THE PROCEDURE FOR THE VALUATION OF REAL PROPERTIES DEVELOPED WITH PASSIVE AND ENERGY-EFFICIENT HOUSES*

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ABSTRACT

The problem of global warming today is omnipresent and various kinds of solutions are suggested to counteract this problem, as well as to balance the environment and the civilization progress which the environment is degraded by. Passive and energy efficient houses, for example, may be such a solution.

The article compares the passive and energy-efficient engineering with traditional, the so-called standard, houses. A procedure for the valuation of developed land was proposed as well, taking into account the specifics of passive and energy-efficient buildings.

Traditional houses consume annually much more energy than passive houses. They also lose a lot of heat due to poor insulation. In the energy-efficient and passive houses the temperature regulates itself using a special technology. Also, the energy generated by equipment and people is used. Such houses produce solar energy using solar panels. Specially selected insulation prevents heat loss, and optimal location of the windows - more to the south, fewer to the north – allows for a maximum use of sunlight for lighting and heating a house.

Material and structural solutions of passive and energy-efficient houses can be taken into account when applying the cost approach in real estate valuation. The proposed statistical models are based on the assumptions of the cost approach, but at the same time, they take market data into account. The article presents an algorithm for the estimation of model parameters and the valuation of developed land. The considerations have been supported by a full analysis of variance.

Keywords: energy-efficient houses, passive houses, valuation of developed land

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INTRODUCTION

The need to protect the environment and to reduce energy costs have stimulated the search for energy-saving solutions in the construction industry. Innovation resulting from the tendency to save energy has influenced the development of energy-efficient construction industry. For several years, Europe has witnessed the interest of investors to erect buildings in low-energy standard. Passive or energy-efficient houses appeared on the real estate market, however, a limit number of such real properties may cause problems when determining their market value in the comparative approach or income approach valuation. Dissimilarity in the valuation of the compared real estate often results from the specific material and design solutions of the low-energy buildings. This specificity can be captured using the cost approach for the valuation, with a simultaneous reference to market data.

PASSIVE HOUSE CONSTRUCTION

The first definition of a passive house was proposed in 1988 by Wolfgang Feist from the Passive House Institute in Dramstadt, Germany. According to the definition, a passive house is a building with exceptionally low energy consumption needed for heating the interior (15 kWh/m² annually). Therefore, a passive structure does not require an active heating system, since the energy is provided by the passive heat sources such as residents, solar energy, electrical appliances, or ventilation. The term "passive", therefore, refers to the state of not providing external conventional energy or, in other words, the lack of activity in its provision.

The building can be called passive only when all its elements meet the requirements of passive construction. In other words - the passivity of such a building is preserved exclusively if all the elements of the house are harmonized while minimizing heat losses, while providing adequate ventilation. Thus, it does not make any sense to install passive windows to an ordinary building due to the fact that heat losses shall occur through elevation and materials used in standard buildings.

In Europe, passive houses have become a category of modern construction engineering and are being designed and built more and more often. Ensuring energy efficiency for the house is essential to obtain high thermal comfort at low energy costs. Such effectiveness is guaranteed by very good insulation of walls, high quality of windows, as well as heat recovery from ventilation. Mechanical ventilation supplies fresh air into a building; a passive house uses it to meet the demand for heating energy through heat recovery from exhaust air. Such a solution is possible only in a very well insulated house in which uncontrolled air flow is not possible.

A passive house is designed to minimize heat losses and to maximize the use of both the energy from its environment and the energy which is generated in the house during its use, and which is derived from the heat losses of home appliances, as well as the energy emitted by the users. A passive house has to ensure the comfort of indoor climate and, as a future standard of construction, it must also be economical, i.e. widely available in terms of construction and operation, as this attribute ensures the possibility for the idea to be propagated and implemented [10].

Passive construction, against all odds, is not much more expensive than traditional one. Depending on the type of the structure, the costs can be estimated at 15-20% of the investment. It is worth remembering, though, that the subsequent use will be with negligible energy demand. Although a passive house, already at the design and construction stages, is approximately 36%. more expensive than the standard one, the owners save from the first day of its use. For example, a passive house with a surface area of 200 m², heated using a heat pump, needs 3,000 kWh per year, which costs 300 PLN, while a 10-year-old standard building needs 22,000 kWh per year, and assuming electrical heating, it is the total expenditure of 5,000 PLN. Expenditures for the construction of a passive house recoup after 30 years.

