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Technical-economical estimation of the renovated Lithuanian schools

Rimidijus Pikutis[1],

Lina Šeduikytė[2]

[1] *Joint-Stock Company "Šiltas namas"*
[2] *Kaunas University of Technology, Faculty of Civil Engineering and Architecture Studentų g. 48, LT-51367 Kaunas*

Lithuanian school buildings constructed before World War II or during the Soviet period have many defects. Most of these buildings have problems such as excessive energy use for heating, windows that are not airtight when closed, defects in the external walls, moisture damage, indoor microclimate parameters which do not correspond to the hygienic norms, etc. As the bulk of energy is consumed for the heating of buildings, this point seems to be the most important in respect of energy savings. Problems appearing in school buildings as well as the results of audits in 30 Lithuanian schools which were supposed to be renovated in the year 2001 are discussed in the article. The loan of 80 million litas was set for the renovation of the educational buildings among 52 municipalities at that time. The distribution of the renovation works in the schools is presented. The direct connection between heat energy savings and the amount of investments for heat saving implementation in the schools is estimated.

Key words: renovation works, energy savings, school buildings

1. INTRODUCTION

The energy performance of buildings is a matter of great concern in Lithuania. Energy performance efficiency certifications for Lithuanian residential buildings have been presented [1]. Proper evaluations of possible energy savings have been discussed [2]. The latest overview of the Lithuanian heating sector districts, improvement trends in heat production, transmission and distribution [3] as well as the planned modernization of district heating systems [4] is presented.

The heating season in Lithuania usually starts and finishes when the average outside temperature of three days is below 8 ˚C (10 ˚C). The duration of the heating season depends on the region and can vary from 191 to 204 days when it starts at 8 ˚C and from 214 to 226 when the heating starts at 10 ˚C.

In regard to economical aspects and energy savings, the benefit gained after the renovation of the buildings depends on:

• *the juridical-economical system in the country which encourages energy savings:*

– the economical assumptions that encourage the user and the producer to save energy used for heating;

– implementation of the systems for the accounting of the used energy and its regulation;

– stimulating implementations, which supply with preference credits or reduction of taxes when the norms of energy for heating are not exceed;

• *the effective application of technical devices used for energy savings:*

– when the heat energy production and distribution systems and building engineering systems are renovated;

– when the building envelopes are renovated.

Stankevičius et al. [5] have presented a report which discusses the energy audit of one secondary school building in Anykščiai and the results of implementing energy saving measures. In the survey, a possible decrease in energy consumption and the order of improvements are also discussed.

The aim of the present work is to discuss the general design characteristics and defects of Lithuanian school buildings, to estimate the effectiveness of the insulation of the building envelopes (walls, roofs, windows and doors) using the audit data of 30 Lithuanian schools, and to evaluate the differences in energy consumption and investments made in these schools.

1.1. Characteristics and main defects of Lithuanian school building envelopes

All Lithuanian school buildings could be divided into the following groups:

• The buildings built before World War II. The walls of such buildings are usually made from ceramic brick masonry 64 or 51 cm thickn. Monolithic intermediate floors, pitched roofs with tiles or slates and windows in separate frames are typical of this period.

• The buildings constructed during the Soviet period. Characteristic of the buildings of this period are walls of cellular concrete (thickness 24 cm) or expanded clay concrete (thickness 30 cm) masonry with flat roofs.

1.2. Roofs

Roofs are one of the most important elements of any building. Firstly, like walls, they are a very important visual element. A pitched roof to disperse rainwater rapidly from the roof of a building has been employed by builders for many centuries. The degree of a pitch, the nature of the roof construction and the type of covering varied widely depending on to the availability of materials, geographical location, building type and architectural style.

The main defect of roofs is leakage. The appearance of moisture spots and mould damages not only the architectural view but also causes problems related to the sanitary-hygiene requirements. It is presumed that almost half of all flat roofs have smaller or larger leakages.

The damage of the coatings of pitched roofs leads to an increasing local rot of the wood. Slating coverings (usually with asbestos) were quite widely used earlier. Nowadays these coverings do not meet the requirements because of many defects and of health problems that may be caused by asbestos. Tarnish and green spots on slating coverings cause architectural problems; cracks lead to the leaking, and afterwards the thermal insulation of roofs is not able to meet even the minimal requirements.

