Criterion to evaluate the “twofold benefit” of the
renovation of buildings and their elements

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Abstract
At present a benefit of energy saving projects for buildings renovation is considered as only the saving of energy. It is obvious, however, that most energy saving measures allow one not only to save energy, but also to improve the building’s condition and in turn to increase the value of a building. In practice, considering only the reduction of energy cost, the implementation of such measures is usually hard to prove through cost effectiveness. The authors of this paper suggest one of possible methods of how the assessment of the cost effectiveness of energy saving measures could include a twofold benefit of building’s renovation—the energy saving and the rehabilitation of the buildings elements physical condition. The presented method could form a “new attitude” towards the assessment of the energy saving projects for buildings renovation.

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1. Introduction

Building renovation projects, whose feasibility is assessed only with regards to energy efficiency, should be considered as the result of an “old attitude”. It is unlikely that such projects meet the concepts of the six essential requirements for construction works [1] as well as the need for sustainable development. Buildings, which form the accumulated wealth of a country during a long time and are frequently the largest asset of each country, should be renovated, considering the benefit as well of the timely renewal of worn out building elements.

The experience of the Energy Efficiency Housing Pilot Project in Lithuania [2,3], which was initiated by the World Bank and directed to the renovation of residential houses and educational institution buildings, has shown that at present, residential and public buildings built between 1960 and 1980 face two problems—an inefficient heat consumption and a deterioration of building elements and engineering systems. This in turn results in conditions inside buildings that do not comply with up-to-date requirements of comfort and safety.

Within the first years of the mentioned project (1997–1998) mainly cost effective measures were implemented, i.e. renovations of heat substations and systems for domestic hot water (DHW) and cold water supply. Investment intensive measures, which could solve the problem of worn out building elements, were not popular because of the low economic criteria defined that considered only the energy efficiency, i.e. the simple payback time exceeded 10 years. However, the latter criterion was a major indicator for receiving the World Bank loan. The situation changed at the beginning of 1999, when the Government of Lithuania introduced a subsidy of 30% for the associations of apartment houses, which invests in increasing the efficiency of energy consumption. This government initiative has encouraged the implementation of such measures as the replacement of windows, insulation of roof and walls. Average investments per residential buildings increased from US$ 22,000 in 1997 to US$ 45,000 in 1999. Thus, the introduction of the subsidy enabled Lithuanians to solve the renewal of buildings elements as well the second problem of buildings but only partly.

Elementary logic allows one to understand that the replacement of windows or the reconstruction of roofs leads not only to the saving of energy in a building. Therefore, the restricted approach focused only on the energy efficiency forces one to choose one of the three following ways: to carry out irrational renovation, to distort the likely results in energy audits, or to refuse the renovation.
The subject of this paper is to explore one of the possible methods of how the assessment of the cost effectiveness of energy saving measures could consider the twofold benefit of their implementation—the energy saving and the renewal of building elements.

2. Main cost effectiveness criteria to assess building renovation measures

Up until now and in most cases, the reduction of heating costs was considered as the sole benefit of the renovation of building construction elements. For this purpose various criteria to evaluate cost effectiveness of energy saving measures were employed. In this section we briefly compare the most popular criteria.

One of the most popular criteria used is a simple payback time because it is readily comprehensible for non-economists. However, one should note, that the simple payback time of an individual energy saving measure or a package of them are to be used only for the superficial evaluation of the cost effectiveness. The major limitation is that the lifetime of an energy saving measure is absolutely not taken into account. An example of this are the results of the monitoring of energy saving projects carried out in Lithuanian schools [4] that have shown that the average simple payback time of such measure as the windows tightening and repair was about 7 years. By not going deeply into this question, it could seem that this measure is cost effective. However, the estimated lifetime of the measure is about 5 years. This means that it does not pay back during its lifetime and therefore, this measure could not be considered as the cost effective one.

Besides, the simple payback time does not allow one to compare unambiguously individual energy saving measures. For example, it is not possible to say that measures are evenly effective if their payback time is the same. Their life times can differ, i.e. one measure can result in lower energy consumption longer than its payback time, while the payback time of another measure can be equal to its lifetime. Thus, if only the payback time of an energy saving measure is presented without presenting its lifetime, a misleading decision could be taken.

Another restriction of the simple payback time is that it does not value the cost of borrowing money. The payback time indicates if savings, resulting from the implementation of a measure, are sufficient to repay a loan. However, it also does not show if the savings are enough to pay the interest. Let us suppose, that the simple payback time of a measure are calculated at 8 years and we are going to take a 10-year loan. Without a loan payments timetable or calculations of additional economic criteria it is hard to assess whether savings, resulted from the measure, are sufficient to cover the loan payments.