ENERGY-EFFICIENT HOUSE - ALTERNATIVE FOR A PASSIVE HOUSE

Since the costs incurred to build a passive house are still quite high today and the investment expenditures will be recouped after about 30 years, the construction of an energy-efficient house is worth considering. Energy-efficient houses are cheaper in their implementation than passive houses, besides the selection of designs adapted to energy-saving technology is already quite large and the Investor can easily choose a house suited to their needs, will be able to purchase materials with appropriate thermal parameters without any problems, and find contractors who have experience in building such a house.

The expenses incurred for building an energy-efficient house are increased by only about 8-10%, and at the demand of such a house for energy is only 40-70 kWh/m² annually. Therefore, it is much lower than the demand of the currently constructed standard houses, for which the value is 120 kW/m² per year. Energy savings thus reach even 60-70%. The costs of additional investment costs will be recouped in several years, which makes the investment in the construction of an energy-efficient house quite profitable [11]. Table 1 compares the basic characteristics of the passive house and the energy-efficient house.

Tab. 1. Comparison of the basic characteristics of the passive and energy-efficient houses, based on: [12]

<table>
<tr><th>Energy-efficient house</th><th>Passive house</th></tr>
<tr><td colspan="2">Design</td></tr>
<tr><td>▪ The shape of the house should be simple, the walls and the roof should have the least folds possible.
▪ The biggest glazing is placed on the south side.</td><td>▪ The shape is based on the rectangular plan, with a gable or shed roof.
▪ The whole south elevation should be glazed.</td></tr>
<tr><td colspan="2">▪ The greatest advantage in both types of the houses is ensured by such a shape in which the ratio between the exterior walls and the cubic capacity of the structure will be the smallest possible. The structure, therefore should be the most compact.
▪ Both in the passive as well as in the energy-efficient houses, the size and amount of the glazing from the north side must be limited to a bear minimum.
▪ In both types of the houses, the same interior design is recommended. The living room and he dining room are located from the south side, while the garage, dressing room and technical facilities from the north, so that they create a buffer zone.</td></tr>
</table>

<table>
<tr><th colspan="2">Walls and roofs</th></tr>
<tr><td>▪ The mean heat transfer coefficient U of the exterior walls shall not exceed 0.2 $W/(m^2 \cdot K)$. Such parameters are achievable if an insulation layer of the thickness of minimum 20 cm is applied for the exterior walls, and 30 cm for the roof.</td><td>▪ Higher requirements as to the thermal insulation of the exterior walls – U shall not exceed 0.12 $W/(m^2.K)$ – it can be achieved by applying a thicker insulation layer of minimum 30 cm, and 50 cm for the roof.</td></tr>
<tr><th colspan="2">Construction</th></tr>
<tr><td colspan="2">▪ Both types of the houses may be erected in various technologies, on condition that the material used ensure the required thermal insulation of the exterior walls, however, in the passive house they should be made of materials with high thermal storage capacity.
▪ Thermal bridges increase the demand for heat, that is why in both types of the houses it is recommended to eliminate them.
▪ Both passive and energy-efficient houses must be airtight. Fresh air is allowed in only through the ventilation system.</td></tr>
<tr><th colspan="2">Windows and doors</th></tr>
<tr><td>▪ Due to the fact that more heat escapes through the windows than through the walls, it is necessary to use carpentry with increased thermal parameters. The heat transfer coefficient U of the entire window and the external door should not exceed 1.3 $W/(m^2 \cdot K)$.</td><td>▪ The heat transfer coefficient of the whole window may not be greater than 0.8 $W/(m^2 \cdot K)$; the same parameters apply to the external door and the garage door.
▪ Large glazing should be equipped with shields which will protect against the loss of heat.</td></tr>
<tr><th colspan="2">Ventilation and heating</th></tr>
<tr><td>▪ The heat source is a modern device with high efficiency (condensing boiler, heat pump). The radiators should have the smallest water capacity possible, and the pipes should be very well insulated.
▪ Free solar energy is also used for heating purposes.</td><td>▪ The house may not have an active heating system.
▪ To heat the house, the installation of mechanical ventilation is used; the air which is blown into the rooms is heated by an electric heater or a heat pump. Solar radiation is yet another source of heat, as well as the heat given off by the residents.</td></tr>
<tr><td colspan="2">▪ In both types of the houses, it is recommended to install the mechanical, intake-exhaust ventilation system with heat recovery.</td></tr>
</table>

The above table clearly demonstrates that both the passive and energy-efficient houses have a significant advantage over traditional construction, taking into account heat recovery and heat loss. A significant advantage of energy-efficient houses is the fact that they can be only 3% more expensive to build than standard houses, which is due to lower requirements than in the case of passive houses.

