Profitability Analysis and Assessment of the Possibility of Applying Renovation and Modernization Measures to Improve the Utility Value of Public Buildings

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Abstract. Utility building value depends, among other things, on the renovation and modernization activities undertaken at the maintenance stage. They result from a correct assessment of the building condition. Lack of appropriate methods, which in a comprehensive way, taking into account the utility requirements for these buildings, would allow to assess the condition of buildings is one of the main reasons for negligence in the proper maintenance of public buildings. With this in mind, the author carried out a study aimed at an in-depth analysis and assessment of the possibility of applying renovation and modernization measures in relation to the improvement of the utility value of the building and the cost of their implementation. As part of the research, a mathematical model was first developed, which was used to carry out the research. As part of the development of the model, a set of criteria relating to technical-utility, economic and environmental requirements was selected and a method for their evaluation was developed. Next, proposals of renovation and modernization activities were presented, the aim of which is to improve the utility value ratio of the building. For its evaluation the method based on the theory of fuzzy sets was used, which at the stage of inference uses expert knowledge included in the fuzzy rules database. The calculated utility value of the proposed renovation and modernization activities is the basis for further research analyses. Optimization tasks consisting in the selection of an appropriate repair variant are carried out by means of appropriate optimization methods. The adopted optimization objectives concerned both the possibility of improving the assumed increase in utility value and limitations in their financing. The assessment of utility value of public utility buildings, which has not been carried out yet, taking into account the current legal and utility requirements, will allow to determine the impact of renovation and modernization decisions taken on this basis on the adopted determinants determining the quality of the maintenance process, i.e. the increase in utility value and maintenance cost. The results of these studies may be important in expanding existing knowledge and the knowledge gained may contribute to changes in the way decisions are made and the improvement of the quality of building maintenance.

1. Introduction

The process of building maintenance starts from the moment it is put into service. From this moment, the key to maintaining its utility value is the skillful performance of both maintenance and, above all, renovation and modernization activities in it. Appearing defects arising from improper design,
workmanship, occurring as a result of wear and tear - use, aging of materials and functional, require the implementation of rational and justified actions [1]. Maintaining a building in a good condition during its initial period of use only requires regular maintenance works, i.e. minor repairs, painting and cleaning. However, even in a regularly maintained building, since the building has been designed, it is gradually losing its usability value due to a lack of fulfilling modern usability requirements [2]. Refurbishment and modernisation of buildings must not completely stop these changes, but may delay them, which will significantly extend their service life.

Changes in the design and applied technologies in the construction industry were reflected in the utility requirements for both residential and public buildings. These changes concern broadly understood issues related to safety, comfort and cost of use, as well as environmental impact. It has therefore become necessary to take account of these changes in buildings that no longer meet them today [3, 4]. In the case of energy-saving requirement, improvement in terms of economy, but also in terms of thermal and acoustic utility comfort is often implemented in the form of thermal modernisation measures [5]. However, the differences in the new approach to building design are clearly visible in the area of accessibility for the elderly and disabled. Modernisation measures that must be carried out must provide the necessary conditions for the efficient and safe use of public buildings without unnecessary architectural barriers for people with all levels of disability, in particular people in wheelchairs. A major problem for most public buildings is meeting the requirements of environmental protection. There is a need for major changes focused primarily on the modernization and replacement of devices that have been using non-renewable energy sources so far [5, 6].

The maintenance of public buildings in case when their adaptation to modern functional requirements is not present cannot and should not be limited only to the preservation of the existing building substance in a good technical condition [2]. Many researchers, in order to change the way the building is assessed so far, stress the need to take into account a wider range of requirements during assessment [3, 7, 8, 9]. This forms the basis for not only standard maintenance, which in addition to the need for renovation also includes the need to modernize and rebuild the building. The inability to ensure the proper level of building maintenance also has other reasons, which can be found in the lack of appropriate tools supporting the manager at the decision making stage. Scientific publications present many interesting solutions based, among others, on expert systems, methods of artificial intelligence [2, 7, 10] as well as methods described in literature as MADM (Multiple Criteria Decision Making) [8, 11]. They have not found a practical application yet, leaving the manager alone to solve problems related to the selection of appropriate material and technological solutions, selection of the most advantageous scope of building renovation, optimisation in the allocation of financial resources [7, 12, 13, 14, 15].

