ISSN 1339-3189

2/2020

Mladá veda

Young Science

Remeselníci pracujúci so sklom v období raného novoveku

Informačné systémy v systéme zdieľaných bicyklov

Vlády SR a vývoj starobného dôchodkového sporenia na Slovensku

Mladá veda
Young Science

MEDZINÁRODNÝ VEDECKÝ ČASOPIS MLADÁ VEDA / YOUNG SCIENCE

Číslo 2, ročník 8., vydané v decembri 2020
ISSN 1339-3189
Kontakt: info@mladaveda.sk, tel.: +421 908 546 716, www.mladaveda.sk
Fotografia na obálke: Aponiovská knižnica, Oponice. © Branislav A. Švorc, foto.branisko.at

VYDAVATEĽ
Vydavateľstvo UNIVERSUM, spol. s r. o.
www.universum-eu.sk
Javorinská 26, 080 01 Prešov
Slovenská republika

Mladá veda
Young Science
ISSN 1339-3189

Vol. 8 (2), pp. 120-128

DETERMINATION THE BUILDINGS LIFE CYCLE COSTS AS A BASIS FOR DESIGN

URČENIE NÁKLADOV ŽIVOTNÉHO CYKLU BUDOV AKO PODKLADU PRI PROJEKTOVANÍ

Martin Hanko, Richard Matúšek[1]

Martin Hanko works as a researcher at the Faculty of Civil Engineering of the Slovak University of Technology in Bratislava. In his research he deals with the topic of building maintenance by applying facility management and construction economics. Richard Matúšek works as an Assistant Professor at the Faculty of Civil Engineering of the Slovak University of Technology in Bratislava. In his research he deals with the topic of facility management in construction.

Martin Hanko pôsobí ako výskumný pracovník na Stavebnej fakulte Slovenskej technickej univerzity v Bratislave. Vo svojom výskume sa venuje problematike údržby budov aplikáciou facility managementu a ekonomiky stavebníctva. Richard Matúšek pôsobí ako odborný asistent na Stavebnej fakulte Slovenskej technickej univerzity v Bratislave. Vo svojom výskume sa venuje problematike facility managementu v stavebníctve.

Abstract
The current state of the environment draws attention to the emphasis on sustainability in the construction industry. The aim of the paper is to point out the possibility to contribute to sustainability also through a considered choice of material solution of building structures. Appropriate selection of materials in the design phase can significantly affect the life cycle costs of the building, especially future operating costs. Investors currently decide on the material solution of building structures mainly according to the amount of investment costs. The paper points out the need to create a suitable methodology that would create the basis for modern technologies and facilitate the process of selection of building materials for investors and designers.
Key words: costs, life cycle, design

[1] Workplace address: Ing. Martin Hanko, PhD., Ing. Richard Matúšek, PhD., Faculty of Civil Engineering STU in Bratislava, Radlinského 11, 810 05 Bratislava
E-mail: martin.hanko@stuba.sk, richard.matusek@gmail.com

Mladá veda
Young Science
ISSN 1339-3189
Vol. 8 (2), pp. 120-128

Abstrakt
Súčasný stav životného prostredia upozorňuje na kladenie dôrazu na udržateľnosť aj stavebného priemyslu. Cieľom príspevku je poukázať na možnosť prispieť k udržateľnosti práve pomocou uváženého výberu materiálového riešenia stavebných konštrukcií. Vhodným výberom materiálov vo fáze projektovania je možné v podstatnej miere ovplyvniť náklady životného cyklu budovy, najmä budúcich prevádzkových nákladov. O materiálovom riešení stavebných konštrukcií sa investori v súčasnosti rozhodujú najmä podľa výšky investičných nákladov. Príspevok poukazuje na potrebu vytvorenia vhodnej metodiky ktorá by vytvorila podklady pre moderné technológie a uľahčila investorom a projektantom proces výberu stavebných materiálov.
Kľúčové slová: náklady, životný cyklus, projektovanie

Introduction

The energy and operational intensity of the building is maximally determined by the material, spatial solution and its technical equipment. (Somorová, 2010) These factors have a direct impact on most of the future operating costs of a building. The efficiency of the investment process is determined by the optimal life cycle costs of the LCC building, namely investment costs and operating costs.

