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An Assessment of the Renovation of Existing Residential Buildings Regarding Life Cycle

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Abstract
The improvement of energy efficiency performance of buildings is considered as a major priority worldwide. New buildings are built as intelligent and low-energy or zero-energy buildings to fulfill the regulations. The reduction of energy consumption is to a large extent associated with the renovation of the old housing stock. More than ever, the construction industry is concerned with improving the social, economic and environmental indicators of sustainability. By applying LCA it is possible to optimise these aspects, from the extraction of raw materials to the final disposal of building materials.
This paper presents a case study of a selected representative apartment buildings (A,B) located in Slovakia, for which the cost-optimal levels of energy performance are determined in terms of life-cycle costs of the building. The methodology used in this study was oriented to detailed description of defined variants of renovations, that will most probably be used in the majority of buildings renovated in Slovakia.
In summary, it can be stated that the application of LCA is fundamental to sustainability and improvement in building and construction.

Keywords - energy performance; energy saving measures; life-cycle costs; cost optimal evaluation

1. Introduction

The Directive on the Energy Performance of Buildings requires that in the following years the EU Member States set cost-optimal levels of energy performance criteria in their regulations, while the methodology of determination of the cost-optimal levels is still in development.

In Slovakia, residential and commercial buildings consume approximately 40% of the total energy consumption.[1] Energy performance of buildings is a key element to achieve the EU climate and energy objectives, namely a 20% reduction of the greenhouse gases emissions and 20% of primary energy savings by 2020. Improving the energy performance of buildings is a cost-effective way of fighting against climate change and improving energy security. [2]

The reduction of energy consumption is to a large extent associated with the renovation of the old housing stock. Economic efficiency of the renovation of a residential building can be assessed by using multiple criteria and life cycle cost analysis of the building. Life cycle assessment is used as an important tool for environmental assessment of buildings, allows the promotion of sustainable buildings with low energy consumption and high efficiency [3].

2. Methods

The EPBD recast comparative framework methodology was established for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements. [4]

2.1 The aim of the study

The main aim of the study was to design economically and energy friendly variant of measures for renovation of apartment buildings. This study analyses the energy efficiency, economic viability and investment costs as of energy renovation of apartment buildings. Three variants of renovation were defined, each variant having different level of thermal insulation of building constructions in order to achieve different energy efficiency levels.

Moreover, in order to motivate the investor to renovate, to evaluate the profitability of the energy efficiency measures and compare different variants of financing schemes, assessment of life cycle of building is needed.

2.2 Description of the apartment buildings

The apartment buildings chosen form the largest part of building stock in Slovakia and they were constructed from materials that are dominant in Slovakia. The largest group is panel apartment buildings built before year 1983 that account for 46% of total net area of old building stock. The second large group of apartment buildings is brick apartment buildings with 17% of total net area of old building stock. [1]

The studied apartment buildings are different in the materials they are made of, year of construction, floor area, height and volume. The description of apartment buildings is in Table 1.

Table 1. Description of apartment buildings

Building	**Apartment building A**	**Apartment building B**
Locality	Bratislava, Slovakia	Bratislava, Slovakia
Structural building system	prefabricated ferroconcrete panel apartment building	Brick apartment building
Year of construction	1978	1974
Number of apartments	48	49
Number of floors	13 , no basement, first floor is a technical floor	6, with basement – garages, cellars
Volume (m^3)	12 329	14 513
Thermal transmittance ($W/(m^2.K)$)		
U_{wall}	1.33	0.70
U_{roof}	0.86	0.54
U_{floor}	1.03	0.56
$U_{window\text{-}replaced}$	1.30	1.30
$U_{window\text{-}original}$	2.70 (wooden frame)	5.20 (steel frame)
View of apartment building		

2.3 Defining the design variants of building renovation

Individual renovation measures were combined into renovation packages-variants. Three variants of renovation have been defined, each variant having different level of thermal protection of building constructions, based on the requirements on thermal protection as defined in the Slovak standards [5].