Knowledge and analysis of methods and models proposed in the literature on maintenance management of buildings was the basis for the development of a decision-making model for the selection of the most advantageous variant of renovation, which the author used in the analysis of cost-effectiveness and the possibility of using repairs in a public utility building.

2. Description of the proposed model
For the studies aimed at analysing cost-effectiveness and evaluating the possibility of using renovation and modernization measures, a model was developed, the operation of which is shown in Figure 1. The operation of the model is based on several calculation stages. The first stage consists in the assessment of the condition of the building according to the adopted criteria. The next stage is the assessment of the utility value of the building, whose inference mechanism is based on expert knowledge. This assessment determines a synthetic indicator of the utility value of the building. The third stage is a proposal of building repairs together with an assessment of their impact on the increase in the value of individual elements. The last stage of the model is the selection of the most advantageous repair variant, consisting of the proposed repairs, carried out according to two different
optimisation variants. In the first variant, the repair variant is searched for, which will meet the adopted assumptions concerning the increase in the value of element assessments at the lowest cost of performance. In the second case, the renovation variant is sought, which for the assumed amount allocated for renovation will allow to obtain the maximum increase in the value of assessments of building elements.

![Figure 1. Model supporting renovation and modernization decisions](image)

2.1. **Assessment of building elements**
The assessment of individual building elements $O_i$ is carried out according to formula 1, according to which the value of assessments $i^{th}$ elements for $j^{th}$ criteria is summed up. A five-point rating scale is used to assess the elements, with 1 being the worst rating and 5 being the best one.

$$O_i = \frac{\sum_{j=1}^{m} o_{ij}}{m} \quad \forall i = 1, 2, ..., n$$

where:
- $o_{ij}$ – assessment of $i^{th}$ element for $j^{th}$ criterion,
- $n$ – number of assessed building elements,
- $m$ – number of assessed criteria.

2.2. **Assessment of building utility value**
The assessment of the utility value of a WUB building is carried out using a fuzzy application system based on the Takagi-Sugeno model (Takagi & Sugeno, 1985) [16]. The values of input variables are 14 $j^{th}$ building elements, while the output variable is the utility value of the building. Each of the
assessed elements is represented by a linguistic variable $x_i$ described by triangular affiliation functions expressed by sets blurred $A^i_j$ in a certain space $X_i$.

$$A^i_j = \left\{ \left( x_i, \mu_{A^i_j}(x_i) \right) : x_i \in X_i, \mu_{A^i_j}(x) \in [0,1] \right\}, \quad (2)$$

where:

$\mu_{A^i_j}(x_i)$ – the degree of affiliation to a fuzzy set $A^i_j$,

$j$ – the number of fuzzy sets for each of these $i^{th}$ building elements.

The assessment of the utility value of a building is carried out in three main stages, i.e. fuzzing, inference and sharpening. In the first stage, the assessments value of $i^{th}$ elements is defined to correspond to them degrees of affiliation $\mu_{A^i_j}(x_i)$ to the fuzzy sets $A^i_j$ of input variable. In the second stage, inference is carried out, which is the basic part of the model that processes the input data (assessments) $o_i$ into appropriate output values $y$.

Conclusion is based on a database of fuzzy rules, which is based on expert knowledge. In order to obtain it the author's method of collecting information from experts was applied. The experts determine the values of $i^{th}$ building elements for each of the five indicators of usable value of the building, i.e.: very high (5), high (4), medium (3), low (2), very low (1), was applied. The knowledge gained is the basis for the development of an inference fuzzy application system rules base using the neuron-fuzzy ANFIS system. The learning process of the ANFIS system requires the determination of the number of fuzzy sets as well as the determination of characteristics and the shape of the affiliation functions that describe them. The initial value (conclusion of the rule) in the adopted Takagi-Sugeno model is written in the form of a functional relation $f(x_1,x_2,x_3) = \sum c_i f_i(x_1)$ between inputs and outputs, while in the premise part the rule is fuzzy:

$$\text{if } x_1 = A_1 \text{ and } x_2 = A_2 \text{ and } ... \text{ and } x_n = A_n \text{ then } f(x_1,x_2,...,x_n). \quad (3)$$

The calculation of the utility value of a building is the result of the activation of the conclusions of individual system rules. In the process of sharpening (defusification), for the Takagi-Sugeno model the "weighted sum" method is applied.