The material solution of the building structures of the building has a priority position in relation to the future maintenance costs during the use phase of the building. As a percentage, the highest component of the total future operating costs of the building is the heating costs. They are decisively influenced by the material and structural design of the building. (Somorová, 2010) By including the facility manager in the design phase of the building, future operating costs can be minimized, and thus also the costs of maintaining the building structure.

Facility managers have valuable tracked information from the use phase of various types of buildings, according to which they are able to define the conditions for future maintenance of building structures.

The Buildings Life Cycle

The life cycle of a building according to (Somorová, 2010) is defined as: "the period from the definition of the purpose of the building through the design, implementation, use and exploitation phase through the physical disposal of the building, renovation or sale."

The basic phases of a building's life cycle and the costs associated with them are shown in Figure 1. Operating costs are: "linked to the use phase of the buildings and are the sum of the costs incurred for the operation of the building, which is provided by the support activities". (Somorová, 2014b)

Investment Costs

A statement of acreage is prepared from the project documentation for various variants of the building structure, which serves as a basis for processing the building budget. The budget will be prepared according to the current price lists of building materials and works in the year of design of the building. The budget sets the investment costs for the construction of the building $CINV_i$ [€]. The ratio of investment costs and the area of construction S determines the investment cost indicator c_{INVi} [€/m^2]. (Hanko, 2017)

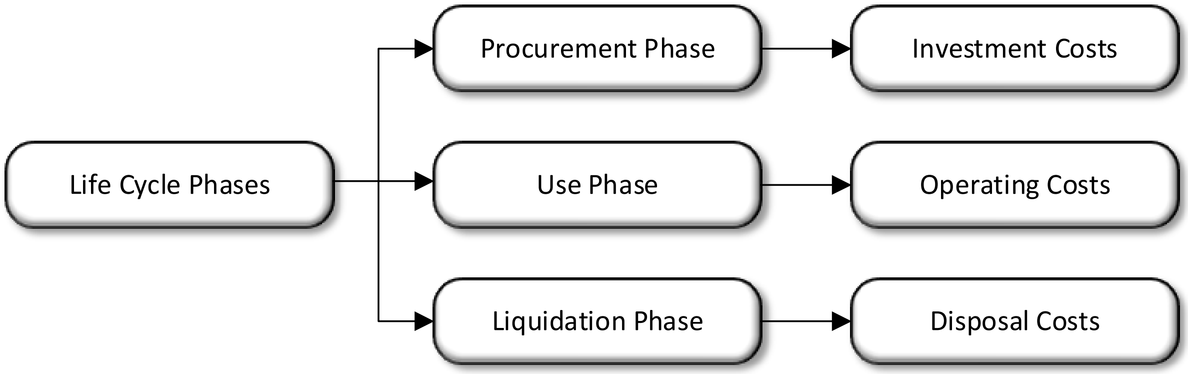


Figure 1 – Costs of Building Life Cycle Phases
Source: Hanko, 2017

Operating Cost

The material solution of building structures directly affects the amount of some operating costs. The article selected operating costs that reach the highest percentage during the life cycle and are directly related to the material solution of building structures are:

A.) heating costs,

B.) maintenance costs.

A.) For the calculation of heating costs (1), the annual heat demand for heating shall be developed in the energy assessment of buildings, according to the applicable standard requirements. In cooperation with the energy supplier, the price per unit of measure cq [€/kWh] for a specific building is determined. Multiplying the annual heat demand Qh [kWh/year] and the price per unit of measure cq [€/kWh] determines the heating costs per year [€/year]. The ratio of heating costs to the area of structure S determines the heating cost indicator c_{OPhi} [€/m^2]. (Hanko, 2017)

$$COP_h = Q_h * cq \tag{1}$$

where:

COP_h are the heating costs [€],

Q_h is the annual heat demand [kWh/year],

cq is the price per unit of energy [€/kWh]. (Somorová, 2010a)

B.) The basis for determining maintenance costs is the maintenance manual for the building structure. It defines individual activities of maintenance of building structures with their periodicity.

The periodicity of maintenance activities are determined by:

- legislative requirements,
- service life of building structures (replacement of layers of building structures),
- facility manager requirements (spread activities evenly over time).

Prices for maintenance activities are set by drawing up a budget according to the valid price lists of building materials and works or by collaborating with companies that provide Facility management services, or directly with companies providing specific maintenance activities. The maintenance cost indicator c_{OPmi} [€/m^2] is determined by dividing the maintenance costs by the area of structure S.
Operating costs are the sum of heating and maintenance costs (2).

$$COP = COP_h + COP_m \tag{2}$$

where:

COP_h are the heating costs [€],
COP_m are maintenance costs [€].(Somorová, 2014a)

Operating costs are variable during the use phase, they depend on the change in the value of money over time and on economic development.

