The Value of a Building – Decision Analysis

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Abstract. The paper involves the procedure and the decision-making trees in determining reconstruction value of a building for prior decision analysis. In the work, there is used the normative model of decision-making, including uncertainty according to the Bayesian theory.

1. Introduction
In literature, there is a huge number of decision analysis studies. There are reviews on different types of decision analysis (cost-effectiveness, cost-benefit, cost-utility, etc.) and studies with mathematical models (decision tree, Markov modelling, Monte Carlo simulation, etc.).

The work was focused on the decision-making tree in valuation of the construction using elements of the cost approach used to estimate the replacement value of the property. A decision tree was considered, as understood in the theory of decision, as a tool for supporting decision-making processes, in which the choices are made between all possible events based on the probability of their occurrence, their consequences (phenomena that a decision may entail), profits and risks through a given event generated.

2. Replacement value of a building – the procedure
The procedure for evaluating the value of a building (WB), understood as the value of its replacement costs, taking into account the degree of wear and tear, is as follows:

1. to conduct an inventory of the object,
2. to examine any technical documentation,
3. to determine the object’s technology,
4. to specify the amount (i = 1, ..., m) of work units (Jj),
5. to specify unit prices (Cj) of construction works together with materials,
6. to determine the costs of preparing technical documentation and construction supervision, etc. (Wkd),
7. to calculate the replacement cost object in new condition (Wo), according to the formula:

$$Wo = \left[ \sum_{i=1}^{m} (J_i \cdot C_j) \right] \cdot (1 + W_{kd}) \cdot w_r$$

where $w_r$ – a correction factor to calculate the value of works in macro-regions
8. to determine the wear and tear of a building (SZ),
9. to determine the replacement value of the object \((W_b)\) while taking into account the degree of wear, according to the formula:

\[
W_B = W_o \cdot (1 - S_\varepsilon)
\]  

(2)

3. Wear and tear of a building structure

The building can be wearied to varying degrees in different ways. There are 3 types of wear and tear of the objects: technical, functional and environmental.

The functional wear is the result from the comparisons of the design application solutions used in the given case to the currently preferred ones (modernity assessment), as well as the comparisons in the scope of finishing standard and equipment with technical devices. For example, Kowalczyk, Grotkiewicz [1] propose to estimate the functional wear according to the formula:

\[
S_{zf} = [1 - \sum_{j=1}^{k} \left( \frac{o_j}{p_j} \cdot W_j \right)] \cdot 100\% 
\]  

(3)

where:

- \(S_{zf}\) – functional wear, (%)
- \(k\) – number of parameters/criteria of assessment,
- \(j\) – \(j\)-th parameter/criterion of assessment,
- \(o_j\) – obtained number of points of assessment for the \(j\)-th parameter (\(o_j\) = from 0 to 3),
- \(p_j\) – maximum number of points of assessment for the \(j\)-th parameter.

The authors define the functional wear as permanent, undesired changes of functional and utility solutions of buildings, referred to the currently applicable standards resulting from technical and technological progress.

The environmental wear is the result from, for example:

- changes in the property environment that cause a nuisance in the use of real estate, such as: construction in the vicinity of the estimated property of an industrial plant, roads with heavy traffic, tram line, unregulated watercourse, etc.
- mining operations carried out or envisaged in a given area, causing permanent damage to the property,
- the harmful impact of the environmentally damaged environment on the durability of buildings and the quality of the land.

Bryt-Nitarska [2] analyses the degree of technical wear in mining areas. The author proposes to add to the classical technical wear influence of mining damage understood as a function, which can be determined on the basis of tests and registration of mechanical scratches that arose as a result of exceeding limit tensile strength of the construction material and finishing elements in buildings exposed to the impact of mining ground deformations. The author claims that mining impacts change the working conditions of the entire structural system in a relatively short time. There is then a significant increase in the internal forces and stresses, which is an explanation why in buildings subject to the influence of substrate deformation, revealed as a result of mining exploitation, the technical condition of the structure determines the decrease in the strength and functional properties of structural elements as well as mining damage.