To have a more objective evaluation, it is more applicable to use other fundamental criteria for the evaluation of the cost effectiveness—a net present value (NPV) and an internal rate of return (IRR). As distinct from the simple payback time these criteria estimate the benefit resulting from an investment, during a certain period of time. Usually, the period of reduced energy consumption resulting from the implementation of one energy saving measure will differ from one of another measure, i.e. the lifetime of measures will not be equal. Therefore, in order to compare the cost effectiveness of individual energy saving measures it is essential to choose the same period for the evaluation and the difference in the lifetime of measures should be taken into consideration by introducing into the calculations the necessary reinvestments and residual value of investments at the end of the chosen period. In that way the criteria of NPV and IRR completely solve the problem related to the lifetime of measures and its difference. To evaluate the cost of borrowing money the NPV and IRR are calculated by using the discounted cash flows, i.e. a discount rate is introduced, which is usually equated to the market’s interest rate. Therefore, in this way the second problem of the simple payback time is solved as well.

To evaluate economic efficiency of energy saving measures a criterion of so-called cost of conserved energy (CCE) [5–7] can be applied. As in the case of the NPV and IRR criteria this criterion takes into consideration both the lifetime of measures and the cost of borrowing money.

The CCE could be calculated according to the following formula:

\[
CCE = \frac{J}{5} \times \frac{d}{1 - (1 + d)^{-n}},
\]

(1)

where investment cost of a measure (in monetary units), \(S\) is the annual savings (in physical units, e.g. MWh), \(n\) the lifetime of a measure (in number of years) and \(d\) the discount rate (in shares of unit).

Usually, results of the CCE coincide with results of the NPV and IRR however the calculation of the CCE is slightly simpler and besides, its interpretation is more readily comprehensible. The CCE indicates what is cheaper: to save energy or to consume it? Let us assume, that the CCE of an energy saving measure is 100 Lt/MWh and the present heat price is 110 Lt/MWh. Therefore, it is obvious that to save energy is cheaper than to consume it and vice versa.

Another advantage of the CCE is that it does not depend on present or future energy prices. For example, if the CCE of a measure is obtained as being higher than the present energy price, but lower than the forecasted energy price, then one could conclude that it is wise to implement this measure.

Further in the paper we will explore how the cost effectiveness of an individual energy saving measure could involve not only the reduction of energy costs, but also the benefit of the renewal of building elements when the criterion of the cost of conserved energy is used in a sufficiently objective way and is more comprehensible for non-economists.
3. Coefficient of building element’s rehabilitation

By taking into account the sole benefit of energy saving, the implementation of the measures, related both to energy saving and the improvement of building element conditions, is rather rarely proven through cost effectiveness. Therefore, it is likely that in some cases of energy audits and in energy saving investment projects for a building’s renovation, the energy consultants deliberately attempt to present artificially magnified energy savings of measures in order to receive an acceptable overall cost effectiveness of a package of energy saving measures.

It is quite obvious that this problem needs to be solved in another way. At first, it should be assumed that the implementation of benefits of some energy saving measures are associated not only with energy saving, but also with the improvement of building element conditions and in turn, with the overall durability and the value of a building.

In contradistinction to the benefit of energy saving, the estimation of the benefit of the renewal of building’s elements in quantitative terms is more complicated [8,9]. Due to this reason it is suggested to divide the investment cost, related to the rehabilitation of a building’s element, into two parts. For this purpose the coefficient of building element’s rehabilitation (a) could be introduced. This coefficient could be determined in two ways: using a linear or a non-linear function of the deterioration of a building’s element condition.

By using the linear function, the coefficient considers only the linear physical deterioration of an element (2):

\[ \kappa = \frac{t_{age}}{t_{life}} \]  

(2)

where \( t_{life} \) is the lifetime of an element (in number of years), \( t_{age} \), the actual age of an element (in number of years). The lifetime of an element \( t_{life} \) is considered as the time from its installation, after which the element should be replaced or completely rehabilitated.

By determining the coefficient of building element’s rehabilitation according to the formula (2), the linear deterioration is used; however, the deterioration of different elements usually has a non-linear distribution. In order to reflect this, a more complicated calculation can be used for the determination of the value of \( \kappa \). When employing the authors suggested formula [9] a non-linear deterioration function of an element, \( \kappa \) can be expressed by the equation:

\[ \kappa = \frac{1}{b} \left[ a - \ln \left( \frac{t_{age} \times l_{hab} + c}{t_{age} + d} - 1 \right) \right] \]  

(3)

where \( l_{hab} \) is the level of rehabilitation (in shares of one), \( a, b \) the coefficients of a function’s restrictions, \( c, d \) the coefficients of function’s proportionality.

In the Eq. (3) the coefficient of a building element’s rehabilitation considers not only the physical deterioration of a building’s elements, but also the fact that individual elements of a building should be renewed or replaced after a particular period.