ASSESSMENT OF THE MARKET VALUE OF REAL ESTATE DEVELOPED WITH LOW-ENERGY BUILDINGS

According to the International Valuation Standards, the cost approach may lead to a direct estimate of the market value of the real property [8]. This assumption allows to establish the above-mentioned category of values for those real properties which are developed with buildings erected in the low-energy standard. The use of the cost approach for the valuation of real properties developed with passive or energy-efficient buildings can result primarily from innovative design, materials and technological solutions, used in the construction of such structures. This specificity may be impossible to take into account as a result of the comparative approach of valuation. The solution is to use the cost approach, while referring to the transaction data of properties which are similar in terms of their development.

The developed land property is complex due to specific parts: land and various buildings. The estimated value of the property in the cost approach takes into account the value of the land and the cost of replacement of its component parts, with regard to their physical, functional and external depreciation. The cost approach allows for the separation of the values of these component parts, for a separate estimation of the values of the land and of the buildings, and then summing up these values. It is possible to model the market value of developed properties based on the concept of cost approach [1], [2]. The costs of replacement of the land component parts should be marketed basing on the reference to the real estate transaction data. Additionally, the differences in physical attributes of real estate should be taken into account by using weights of real estate similarity. Most frequently, the market attributes of real properties are taken into account in the local approach, but the literature also provides examples of taking the global attributes of real properties into account[6], [7].

Assuming that the property is developed with one building, the functional condition has the following form:

$$C_{T_i} = S_{g_i} \cdot c_g + K_{O_i} \cdot u_{K_O} - K_{O_i} \cdot s_{ZC_i} \cdot u_{ZC} \quad \leftarrow \quad p_i \tag{1}$$

where:

- C_{T_i} - transaction price of the i-th sold property developed with low-energy building,
- S_{g_i} - land surface area of i-th property,
- c_g - unit price of land,
- K_{O_i} - replacement cost of the building (component of i-th property),
- s_{ZC_i} - degree of total depreciation of the building (component of i-th property),
- u_{K_O} - market index of the replacement cost of the building,
- u_{ZC} - market index of the degree of total depreciation of the building,
- p_i - weight of the similarity between the real property being valued and the sold i-th property.

The weights of the similarities can be described by the following formula [9]:

$$p_i = \frac{1}{0{,}25 + \sum\left(a_{j_i} - \bar{a}_j\right)^2} \tag{2}$$

where:

- a_{j_i} - j-th attribute of the i-th sold developed property,
- $\bar{a}_j$ - j-th attribute of the real estate being valued.

Equations can be written for several similar properties. Equation system can be expressed in the matrix form:

$$[C_T] = \left[[S_g] \ \mid \ [K_O] \ \mid \ [Z]\right] \times \begin{bmatrix} c_g \\ u_{K_O} \\ u_{ZC} \end{bmatrix} + [\delta_T] \quad \leftarrow \quad [P] \tag{3}$$

where:

$[C_T]$ - transaction price vector of developed properties,

$[S_g]$ - column vector created by land surface area of successive developed properties,

$[K_O]$ - column vector created by replacement cost of buildings,

$[Z]$ - vector created by products of reconstruction cost and degree of total depreciation of the building $(Z_i = -K_{O_i} \cdot s_{ZC_i})$,

$[P]$ - diagonal matrix of weights of the similarity between the real properties,

c_g - unit price of land,

u_{K_O} - market index of the replacement cost of the building,

u_{ZC} - market index of the degree of total depreciation of the building.

Estimation is required by: the unit price of land and the market indices.

The parametric model is applicable if the number of estimated parameters is smaller than the number of similar properties with known transaction prices. Modeling of real estate value authors presented in publications [5], [9]. Estimating parameters in multi-parameter Gauss-Markov model was presented in work [4].