The appearance of blisters, defects near connections with parapets or other vertical surfaces improper installation of rainwater goods are common for flat roofs. A proper maintenance of the rainwater system on any building is essential for its long-term preservation.

Quite often mechanical tears on the coverings appear after careless works on the roofs, unqualified installation of antennas.

It should be mentioned that the mounting of new roof coverings and replacement of mouldered roof constructions is not very complicated and expensive work. The insulation of attics is very effective, too. The situation is more complicated with mouldered ceilings, when usually major regair of the whole building are needed.

Modern roof coverings substantially differ from the old ones. They are reinforced with polyester or glass fabrics, also bitumen with different modified polymers is used for the coverage.

1.3. Walls

The peeling of paint usually occurs on building facades, mainly on plastered walls, columns and other areas exposed to excessive rain and dampness. Some buildings located near the sea may face a greater risk. The winds, rains and the sun can easily make the surfaces of paint chalky, wrinkled or blistered. In many heritage buildings, several layers of paints have been applied onto the plastered walls over the decades. Apart from lime wash, other types of paints used include emulsion, oil-based, tar, bituminous and oil-bound water paints. Different types of paints require different methods of removal.

External walls may be harmful to the building if they are structurally unsound. Vertical or diagonal cracks in the wall (Fig. 1) are common symptoms of structu-

Fig. 1. Vertical and diagonal cracks and other defects in walls

ral instability. Such defects should be investigated promptly and the causes should be diagnosed: be it the foundations, weak materials and joints; or any shrinkage or thermal movements, such as those of timber window frames.

Diagonal cracks, usually widest at the foundations or even terminating at the corner of a building, often occur when shallow foundations are laid on shrinkable subsoil which is drier than normal, or when there is a physical uplifting action, such as a large tree's main roots close to the walls.

The common causes of leaning walls include a spreading roof which forces the weight of the roof down towards the walls, sagging due to soil movement, weak foundations due to the presence of dampness, shrinkable clay soil or decayed building materials; what is more, the disturbance of nearby mature trees with roots expanding to the local settlement can also cause the leaning of walls.

Fungal stains or mould occur when there is moisture in walls. They flourish in an environment of high humidity with the lack of ventilation. The presence of microorganisms in the indoor environment can cause health or comfort problems [6]. Harmful growth includes creeping and ivy plants that can grow either on walls, roofs or gutters. This usually happens when dirt penetrates into small openings in walls and mortar joints, creating suitable grounds for seeds to grow. Roots can go deep into the existing holes, causing further cracks and water penetration.

1.4. Windows

Old windows do not meet the requirements which are made to these products today. Modern windows have to meet very high requirements, such as a good aesthetic look, durability, easy care, frugality and good thermal insulation.

The following defects could be detected in old windows:

- window frame deformations with the case, large cracks, due to badly prepared wood, hinges and weak closing mechanisms;

Fig. 2. Defects in windows

- the bad thermal insulation of windows (between glass and window frame; between window frame and casings; between casing and wall);
- the moulder of window wooden part, especially underneath where water gathers;
- incorrect installation of the tin part of the windowsill.

There are some accidents in practice when it is not possible to clean windows because their frames cannot stay in cases and glass in frames.

It is not useful to invest money in big reconstructions of windows; therefore, it is better to seal windows as a temporal (10–12 years) heat saving implementation. In many cases, it is useful to replace old windows with new effective ones. The decrease of cold air infiltration and better indoor microclimate conditions will result from this process. The reduced window area also should be taken into consideration.

2. METHODS

2.1. The investigation object

The results of 30 audits of Lithuanian schools which were supposed to be renovated in the year 2001 were collected and used for the investigation. 80 million litas was the total sum of the loan for the renovation of the educational buildings at that time. The finance was divided among 52 municipalities.

2.2. The economic parameters

The value of money is varying in time because of the relation between their demand and supply. The norm of the devaluation of money in time should be calculated before the economic calculations. It is advisable to equate the norm of the devaluation to the smallest interest rate of the market. It is essential to evaluate the levels of general inflation and a possible increase of the tariffs for the fuel or heating.