2.3. Assessment of proposed repairs to the building

The set of repairs proposed for the building was determined on the basis of the value assessment of $i^{th}$ building elements. Each of the proposed repairs ensures an increase in the element value in relation to one or more criteria. Some of the repairs can be treated as alternative solutions, which means that they cannot be used together. An estimation of the increment of each of $r^{th}$ repairs in relation to $i^{th}$ element of $j^{th}$ criterion shall be carried out according to formula (4).

$$\Delta o_{ijr} \leq (o_{y_{max}} - o_{y}) \quad \forall i = 1,2,\ldots,n \quad \forall r = 1,2,\ldots,s, \quad (4)$$

where: $o_{y_{max}}$ – maximum assessment value of $i^{th}$ element for $j^{th}$ criterion.

2.4. Optimization in the selection of repairs

The selection of the analyzed repairs for the building is carried out according to certain assumptions, which determine the desired increase in the utility value of the building, or limit this choice by making budget assumptions. Each case requires a different approach - a mathematical model. In the first case,
we are looking for the most advantageous renovation variant within the available/specified budget for renovation. In the second case, we are looking for the cheapest renovation variant to obtain the assumed values of the criteria.

Case 1: Proposed repairs to a building cannot be entirely included in the renovation plan as their cost exceeds the financial means available to the building manager for renovation purposes. In this situation, the most advantageous renovation variant is sought as a set of repairs \( N = \{n_1, n_2, ..., n_t\} \). In this case, the assessment of the solution \( S \) is carried out on the basis of equation (7). The search for the best solution is determined by the objective function (5). The solution is a renovation option, the cost of which cannot exceed the financial resources available within the budget \( B \), as described in the equation (6). The mathematical model of this approach is written as follows:

\[
\max z : z = S, \quad (5)
\]

\[
C \leq B, \quad (6)
\]

\[
S = \sum_{i=1}^{n} O_i + \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{h=1}^{u} \sum_{r=1}^{l} \Delta o_{ijr} \cdot x_{ih}, \quad (7)
\]

Case 2: The optimisation task is to search for the cheapest variant of the renovation, which will allow to improve the value of criteria assessments up to a set level \( z_i \). the assessment of the increase in value of criterion \( p_j \) resulting from accepted repairs is carried out on the basis of equation (6). The search for the best solution is determined by the objective function (4). The renovation solution is a set of repair variants \( N \) whose cost is the lowest \( C \) (5). The mathematical model of the described approach is written down as follows:

\[
\min z : z = C, \quad (8)
\]

\[
C = \sum_{h=1}^{u} \sum_{r=1}^{l} c_r \cdot x_h, \quad (9)
\]

\[
p_i \geq u_i, \quad \forall j = 1, 2, ..., m, \quad (10)
\]

\[
p_i = O_i + \sum_{h=1}^{u} \sum_{r=1}^{l} \Delta o_{ijr} \cdot x_{ih}, \quad i = 1, 2, ..., n, \quad (11)
\]

\[
u_i = z_i - o_i, \quad (12)
\]

\[
\sum_{h=1}^{u} x_{ih} = 1 \quad x_{ih} \in \{0,1\} \quad h = 1, 2, ..., u, \quad (13)
\]

\[
x_{ih} = \begin{cases} 1, & \text{if renovation in } j \text{ th variant of } i \text{ th element}, \\ 0, & \text{otherwise,} \end{cases} \quad (14)
\]

where:

\( C \) – cost of renovation variant,
\( c_r \) – cost of \( r^{th} \) repair,
\( x_h \) – binary variable,
\( p_j \) – value increase for \( i^{th} \) element after repair,
\( z_i \) – assumed value for \( i^{th} \) element,
\( o_i \) – value assessment of \( i^{th} \) element before repair,
\( u_i \) – searched value of value increase for \( i^{th} \) element.
3. Calculation example
The analysis was based on a public utility building constructed in traditional technology. A set of seven criteria, which are baseline requirements [17], were used for its assessment.

- $k_1$ – construction safety,
- $k_2$ – energy saving and thermal insulation,
- $k_3$ – protection against noise,
- $k_4$ – adequate hygienic, health and environmental conditions,
- $k_5$ – fire safety,
- $k_6$ – utility safety and facilities availability,
- $k_7$ – sustainable use of natural resources.