The estimators of the unit price of land, of the market index of the replacement cost of the building, and of the market index of the total depreciation of the building in the matrix form, can be expressed by the following formula:

$$\begin{bmatrix} \hat{c}_g \\ \hat{u}_{K_O} \\ \hat{u}_{ZC} \end{bmatrix} = \left(\left[[S_g] \ \mid \ [K_O] \ \mid \ [Z]\right]^T \cdot [P] \cdot \left[[S_g] \ \mid \ [K_O] \ \mid \ [Z]\right]\right)^{-1} \cdot \left[[S_g] \ \mid \ [K_O] \ \mid \ [Z]\right]^T \cdot [P] \cdot [C_T] \tag{4}$$

The estimator of random deviations to the transaction prices is expressed by the relationship:

$$[\hat{\delta}_T] = [C_T] - \left[[S_g] \ \mid \ [K_O] \ \mid \ [Z]\right] \cdot \begin{bmatrix} \hat{c}_g \\ \hat{u}_{K_O} \\ \hat{u}_{ZC} \end{bmatrix} \tag{5}$$

Based on the random deviations of the model, the analysis of variance is performed. For the presented model, the residual variance takes the following form:

$$\hat{\sigma}_0^2 = \frac{[\hat{\delta}_T]^T \cdot [P] \cdot [\hat{\delta}_T]}{n-3} \tag{6}$$

where:

n - the number of similar properties with known transaction prices.

Using the general definition of the variance of the multivariate random variable, the analysis of variance of the estimated parameters can be performed:

$$Cov[\hat{c}_g, \hat{u}_{K_O}, \hat{u}_{ZC}] = \hat{\sigma}_0^2 \cdot \left(\left[[S_g] \ \mid \ [K_O] \ \mid \ [Z]\right]^T \cdot [P] \cdot \left[[S_g] \ \mid \ [K_O] \ \mid \ [Z]\right]\right)^{-1} \tag{7}$$

To estimate the market value of the developed real property on the basis of the presented algorithm, it is necessary to know the surface area of the land and to determine the replacement cost of the building, which is the component part of the land, and its total wear. These values are written in a single-row matrix:

$$\left[[S_g] \;\mid\; [K_O] \;\mid\; [Z]\right] = \left[\bar{S}_g \;\mid\; \bar{K}_O \;\mid\; -\bar{K}_O \cdot \bar{s}_{ZC}\right] \tag{8}$$

where:

$\bar{S}_g$ - land surface area of property being valued,
$\bar{K}_O$ - replacement cost of the building (component of property being valued),
$\bar{s}_{ZC}$ - total depreciation of the building (component of property being valued).

The market value of the real property developed with a low-energy building is expressed by the following formula:

$$W_N = \left[\bar{S}_g \;\mid\; \bar{K}_O \;\mid\; -\bar{K}_O \cdot \bar{s}_{ZC}\right] \cdot \begin{bmatrix} \hat{c}_g \\ \hat{u}_{K_O} \\ \hat{u}_{ZC} \end{bmatrix} \tag{9}$$

Basing on the algorithm, it is also possible to determine the variance of the estimated market value of the developed property:

$$V(W_N) = \sigma^2(W_N) = \left[\bar{S}_g \;\mid\; \bar{K}_O \;\mid\; -\bar{K}_O \cdot \bar{s}_{ZC}\right] \cdot Cov\left[\hat{c}_g\,, \hat{u}_{K_O}, \hat{u}_{ZC}\,\right] \cdot \begin{bmatrix} \bar{S}_g \\ \bar{K}_O \\ -\bar{K}_O \cdot \bar{s}_{ZC} \end{bmatrix} \tag{10}$$

CONCLUSION

Passive and energy-saving construction industry is developing. The buildings erected in the low-energy standard have become the category of modern construction. Due to the technological, material and engineering progress, valuation of real estate developed with low-energy buildings may become a problem in this specific industry. In particular, it concerns the determination of the market value in the comparative approach, where it is difficult to take into account the specificity of passive or energy-efficient buildings.

The presented valuation procedure was based on the assumptions of the cost approach. The algorithm, which is based on the market and non-market data, allows to specify the most probable market indices of the replacement value and the total depreciation of buildings, as well as the unit price of land. According to the International Valuation Standards, the replacement values of buildings are determined by the methodology typical for the cost approach - appraisers apply in practice two methods and three techniques [3]. The values of the parameters from estimation are specific to the market which the market data is derived from. Using weights of similarity for the real estate being valued results in these parameters being calculated for the level of the attributes of the real estate being valued. Valuation of developed real estate with different attribute values would require some adjustments due to the differences in the attributes of the real property being valued and the attributes of the property for which the parameters were estimated. The presented formulas for the analysis of variance allow to infer the degree of confidence relative to the obtained results.

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