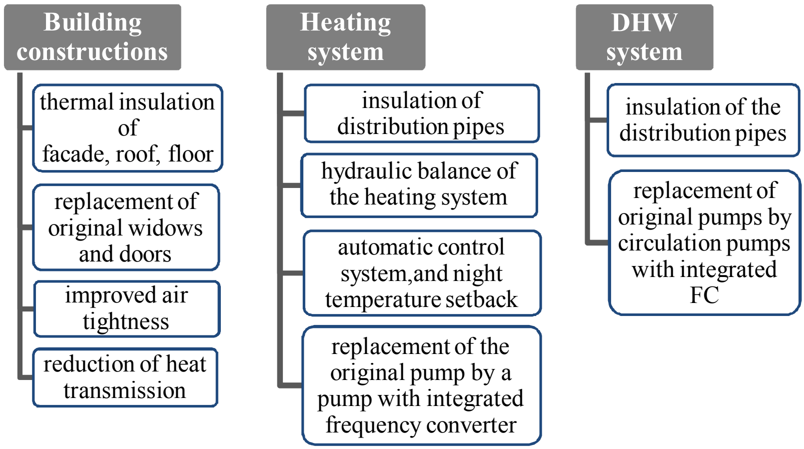

Fig.1 Designed energy saving measures [6]

External walls are insulated with a contact insulation system made of expanded polystyrene to the height of 22,4m (8th floor) and of mineral wool from 9th to 13th floor. The roof has the thermal insulation made of expanded polystyrene.

Table 2. Variants of renovation of building constructions A, B

Variants of building renovation	Variant no.1 (V1)		Variant no.2 (V2)		Variant no.3 (V3)	
Building	A	B	A	B	A	B
Thickness of insulation (cm)						
Facade	8	10	14	15	20	22
Roof	14	14	30	30	30	30
Floor	-	-	-	4	-	4
Heat transfer coefficient U (W/(m^2.K))*						
Facade	0.29 (0.32)	0.30 (0.32)	0.20 (0.22)	0.21 (0.22)	0.15 (0.15)	0.15 (0.15)
Roof	0.17 (0.20)	0.17 (0.20)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)
Floor	-	-	-	0.5 (0.85)		0.5 (0.60)
Windows	1.0 (1.4)	1.0 (1.4)	1.0 (1.0)	1.0 (1.0)	0.6 (0.6)	0.6 (0.6)
Satisfy U-value requirements actual from year	2012		2016		2020	

* Values in brackets represent the minimum requirements of Slovak standards [5]

2.4 Life-cycle costs

Many building owners apply the principles of life cycle cost analysis in decisions they make regarding construction or improvements to a facility.

Compared to other products, buildings are more difficult to evaluate for the following reasons: they are large in scale, complex in materials and function and temporally dynamic due to limited service life of building components and changing user requirements. [7]

Following the Commission delegated regulation (EU) No 244/2012, the formula for calculating global LCC is:

$$LCC = C_O + O + M\&R + C_L \qquad (EUR) \tag{1}$$

where: C_O - investments to saving measures
O - operation costs
$M\&R$ - costs of repairs and maintenance
C_L - demolition costs

The period of 30 years from implementation of the renovation was considered → predicted economic lifetime of measures on the building envelope. Demolition costs were not considered, we assumed to be the same for all variants. The cost of debt service was not considered; the highest debt service cost would be for the highest loan from the bank (V3).

The calculation includes the following costs:

- *Investments to energy saving measures*
  All investments associated with the renovation, particularly the costs of material and installation costs (work). The costs of different items in the calculation were based on prices from company catalogues and from price offers made by construction companies.
- *Operation costs for heating*
  Depends on the heat demand for heating and DHW and on the efficiency of heating and DHW systems (determined by a calculation), the climatic conditions (for the site Bratislava, Slovakia) and on the behaviour of users (standardized). The price of heat was based on annual reports of the Office for regulation of network industries, which regulates the price heat in Slovakia.
- *Costs of repairs of the residential building*
  Include costs of regular repairs of facade, roof, windows and distribution pipes of the heating and DHW systems. This was based on the expected time of failure of the construction and expected repair interval (e.g. jointing of cracks and panel joints, cleaning of the facade, repair of roof outlets, remediation of cracks around the windows,...).