Time Value of Costs

The money that will be available in the future has a different value than the money that is available today. The main factors that affect the time value of money are time and rate of return. Dynamic investment valuation methods are used to calculate the future value of current money. According to dynamic methods, calculation indicators consider the time factor, to a lesser extent they also consider the risk factor. After n-years, the future value of current money depends on the present value and the method of interest. When interest is calculated from the present value as well as from accrued interest, it is a complex interest rate. Interest can be accrued to the present value with different periodicity, most often accrued once a year. (Ilavský at al., 2012) (Benčík, 2009)

When interest is added to the present value of money once a year after n years, the future value of money is expressed by the formula (3):

$$BH = B_0 * (1 + i)^n \tag{3}$$

where:

BH is the future value of capital [€],
B_0 is the input value of capital [€],
n is the number of years,
i is the interest rate expressed in decimal form. (Ilavský at al., 2012)

The state of the money market is expressed by the interest rate. We distinguish between nominal and real interest rates. The nominal interest rate (5) takes into account the degree of risk and the impact of the locality and is not adjusted for the impact of inflation and taxation. The real interest rate (4) is always lower than nominal, it is adjusted for the effect of inflation, it represents real income and it is more accurate than nominal. (Ilavský at al., 2012) (Benčík, 2009)

$$i_r = \frac{i_n * (1 - D) - F}{1 + F} \quad (4)$$

where:

i_r is the real interest rate expressed in decimal form,
i_n is the nominal interest rate expressed in decimal form,
D is the tax rate expressed in decimal form,
F is the rate of inflation expressed in decimal form. (Ilavský at al., 2012)

Nominal interest rate u_n:

$$u_n = u_B + u_{PU} + u_{riz} + u_{pol} \quad (5)$$

Where:

u_b is the key interest rate of the European Central Bank [%],
u_{PU} is a trade surcharge of financial institutions [%] Table 1,
u_{riz} is an expression of the degree of risk [%] Table 1,
u_{pol} is an expression of a locality [%] Table 2. (Ilavský at al., 2012)

A Group of Buildings	Type of Construction	Classification of Constructions	$u_{PU} + u_{riz}$
A	Residential Buildings	KS 111, KS 112, KS 113	2% - 6%
B	Non-residential Buildings	KS 121 – KS 124, KS 126	2% - 8%
C	Industrial Buildings Agricultural Buildings Engineering Structures	KS 125 KS 127 KS 2ex	2% - 14%

Table 1 – Indicative Values of the Risk Level Also Taking Into Account the Trade Surcharges of Financial Institutions
Source: Ilavský at al., 2012

Municipalities	u_{pol}
Bratislava	1% - 2%
Regional capitals and towns: Piešťany, Vysoké Tatry, Trenčianske Teplice, Poprad, Zvolen, Liptovský Mikuláš, Martin	1% - 4%
District offices and district cities	2% - 4%
Other municipalities with more than 15,000 inhabitants	2% - 4%
Other municipalities from 5 thousand to 15, thousand inhabitants	2% - 5%
Other municipalities from 2 thousand to 5 thousand inhabitants	3% - 6%
Other municipalities with less than 2,000 inhabitants	3% - 8%

Table 2 – Indicative Values of the Degree of Impact of the Locality
Source: Ilavský at al., 2012

The interest rate is highly variable and depends on a number of factors such as the rate of inflation, the tax, the degree of risk, the state of the money markets, so it cannot be considered

Vol. 8 (2), pp. 120-128

as an exact constant number. However, the same interest rate will be used for all variants and therefore the values obtained by calculation are comparable with each other.
The sum of the investment costs in the year of design of the building and the sum of operating costs during the life of the building are the life cycle costs (6).

$$LCC = CINV + \sum_{t=0}^{T} COP * (1+i)^{T} \tag{6}$$

where:

LCC are the life cycle costs of the building [€],
CINV are investment costs [€],
COP are operating costs [€],
i is the interest rate expressed in decimal form,
T is the lifetime of the building [years]. (Somorová, 2014a)