The ordinary time (years) of the payment [7]:

$$PB = \frac{I_0}{\Delta S}, \tag{1}$$

where:

I_0 – the capital investments by the price of the first year, Lt,

ΔS – the annual savings by the price of the first year, Lt/year.

The real time of the payment (recalculated):

$$PO = \frac{-\ln\left(1 - r\frac{I_0}{\Delta S_i}\right)}{\ln(1+r)}, \tag{2}$$

$$r = \frac{1}{1+e}\left(\frac{r_n - i}{1+i} - e\right), \tag{3}$$

where:

r – the net profit / interest rate when the increased cost of energy for heating is evaluated, units / year;

e – the net (with subtracted inflation) increase of the cost of energy for heating, units / year;

i – general inflation, units / year;

r_n – the nominal profit / interest rate, units / year.

The index of the profitability of investments

$$NPQ = \frac{\frac{1-(1+r)^{-n}}{r}\Delta S - I_0}{I_0}. \quad (4)$$

The permissible (marginal) investments:

$$GPI = \frac{1-(1+r)^{-n}}{r}\Delta S. \quad (5)$$

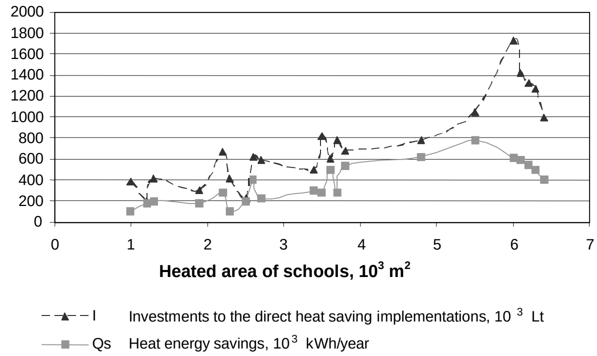

Fig. 3. Connection among heated area, energy savings and investments

The calculation methods presented above are used for the evaluation of the technical–economic parameters.

3. RESULTS AND DISCUSSION

The processed results of 30 audits are presented in Table.

The most effective solutions were proposed by engineers-consultants who together with school principals and employees of municipalities were coordinating the main work. Due to the lack of finance only partial renovation of the schools was possible.

The heat energy savings, depending on the amount of the investments to the direct heat saving implementations, are presented in Fig. 3.

Referring to the results, it could be stated that there is a direct relation between the above-mentioned factors. The existing deviations could be explained by the difference of the chosen renovation works and prices.

Different renovation works were accomplished in the schools to save heat energy (Fig. 4). The renovation of old windows or their replacement with new ones was accomplished in all schools. Infrequent renovation work was the insulation of walls.