3. Results

The results of the calculation of the life cycle costs of the building A (panel building) are shown in the next Table 3. The results of the calculation of the life cycle costs of the building B (brick building) are shown in the next Table 4. For the calculations the 2% discount rate was applied, which can be considered suitable for the long-term life cycle calculations. This relatively low rate reflects the benefits that investments in energy efficiency brings to users of the building throughout the life cycle.

Table 3. Total costs during the 30-year life cycle of the building A

Criteria for the evaluation	Original condition	V1 (currently in force)	V2 (since 2016)	V3 (since 2021)
Investments (EUR)	0	415 360	466 076	507 524
Costs of repairs (EUR)	96 900	16 300	16 300	16 300
Operation costs for heating(EUR)	2 244 734	560 885	438 694	386 679
Total life cycle costs(EUR)	**2 341 634**	**992 545**	**921 070**	**910 503**
Rank by the lowest LC costs	**4**	**3**	**2**	**1**

Table 4. Total costs during the 30-year life cycle of the building B

Criteria for the evaluation	Original condition	V1 (currently in force)	V2 (since 2016)	V3 (since 2021)
Investments (EUR)	0	218 319	258 604	267 631
Costs of repairs (EUR)	96 900	16 300	16 300	16 300
Operation costs for heating(EUR)	2 283 022	1 143155	961 033	916 115
Total life cycle costs(EUR)	**2 379 922**	**1 377 774**	**1 235 937**	**1 200 046**
Rank by the lowest LC costs	**4**	**3**	**2**	**1**