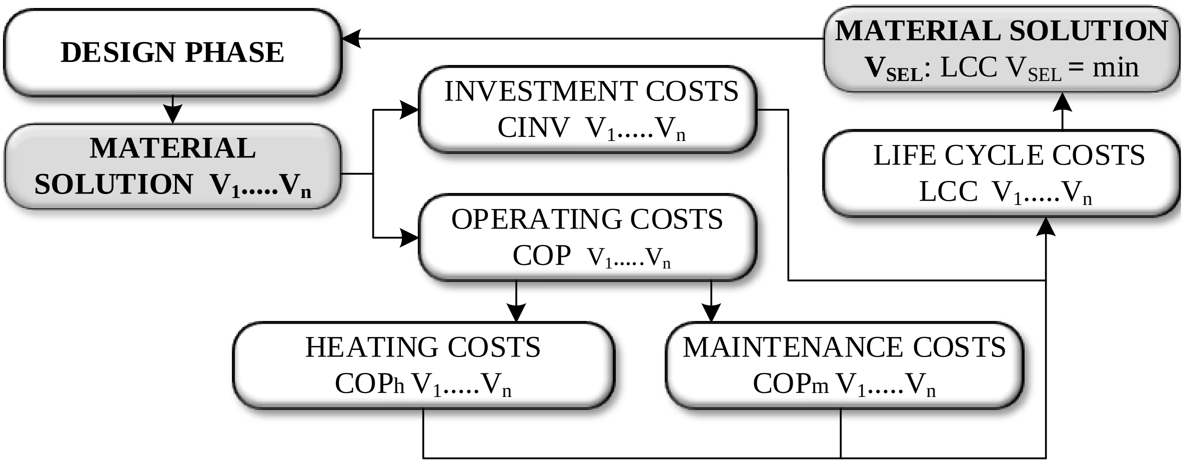
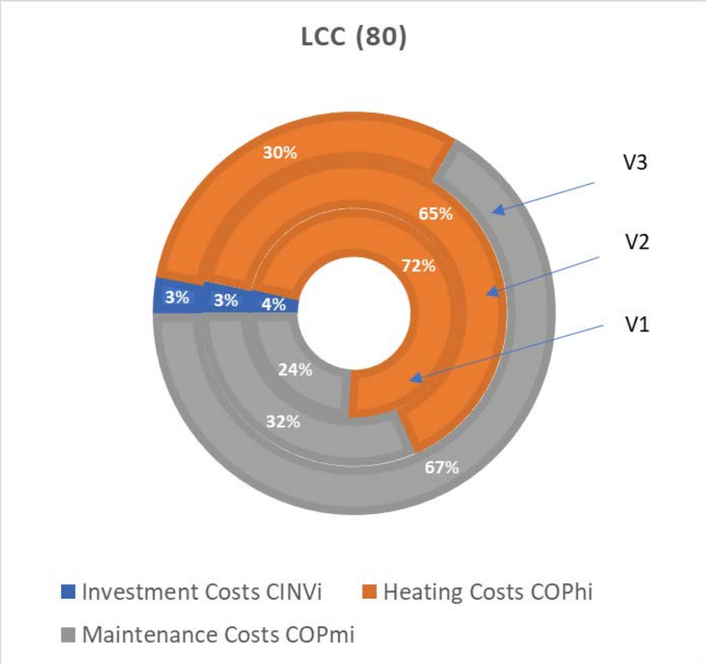


Figure 2 – Proposal of Methodology for Selection of the Building Structure
Source: Authors

