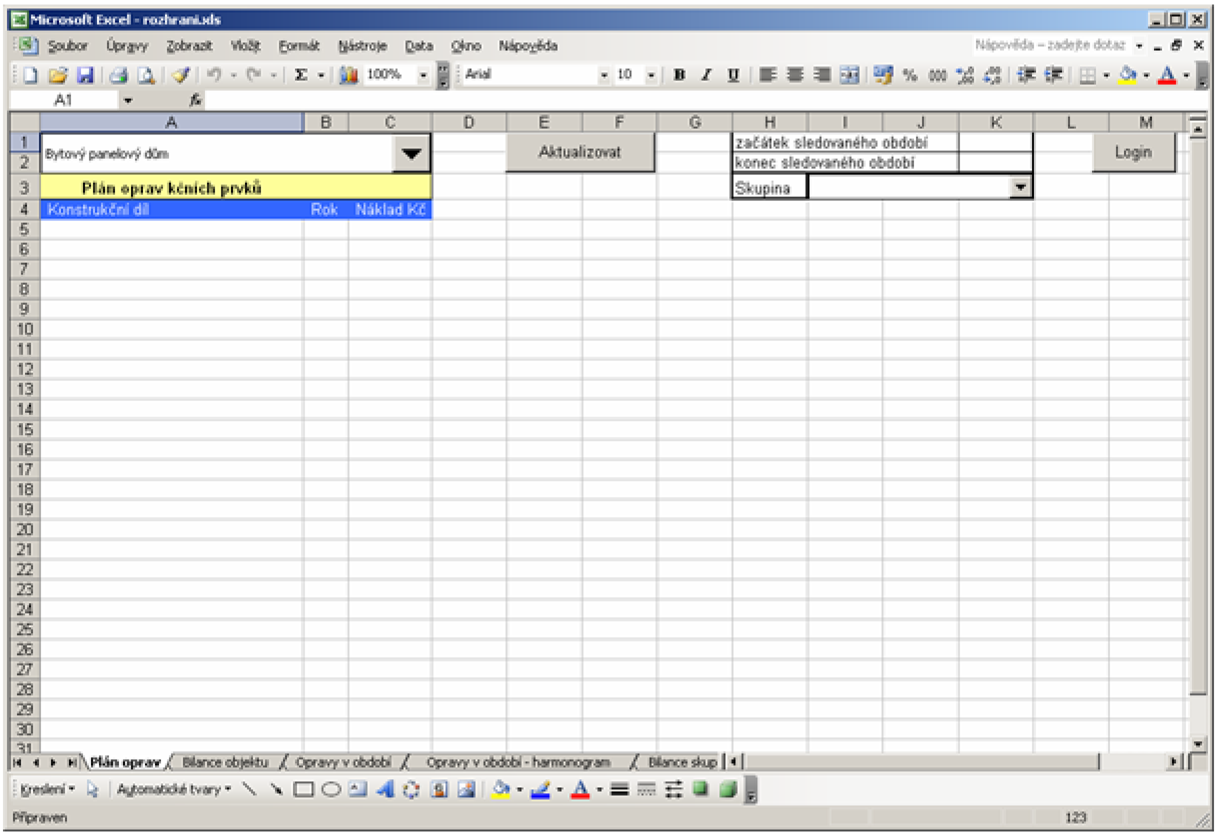

Figure 3: Buildpass – "Excel Interface"

The Buildpass application offers a preview of the main building data and its structure through an interactive interface where the user can digitally "walk" through the modeled building. The interface contains two-dimensional pictures (photos, drawings, drafts, etc.), as well as links for other building details or related documents.

Conclusion and discussion

The application of Buildpass offers a tool, which is useful not only to industry professionals but also to users, interested in the economic aspects. The modular structure of the software model [14] allows for individual adjustments in specification of the algorithmically generated schemes. The user is allowed to utilize their specialism within the industry or add specifications based on consultation with other professionals. The overall calculating time of the analysis depends on individual user requirements and the type of export data. Nevertheless, under normal circumstances it is possible to process the majority of the building components within a few minutes.