Each of these elements is assessed according to $j^{th}$ criteria. Then, a final assessment of each building element was carried out based on equation (1). The results of the calculations are summarised in table 1.

| $i$ | Nazwa elementu | Assessment $o_{ij}$ | $O_i$ [pts] |
|----|---------------|---------------------|-----------|
| 1  | Walls         | 3 1 1 2 4 N N 2.2  |
| 2  | Slab          | 5 2 1 N 4 N N 3    |
| 3  | Roof          | 3 2 1 2 3 N 1 2.2  |
| 4  | Joinery       | N 1 1 1 1 1 N 1    |
| 5  | Staircases    | N N N 2 2 1 N 1.67 |
| 6  | Entrances to a building | N N N 1 N 1 N 1 |
| 7  | Elevators     | N 1 N 1 N 1 N 1    |
| 8  | Corridors     | N N N 2 2 1 N 1.67 |
| 9  | Offices       | N N N 2 2 1 N 1.67 |
| 10 | Hygenic and sanitary rooms | N N N 1 4 1 N 2 |
| 11 | Ventilation installation | N 1 N 2 N N 1 1.33 |
| 12 | Electrotechnical instalation | N 1 N N 1 N 1 |
| 13 | Water and sewage system | N 1 N N N N 1 |
| 14 | Central heating installation | N 1 N N N N 1 |

Assessment of WUB building utility value [pts] 1.11

N – not assessed, L– Lack of impact

On the basis of an assessment of the value of the elements $o_{ij}$ in terms of $j^{th}$ criteria, 24 repairs were proposed. Each of them allows to obtain an increase in value for one or more criteria. For four elements of the building, i.e.: external walls, roof, window joinery, entrance to the building, ventilation two alternative solutions to choose from were proposed. Each repair was assessed and its value increase for the element for each of $j^{th}$ criteria was determined in accordance with dependencies (1) and (3). The results of the calculations are summarized in table 2.
Table 2. Proposed repairs in the building with increase values for \( i^{th} \) elements

| Repair number \( r \) | Repairs                                         | Nr elementu \( i \) | Assessment increase in value \( \Delta p_{ijr} \) [pts] | Assessment increase in value \( \Delta q_i \) [pts] | Repair cost \( c_r \) [zł] |
|----------------------|-------------------------------------------------|----------------------|--------------------------------------------------------|-------------------------------------------------|------------------------|
| 1                    | Insulation of external walls                    | 1                    | 1 3 4 2 1 N N                                        | 2,2                                              | 235                    |
| 2                    | Insulation of external walls                    | 1                    | 1 3 4 2 -1 N N                                      | 1,8                                              | 187                    |
| 3                    | Thermal and moisture insulation of basement walls| 1                    | 1 1 L 1 L N N                                      | 0,6                                              | 38                     |
| 4                    | Insulation of the basement ceiling              | 2                    | L 3 L N 1 N N                                      | 3                                                | 30                     |
| 5                    | Replacement of roof                             | 3                    | 2 L L 1 L N N                                      | 0,6                                              | 34                     |
| 6                    | Replacement of roof and insulation of the floor of the last storey | 3 | 2 3 4 3 2 N N | 2,8 | 102 |
| 7                    | Replacement of interior stair cladding          | 5                    | N N N 3 L 2 N                                        | 1,67                                             | 23                     |
| 8                    | Replacement of window joinery                   | 4                    | N 3 3 3 L 3 N                                        | 2,4                                              | 151                    |
| 9                    | Replacement of window joinery                   | 4                    | N 3 3 3 3 3 3 N                                     | 3                                                | 195                    |
| 10                   | Replacement of floors                           | 2                    | L L 4 N L N N                                       | 1                                                | 286                    |
|                      |                                                  | 8                    | N N N 3 L 4 N                                        | 1                                                |                        |
|                      |                                                  | 9                    | N N N 3 L 4 N                                        | 1                                                |                        |
|                      |                                                  | 10                   | N N N 4 L L N                                        | 1,33                                             |                        |
| 11                   | Replacement of staircase balustrades and handrails | 5  | N N N L B 2 N                                     | 0,67                                             | 11                     |
| 12                   | Construction of driveway and reconstruction of entrance stairs | 6  | N N N 4 N 3 N                                     | 3,5                                              | 32                     |
| 13                   | Reconstruction of entrance stairs               | 6                    | N N N 4 N 1 N                                        | 2,5                                              | 15                     |
| 14                   | Replacement of entrance door                    | 4                    | N 1 1 1 1 N 1                                       | 1                                                | 10                     |
| 15                   | Installation of markings and protection for the blind | 6   | N N N L N 1 N                                      | 0,5                                              |                        |
|                      |                                                  | 8                    | N N N L L 4 N                                        | 1,33                                             | 23                     |
|                      |                                                  | 9                    | L N N L L 4 N                                        | 1,33                                             |                        |
|                      |                                                  | 10                   | N N N L L 1 N                                        | 0,33                                             |                        |
| 16                   | Installation of bathroom equipment for the disabled | 10 | N N N L L 3 N 1                                    | 3                                                | 29                     |
| 17                   | Replacement of elevator                        | 7                    | N 4 N 4 N 4 N                                        | 4                                                | 95                     |
| 18                   | Installation of fire alarm and warning systems  | 5                    | N N N L 3 L N                                        | 1                                                | 13                     |
|                      |                                                  | 8                    | N N N L 3 L N                                        | 1                                                |                        |
|                      |                                                  | 9                    | N N N L 3 L N                                        | 1                                                |                        |
|                      |                                                  | 10                   | N N N L 1 L N                                        | 0,33                                             |                        |
| 19                   | Installation of mechanical ventilation          | 11                   | N 4 N 3 N N 4                                        | 3,67                                             | 75                     |
| 20                   | Installation of window diffusers                | 11                   | N L N 1 N N L                                        | 0,33                                             | 5                      |
| 21                   | Installation of photovoltaic system             | 12                   | N 2 N N N N                                        | 3                                                | 78                     |
| 22                   | Installation of LED lighting                    | 12                   | N 2 N N N N                                        | 1                                                | 14                     |
| 23                   | Installation of solar system                    | 13                   | N 4 N N N N                                        | 4                                                | 55                     |
| 24                   | Installation of heat pump                       | 14                   | N 4 N N N N                                        | 4                                                | 65                     |