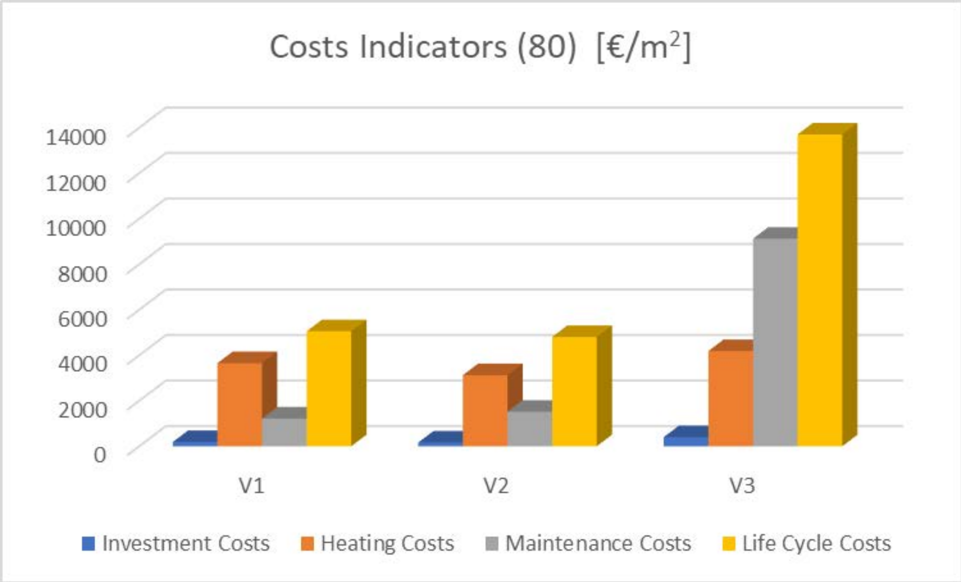


Graph 1 – Life Cycle Costs Ratio of the Building Cladding Structure
Source: Authors

The proposed procedure for solving the methodology is shown in Figure 2 for better clarity. The diagram shows the course of the evaluation of the structure, where the designer during the design phase will design a material solution for building structures. For individual constructions, individual life cycle costs will be processed according to the methodology. Based on the minimum LCC, the investor will choose a suitable solution. The determined costs, after reference to the unit area lcci [€/m^2], can serve as a starting point for the design.
Determining conditions were set during the creation of the methodology:

1. The building will be designed in an environment with standard weather conditions.
2. During the construction of the building structures of the building, the relevant technological regulations will be observed, the necessary quality of the implemented structure will be ensured.
3. The methodology was developed for selected building structures: external wall.
4. The filling constructions of the openings in all variants will be identical, they will have the same thermal technical properties and the same area of the opening parts.

The methodology was incorporated for three variants of external wall on the administrative building. V1 was considered as a masonry wall made of ceramic blocks, V2 was considered as a reinforced concrete wall with insulation, V3 was considered as an all-glass facade. Graph 1 shows the ratio of selected LCC costs over 80 years of life. The highest operating costs were achieved during the specified period by V3, which was caused mainly by high maintenance costs of the structure. The V2 material solution has the lowest investment and future selected operating costs during the life cycle. The heights of the individual cost indicators over 80 years of life expressed per unit area (1 m^2) are shown in Graph 2.



Graph 2 – Life Cycle Cost Indicators Ratio of the Building Cladding Structure
Source: Authors

Conclusion

During the design phase of buildings, the costs associated with their future management and maintenance should also be used as a starting point for designers. The processing of life cycle costs indicators lcc_i, such as the sums of investment costs c_{INVi} and operating costs c_{OPhi}, c_{OPmi} for different variants of building structures can serve as a basis for the processing of the database of indicators. The determined indicators according to the proposed methodology should form part of the input data for solving the problem of selection of building structures using BIM technologies. An effective tool for deciding on building materials can be the proposed methodology, which would be used in a simple and quick way to determine the selected life cycle costs, ie investment costs and other operating costs, even during the design of buildings.

This article was recommended for publication in a scientific journal Young Science by:
doc. Ing. Eva Jankovichová, PhD.

The paper was developed with the Project VEGA No. 1/0511/19.

References

1. BENČÍK, M., 2009. *Rovnovážna úroková miera. Teoretické koncepty a aplikácie*: Research Study. Bratislava: NBS. ISSN 1337-5830.
2. HANKO, M., 2017. *Zefektívnenie údržby stavebných konštrukcií budov v systéme FM:* Dissertation Thesis. Bratislava: STU.
3. ILAVSKÝ, M., M. NIČ and D. MAJDÚCH, 2012. *Ohodnocovanie nehnuteľností*. Bratislava: MIpress. ISBN 978-80-971021-0-4.

4. SOMOROVÁ, V., 2010. *Údržba budov. Facility management*. Bratislava: Publishing STU. ISBN 978-80-227-3372-4.
5. SOMOROVÁ, V., 2014a. *Determination of the Optimum Variant of the Material Solution of Building Construction from the Aspect of Effectiveness of the Real Estate Development.* In: Advanced Materials Research: selected, peer reviewed papers from the 2014 3rd Global Conference on Civil, Structural and Environmental Engineering (GCCSEE 2014). Chengdu, China, 21.-22.10.2014. pp. 2454-2458.
6. SOMOROVÁ, V., 2014b. *Facility management*. Praha: Professional Publishing. ISBN 978-80-7431-141-3.