The application has been developed as a modular system. It is possible to add other tools, which can be processed in additional areas and linked with particular building construction problems. The software export provides users with practical instructions for managing building repairs and refurbishments. Linkage with the technical standards is a potential further step for the application, however contribution to the technical database and elaboration of the Facility Management expenses is crucial.

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References

[1] BULL, J.W. *Life Cycle Costing for Construction*. 1st edition. London : Taylor & Francis, 1993. 172 s. ISBN 978-07-51-40056-4.

[2] KHOJANDI, A.; MAILLART, L. M.; PROKOPYEV, O.: Optimal planning of life-depleting maintenance activities. *IIE Transactions*. 2014, Vol. 46, iss. 7, p. 636-652. ISSN: 0740817X.

[3] FRANGOPOL, D.m., et al. *Life-cycle Cost Analysis and Design of Civil Infrastructure Systems*. 1st edition. Honolulu : ASCE Publications, 2001. 323 s. ISBN 978-07-84-40571-0.

[4] SEELEY, I.H. *Building Maintenance*. 2nd edition. London : Macmillan Education, 1987. 452 s. ISBN 978-03-33-45701-6.

[5] LIU, H.; WU, W.: Computer Integrated Construction and Facility Management. *3rd International Conference on Civil Engineering, Architecture and Building Materials*. 2013, vol. 357-360, pp: 2865-2868. Zurich : Trans Tech Publications Ltd. ISSN: 1660-9336.

[6] MOTAWA, I.; ALMARSHAD, A.: A knowledge-based BIM system for building maintenance. *Automation in Construction*.2013, vol. 29, p. 173-182. ISSN: 09265805.

[7] VOICU, M.C.; BANCIU, A.; DRAGOTA, M.; et al.: Study on Residential Assemblies. Database and Algorithms. MICBE '09: *Proceedings of THE 10th WSEAS International Conference on Mathematics and Computers in Business and Economics,* 2009, pp. 159-164. Athens: World Scientific and Engineering Acad and Soc. ISSN: 1790-5109.

[8] LIM, C.; CHO, S.; LEE, Y.; et al: 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,* 2005, vol. 18, pp. 195-201. Leeds: Maney Publishing. ISSN: 1364-0461.

[9] VESELÝ, J., MIKŠ, L., et at.: *Technical requirements for construction*. Prague : Verlag Dashöfer, 2290, 120-155.

[10] SCHNEIDEROVÁ, R.: The Building's Value Assesment using the Utility and the LCC. *In Central Europe towards Suistainable Bulding 07 Prague*. Prague: CTU, Faculty of Civil Engineering, 2007, vol. 1, p. 126-131. ISBN 978-80-903807-8-3.

[11] MACEK, D. - MĚŠŤANOVÁ, D.: Multi-criteria Evaluation of Crash Barrier System Types. *The Baltic Journal of Road and Bridge Engineering*. 2009, vol. 4, no. 3, p. 108-114. ISSN 1822-427X.

[12] LIU, C.; LI, Q.: Study on Life-Cycle Cost Control of Green Building. *Proceedings of 2011 International Conference on Construction and Real Estate Management*.2011, pp. 411-414. Beijing: China Architecture & Building Press. ISBN:978-7-112-13701-5.

[13] KIVILUOMA, R.; KORHONEN, P: Guidelines for calculating the life cycle costs. *6th International Conference on Bridge Maintenance, Safety and Management*. 2012, pp. 2057-2063. Boca Raton : CRC Press Taylor & Francis Group. ISBN: 978-041562124-3.

[14] MACEK, D.: *Renovation and Maitenance Planning for Buildings*. In VI International Eurasian Symposium. Ekaterinburg: Ural University Publisher, 2011, s. 63-68. ISBN 978-5-94984-355-0.