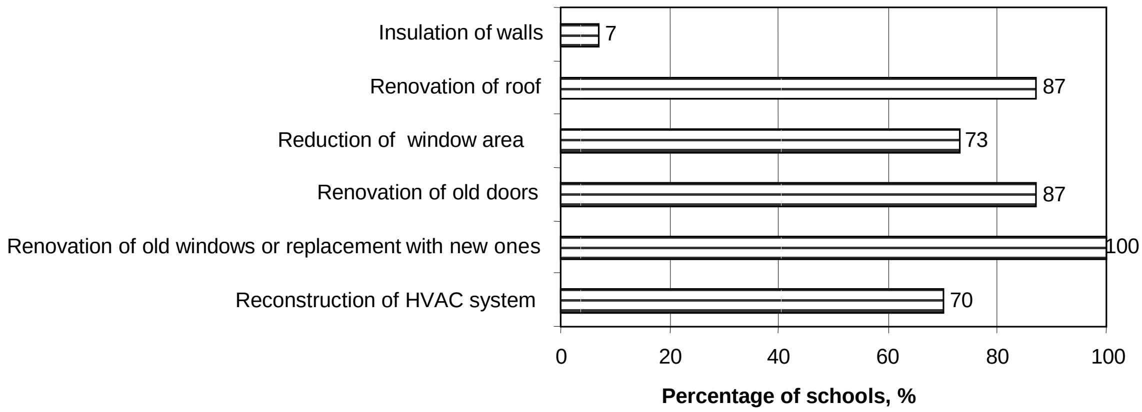

Fig. 4. Distribution of the renovation works in the schools

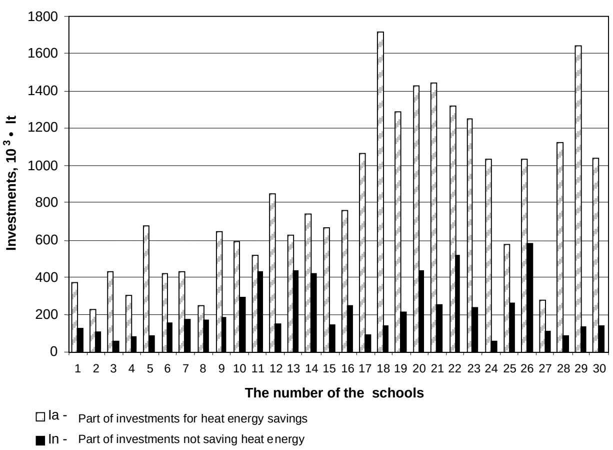

Fig. 5. Investments in the study schools

The renovation of the 30 schools is evaluated in an integrated approach. Not only renovation works for the heat energy savings are taken into account, but also the improvement of the exploitation characteristics of the buildings (reconstruction of masonry, reparation of joints, moisture protection) is evaluated.

Although these implementations do not save heat energy and the duration of the total dividend time is growing and savings are decreasing, they are mandatory to ensure the durability of the used implementations. The investments in the 30 schools to heat energy saving and the improvement of exploitation characteristics are presented in Fig. 5. Summarizing the statistical results, it can be stated that 80% of total investments were allotted to heat energy savings.

Table. **Results of energy audit of 30-y schools**

Number	Town, the name of the school	The heated area, m	Energy demand, $10^3 \cdot$ kWh	Investments, 10^3 Lt						
				Total	For replacement of windows	For renovation of doors	For insulation of walls	For renovation of roofs	For reduction of windows area	For the HVAC system
1	Marijampolė, Antanavas pr. sch.	967	213.9	496.8	105.0	15.0	133.0	29.0		90.0
2	Prienai, Kunigiškės pr. sch.	1176	325.4	332.7	77.5			40.1	10.2	100.0
3	Alytus, Makniūnai s. sch.	1373	459.7	485.8	161.7	40.4		136.0	1.9	90.0
4	Vilkaviškis, Keturvalakiai pr. sch.	1916	455.7	381.4	110.0	20.0				170.0
5	Alytus, Alovė s. sch.	2199	703.5	765.2	234.6	41.2		236.3	12.7	150.0
6	Rokiškis, Panemunėlis s. sch.	2302	559.3	575.5	261.6	21.8		86.6	13.6	36.0
7	Kaunas, Babtai s. sch.	2325	500.9	604.0	230.3	11.2		71.5	19.4	100.0
8	Alytus, Pivašiūnai s. sch.	2454	780.9	418.2	231.7				20.6	
9	Leipalingis s. sch.	2696	658.7	829.8	307.3	6.3		211.4	21.7	100.0
10	Ukmergė, Taujėnai s. sch.	2786	790.1	881.5	480.6	1.0		89.0	20.8	
11	Ukmergė, Senamiestis s. sch.	3350	607.9	946.0	368.2	10.7		65.3		70.0
12	Vilkaviškis, Gižai s. sch.	3430	880.7	997.1	410.0	21.0		291.0		125.0
13	Vilnius, Užupis s. sch.	3576	849.7	1064.1	402.0	33.0		192.0		
14	Molėtai, Alanta s. sch.	3739	999.0	1154.5	432.9	63.4		228.7	5.8	7.0
15	Molėtai s. sch.	3822	754.5	809.7	356.5	23.1		203.3	22.8	60.0
16	Švenčionys, Z. Žemaitis s. sch.	4825	1160.8	1006.9	450.6	14.9		294.8		
17	Pasvalys, P. Vileišis s. sch.	5517	1356.5	1155.2	600.5	41.0		266.4	20.6	132.2
18	Radviliškis, Vaižgantas s. sch.	6127	1539.4	1857.5	901.3	4.9		508.8	89.6	215.7
19	Mažeikiai, Sodai s. sch.	6190	1402.9	1502.1	865.1	108.9		236.4	74.6	4.2
20	Šilutė, M. Jankus s. sch.	6203	1378.3	1860.1	863.7	32.9	47.7	392.5	50.6	40.0
21	Zarasai, P. Širvys s. sch.	6203	1432.4	1697.0	836.3	36.5		360.0	88.8	120.0
22	Vilnius, Karoliniškės s. sch.	6203	1447.0	1831.0	834.2	28.7		332.3	121.6	
23	Kaunas, Garliava Jonučių s. sch.	6223	1315.1	1487.0	716.9	34.1		223.8	74.8	200.0
24	Kaišiadorys, V. Giržadas s. sch.	6252	1348.6	1088.0	729.1	15.2		233.1	53.3	
25	Zarasai, Ąžuolas s. sch.	6778	1678.6	832.1	450.5	7.0			34.0	80.0
26	Tauragė, M. Mažvydas s. sch.	7015	1366.5	1610.0	658.0	11.8		197.5	23.5	140.0
27	Prienai, Ąžuolas s. sch.	7060	1246.4	386.9	40.0			236.8		
28	Akmenė s. sch.	7366	1335.5	1204.7	483.1	20.3		437.5	34.3	142.5
29	Kaišiadoriai, Žiežmariai s. sch.	7376	1669.1	1777.7	560.0	38.0		1045.0		
30	Jonava, Santarvė s. sch.	10375	1881.4	1181.3	920.7				121.0	
	Total:			31219.8	14079.9	702.3	180.7	6645.1	936.2	2172.6