Values of the coefficients of a function’s restrictions are calculated according to the following Eqs. (4) and (5):

\[ a = \ln \left( \frac{t_{life} \times l_{hab} + c - d}{d} \right) \]  

(4)

\[ b = a - \ln \left( \frac{c - d}{t_{life} \times l_{hab} + d} \right) \]  

(5)

One of coefficients of a function’s proportionality is expressed by the Eq. (6):

\[ d = \frac{c + l_{hab}}{2} - l_{hab} \]  

(6)

where \( l_{hab} \) is the rehabilitation period, i.e. a period, after which the physical condition of an element should be rehabilitated (in years). A decision as to which value to attribute to this indicator, often depends on how many indicators are provided for in legal the documents of a buildings’ durability regulation. Otherwise, \( l_{hab} \), indicator could be determined according to a methodology especially elaborated to reflect the defect evaluation, performed by experts, of an individual building’s element. Such methodologies are found in the legal documents that regulate the maintenance of buildings. If the value of \( l_{hab} \) is unknown, it could be assumed according to the following condition (7):

\[ l_{hab} < t_{life} \]  

(7)

The nature of an element’s deterioration can be changed by employing the second coefficient of proportionality \( c \). The value of which can be chosen by following the condition (8):

\[ c > |l_{hab} - 2 \times l_{hab}| \]  

(8)

The coefficient of building element’s rehabilitation indicates, which part of an investment cost of a measure can be attributed to the rehabilitation of an individual building’s element condition? Then the rest of the investment cost relates

![Fig. 1. Dependence of CCE values of some energy saving measures, related to the rehabilitation of building’s elements, on the age of the corresponding element of a building.](image-url)
to the energy saving. By employing one or several economic criteria, the cost effectiveness of a measure is assessed only for that part of an investment’s cost, which is considered as being related to the energy saving. Due to the reasons presented in the previous section, we suggest one to use the criterion of the cost of conserved energy (following formula (1)). If the deterioration level of an individual building’s element condition is very high or even equal to a unit, the whole investment cost of the measure, related to this element, will be attributed to the rehabilitation of the element’s condition; and the cost effectiveness of the measure will be the highest, i.e. the CCE will be equal to zero. In other words, in order that the building could normally further function this element should be completely renewed or replaced. Otherwise, in an extreme case cost effective energy saving measures, installed in other elements of the building, can be destroyed. Taking into consideration the coefficient of $\kappa$, the final CCE calculation formula is (9):

$$CCE_B = (1 - \kappa) \times \frac{I}{S} \times \frac{d}{1 - (1 + d)^{-n}}.$$  \hspace{1cm} (9)

Fig. 1 presents the diagrammatic view of the CCE$_B$ of individual energy saving measures. Knowing the present energy price in a building, from the chart one could determine the time moment from when it would be reasonable to completely renovate or replace the building’s element which has influence on the energy consumption in addition to other its functions. It would be a dot, where the curve of CCE intersects the horizontal line, representing the energy price in a given locality.

4. Practical application of proposed method

The survey of results is based on the initial phases of the project “World Bank Supports Education Improvement, Distribution of the values of CCE of the insulation of a slopped roof is represented by using the non-linear calculation of the coefficient of building element’s rehabilitation, while values of CEE of other measures— use the linear calculation of the coefficient."
5. Conclusions

1. The application of the traditional approach of a sole energy efficiency benefit to assess the feasibility of the energy saving projects of a buildings’ renovation can not enable one to consider neither the six essential requirements for construction works nor the concepts and principles of the sustainable development in the sector. One of the first steps to involve these aspects into the assessment of the projects is to recognize, that some energy saving measures result in a twofold benefit of the renovation. Their implementation will allow one not only to save energy, but also to rehabilitate the worn out building’s elements.

2. In this paper the coefficient of a building element’s rehabilitation is proposed as one of the possible methods of how, when taking into account both the energy saving and the improvement of building’s elements condition, it would be possible to involve the benefit of the rehabilitation of elements into the energy saving projects for a buildings’ renovation. This indirectly expressed benefit appears as the avoidance of a reduction of the total value of a building through the rehabilitation of the technical characteristics of a building’s elements with regard to their functionality and safety.

3. Taking into account the level of the building’s element deterioration, the coefficient of building element’s rehabilitation opens the possibility to have a methodologically unified criterion, which would allow one to involve into the energy saving projects the renovation of building’s elements, which have influence on the energy consumption and also are dealing with other functional purposes. Primarily this concerns a building’s partitions (walls, windows, roofs).

4. The proposed function of the element’s deterioration has flexible features and thereby allows one to employ the information about the nature of the element’s deterioration that is available from the operators of buildings, in order to assess the element’s renovation feasibility and for other purposes.

5. On the basis of the presented method, the buildings’ renovation projects and programs have the possibility to elaborate the project’s assessment methodology with a wider approach. Certainly, there is an open area to supplement it with other criteria that meet other aims of a project as well.

References