The technical wear of a building is a natural aging process, like human. During being used, building structures subject to aging processes of varied mileage which depend on many factors, including:

- type of the building structure,
- age of the building object,
- type of building materials used,
- quality of the materials used,
• possible design mistakes,
• possible construction errors,
• quality of construction work,
• how the object is used,
• how to carry out current renovations,
• operating conditions,
• environmental conditions,
• random cases

During an inspection of individual building’s elements, special attention should be paid to the occurrence of damage, defects, losses, scratches and corrosion. The following conditions must be taken into account:
- assumed technical durability (life) of the element;
- information on executed repairs and maintenances components;
- the period of the existing operating element.

There are many methods of assessing the technical condition: starting from the simplest time methods based on two basic parameters – the age of the building and its durability (Ross methods – Eq. [5-8]), through visual methods [3], ultimate limit state methods [4], reaching more complex methods that take into account random factors [5], or properties of neural networks [6, 7].

In the real estate valuation, the most common method being used is the average weighted technical wear method calculated according to the formula:

\[ S_{zt} = \sum_{i=1}^{m} \left( \frac{U_i \times S_{zi}}{100} \right) \times 100\% \] (4)

where:
\( S_{zt} \) – average weighted degree of technical wear of the building structure, (%)
\( U_i \) – percentage share of the \( i \)-th element in the construction costs of the entire building in the new condition,
\( S_{zi} \) – degree of wear and tear of the \( i \)-th element expressed as a percentage.

Table 1 shows an example of how to determine the technical wear of a building. The object is an uncomplicated new building - a garage for a passenger car.

| No \( i \) | element of the building | \( i \)-th element share \( U_i \) [%] | degree of wear and tear of the \( i \)-th element \( S_{zi} \) [%] | degree of wear and tear [%] |
|----------|------------------------|-------------------------------|-------------------------------|-----------------|
| 1        | earthworks             | 4.64                          | 0                             | 0.00            |
| 2        | foundations            | 26.61                         | 0                             | 0.00            |
| 3        | construction walls     | 13.57                         | 0                             | 0.00            |
| 4        | roof truss             | 12.09                         | 0                             | 0.00            |
| 5        | roofing                | 10.87                         | 10                            | 1.09            |
| 6        | internal plasters      | 1.65                          | 5                             | 0.08            |
| 7        | external plasters      | 8.46                          | 5                             | 0.42            |
| 8        | painting               | 0.82                          | 15                            | 0.12            |
| 9        | windows and doors      | 12.75                         | 0                             | 0.00            |
| 10       | roof works             | 4.24                          | 0                             | 0.00            |
| 11       | electrical installations| 4.3                           | 0                             | 0.00            |
| TOTAL:   |                        | 100                           |                               | 1.72            |
Many valuers estimate the degree of technical wear from the well-known "Ross formulas", presented in the literature under various names.

Taking the signs:
- \( S_z \) - the degree of technical wear of a building,
- \( t \) - service life of the building,
- \( T \) - expected lifetime of the building (durability of the building).

1. **linear method ("classical Ross formula"),** used to estimate the technical wear of buildings with a renovation management below the average:

\[
S_z = \frac{t}{T} \cdot 100\%
\]

2. **non-linear method ("Unger formula"),** used to estimate the technical wear of buildings with an average renovation management

\[
S_z = \frac{t(t+T)}{2T^2} \cdot 100\%
\]

3. **non-linear method ("Romsterfen formula"),** used to estimate the technical wear of buildings with above-average repair economy:

\[
S_z = \frac{t(2t+T)}{3T^2} \cdot 100\%
\]

4. **parabolic method ("Eytelwein formula"),** used to estimate the technical wear of buildings with a very good renovation economy:

\[
S_z = \frac{t^2}{T^2} \cdot 100\%
\]

### 4. Replacement value of a building – decision tree

The replacement value of the object \((W_o)\) is a function (see Eq. 2-3):

\[
W_B = [(\sum_{i=1}^{m}(I_i \cdot C_{ij})) \cdot (1 + W_{kd}) \cdot W_r] \cdot (1 - S_z)
\]

A decision-making tree was considered as the sum of 3 steps:
- the first step (see figure 1): \(\sum_{i=1}^{m}(I_i \cdot C_{ij})\)
- the second step (see figure 2): \(W_{kd}\)
- the third step (see figure 3): \(1 - S_z\)