4. CONCLUSIONS

1. Renovation works should include not only implementations for heat energy saving, but also improvement of the exploitation characteristics of buildings.

2. The frequently used renovation work in the study schools was renovation of old windows or their replacement with new ones. It was accomplished in all 30 schools. However, insulation of walls was made only in 7% of the schools.

3. 80% of the total investments were allotted to the renovation works that save heat energy.

4. A direct relation between heat energy savings and the amount of investments for heat saving implementation in 30 Lithuanian schools was estimated.

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Rimidijus Pikutis, Lina Šeduikytė

RENOVUOTŲ LIETUVOS MOKYKLŲ PASTATŲ TECHNINIS-EKONOMINIS ĮVERTINIMAS

S a n t r a u k a

Dauguma Lietuvos mokyklų buvo pastatytos sovietiniais laikais ar net anksčiau. Šiuo metu senos statybos mokyklose iškyla problemų, susijusių su išorinėse sienose, stogų paviršiuje ir konstrukcijose esančiais defektais, vidaus drėgme, nesandariais langais, patalpų mikroklimato parametrais, taip pat per dideliu energijos sunaudojimu šildymui.

Šiame straipsnyje pateikiamas atliktų techninių-ekonominių renovacijos priemonių palyginimas trisdešimties Lietuvos mokyklų auditų pagrindu. Pateiktas renovacijos darbų pasiskirstymas nagrinėjamose mokyklose.

Atlikus statistinį įvertinimą, pateikiamas šildomo ploto, šiluminės energijos sutaupymų bei investicijos dydžio ryšys. Visi išvardyti veiksniai yra susiję, o esami nukrypimai paaiškinami pasirinktų renovacijos priemonių įvairove, skirtingomis kainomis. Pažymėtina, kad 80% bendrų investicijų buvo skirta energiją taupančioms priemonėms.

Raktažodžiai: renovacija, energijos taupymas, mokyklų pastatai

Римидиюс Пикутис, Лина Шедуйките

ТЕХНИКО-ЭКОНОМИЧЕСКАЯ ОЦЕНКА РЕНОВАЦИИ В ШКОЛАХ ЛИТВЫ

Р е з ю м е

Многие школы в Литве были построены в советское время и даже ранее. В школах старой постройки возникают проблемы из-за дефектов наружных стен, внутренней влажности, негерметичности окон, а также из-за высокого потребления энергии, расходуемой на отопление, и т. д.

В данной статье на основании энергетических аудитов, проведенных в тридцати школах Литвы, дается технико-экономическая оценка средств реновации. В результате статистического анализа представлена связь между отапливаемой площадью, экономией теплоэнергии и суммой инвестиций. Следует отметить, что 80% общих инвестиций вкладывалось в средства реновации, направленные на экономию энергии, расходуемой на отопление.

Ключевые слова: реновация, экономия энергии, школы