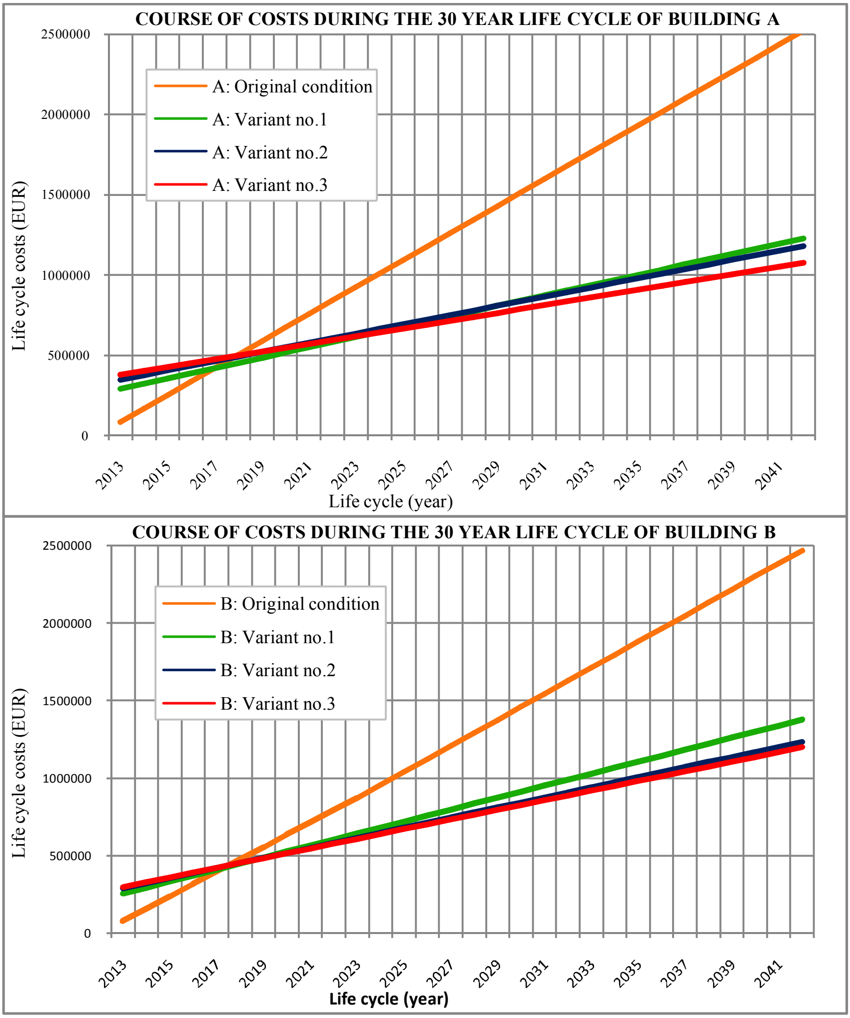

Fig.2 Time course of total life-cycle costs of apartment building A,B

4. Discussion

Economic calculations of renovation variants showed, that the total life cycle costs of both apartment buildings – A, B are lowest in variant with the highest level of thermal insulation, that can be considered, as the most profitable; although the initial costs are highest, the low operation costs ultimately lead to the lowest costs during the whole life cycle of the building. However, the cost of debt service was not considered in the calculation. The highest debt service cost could possible lead to the highest loan from the bank (Variant no.3), which could in turn change the rank of the respective variants. Had the debt service been considered, it can be predicted that the Variant no. 2 would have been the most cost-optimal one. Demolition costs were not considered, either; however, it can be assumed to be the same for all variants.

5. Conclusion

The renovation requirement was satisfied by using additional thermal insulation for the whole building envelope, by replacing Windows and by application of energy saving measures in heating and DHW. From the energy saving point of view, there is not much need to insulate the basement ceiling, but it is included to avoid cold floors in the ground floor apartments.

The analysis showed a potential of energy consumption reduction of more than 50 % by implementing the energy efficiency measures. In terms of calculations for the period of 30 years, we came to the conclusion that most convenient variant of renovation is the Variant no. 3. However, some of the costs were not considered in the LCC analysis; mainly the costs of the debt service could significantly influence the profitability of the respective renovation variants. Life-cycle cost calculations for different variants of renovation showed that the cost-optimum level for the renovation of different apartment buildings panel-A, brick-B, was the most convenient Variant no.3 that satisfy the thermal requirements for zero-energy buildings.

The success of the renovation project depended mostly on the detailed design of the renovation solutions and ability to direct the apartment owners to make the right choices.

References

[1] Residential and Non-residential Building Stock Renovation Strategy, Slovak Republic. Bratislava, 2014.

[2] W. Eichhammer, T. Fleiter, B. Schlomann, S. Faberi, M. Fioretto, N. Piccioni, S.Lechtenböhmer, A. Schüring, G. Resch, Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries, Final Report for the European Commission Directorate-General Energy and Transport, 2009.

[3] C. Becchio, et al., Cost optimal Levels of Energy Requirements for Nearly-Zeb: Application to an Italian Reference Building for existing Offices. *CLIMA 2013 11th REHVA World Congress "Energy efficient, smart and healthy buildings"*, Prague; (2013)

[4] Directive 2010/31/EU of the European Parliament and of Council of 19 May 2010 on the energy performance of buildings (recast). Official Journal of the European Union

[5] STN 73 0540-2: 2012 Thermal protection of buildings. Thermal performance of buildings and constructions. Part 2: Performance requirements.

[6] J.Kmeťková, *Technical and economic assessment of complex renovation of apartment building*. Diploma thesis. SvF STU, Bratislava, (2013).

[7] Asdrubali F, Baldassarri C,FthenakisV. Life cycle analysis in the construction sector: guiding the optimization of conventional Italian buildings. Energy and Buildings 2013;64:73–89.)