By analysing those decision-making trees (Fig.1-3), the best choice of experience, and then the best selection of actions can be determined. According to the Bayesian decision theory, where the relationship between the probability of the hypothesis before getting the evidence \(P(H)\) and the probability of the hypothesis after getting the evidence \(P(H|E)\) is:

\[
P(H|E) = \frac{P(E|H) \cdot P(H)}{P(E)}
\]

where
- \(H\) – a hypothesis
- \(E\) – evidence

If the preferences of choice, that is the value of the results, are the responsibility expressed, then the expected value is the logical basis of the choice of choice among alternative actions, as it has been proved by Benjamin & Cornell [8].
Figure 1. Decision/event tree for step 1 $\sum_{i=1}^{m} (J_i \cdot C_{ji})$, where n>2.

Figure 2. Decision/event tree for step 2 $W_{kd}$
5. Conclusions
Knowledge of the basics of civil engineering is extremely important in determining the replacement value of the real estate where the property appraiser estimates the value of the costs incurred for the purchase of the plot and the construction of a similar building taking into account its technical wear. According to the TEGOVA European Valuation Standards [9]: “It is imperative that the valuer, in addition to his qualifications as a valuer under the EVS, is conversant with the methods employed in this type of work and that he is in possession of the necessary expertise (knowledge and understanding) and have the experience needed to carry out such assignments. Minimum recommended qualifications are listed in the following, and the valuer is expected to possess a sound knowledge of the topics including:

- building costs and building constructions;
- local and national building regulations;
- local planning constraints;
- insurance contracts;
- insurance coverage and limitations;
- estimates of expected time for repairs;
- market values;
- rental rates.

The decision theory indeed includes the features of usual risk assessment in terms of the prior and the posterior decision analysis but, moreover, opens up new possibilities as compared to usual risk assessment by means of the pre-posterior decision analysis. [10]

It is also worth developing new methods of object evaluation using elements of the reliability theory of the structure [11] as:
- simple reliability index,
- probability of failure,
- First/Second Order Reliability Method (FORM/SORM),
- Monte Carlo Method,

Figure 3. Decision/event tree for step 3 \([1 - S_x]\)
- First crossing problem – Rice’s rule,
- Bayesian sets,
as well as models for assessing the degradation of objects' value during their operation.

References
[1] Z. Kowalczyk, K. Grotkiewicz “Wear of Farm Buildings in Selected Farms” *Agricultural Engineering*, Vo l. 2 0, No.2, p p.109 -116, 2019
[2] I. Bit-Nitarska, “Reasons for enhanced technical wear and tear of buildings on areas affected by underground mining operations” *Zeszyty Naukowe Instytutu Gospodarki Surowcami Mineralnymi i Energii PAN*, No 101, pp. 61-70, 2017 (in polish)
[3] M. Podwórm, W. Mironowicz, „Practical aspects of evaluating the degradation of buildings for the purposes of real property valuation”, *Rzeczoznawca Majątkowy*, 93 pp. 8-13, 2017 (in polish)
[4] S. Duży, G. Dyduch, “The influence of environmental factors on the underground buildings support construction technical wear”, *Górnictwo i Geologia* 5.2., pp.37-46, 2010 (in polish)
[5] A. Wodyński „Technical wear of buildings in mining areas” *Uczelniane Wydaw. Nauk. -Dydakt. AGH, Kraków*, 2007. (in polish)
[6] Z. Waszczyszyn „Neural Networks in the Analysis and Design of Structures”, *CISM Courses and Lectures No. 404*, Springer, Wien - New York, 1999
[7] P. Knyziak „Estimating the technical deterioration of large-panel residential buildings using artificial neural networks” *Procedia Engineering* 91, pp. 394 – 399, 2014
[8] J. Benjamin, A. Cornell., “Probability, Statistic and Decision for Civil Engineer, *McGraw-Hill Books*, 1970
[9] TEGOVA European Valuation Standards, EVS 2016
[10] M.H. Faber, Risk assessment and decision making in civil engineering, *AMAS Course on Reliability – Based Optimization*, pp.35-56, 2002
[11] R. E. Melchers, Structural Reliability Analysis and Prediction, *John Wiley&Sons*, 1999