The aim of further calculations was to find the most advantageous scope of building renovation in order to obtain the assumed assessment values of \( z_i \) building elements. First of all, calculations were carried out with the adopted optimization criterion, which is minimizing the cost of renovation in order to obtain the assumed values of building element assessments. Three different renovation and modernization scenarios were developed for the calculations. In the first of them, the need to carry out a renovation aimed at obtaining a good assessment of the condition of the building was assumed. Therefore, an assumption was made, referring to all the elements, which states that the value of each of the elements must be at least good \( z_i \gtrsim 4 \). The results of the calculations are summarized in Table 3.
Table 3. Selected repairs and the cost of their execution for the assumed values of building elements.

| Number of element $i$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|-----------------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|
| Assumed value $z_i$ [pts] | 4 |   |   |   |   |   |   |   |   |    |    |    |    |    |
| Obtained value $p_i$ [pts] | 4 | 3 | 5 | 3 | 4 | 3 | 3 | 4 | 5 | 4 | 4 | 3 | 6 | 7 |
| Repair number $r$ [pts] | 2 | 6 | 8 | 11 | 15 | 17 | 15 | 18 | 18 | 19 | 21 | 23 | 24 |   |
| Renovation cost $C$ [PLN] |   |   |   |   |   |   |   |   |   |    |    |    |    | 1 016 000 |
| WUB [pts] |   |   |   |   |   |   |   |   |   |    |    |    |    | 3.71 |

The second scenario assumed the need to modernize the building in terms of improving the safety of use and adaptation for the disabled. Therefore, for building elements $i = 4,5,6,...,10$, i.e. those which have an impact on the improvement of the value of this requirement, the assumption $z_i \geq 4.5$ pts was made. For the remaining elements, with the omission of the elements related to the criterion $k_7$, the assumption of repairs to the average condition, i.e. $z_i \geq 3$ pts, has been made. The results of the calculations are presented in Table 4.

Table 4. Selected repairs and the cost of their execution for the assumed values of building elements.

| Number of element $i$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|-----------------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|
| Assumed value $z_i$ [pts] | 4.5 | 4.5 | 4.5 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
| Obtained value $p_i$ [pts] | 4.6 | 5 | 5 | 5 | 3 | 34 | 5 | 5 | 3 | 67 | 3 | 67 | 3 | 67 |
| Repair number $r$ [pts] | 1 | 10 | 10 | 16 | 14 | 11 | 15 | 15 | 18 | 18 | 15 | 16 | 18 |   |
| Renovation cost $C$ [PLN] |   | 1 123 000 |   |   |   |   |   |   |   |    |    |    |    |    |
| WUB [pts] |   | 3.367 |   |   |   |   |   |   |   |    |    |    |    |    |

The last third scenario assumed the need to modernize the building in the following areas: improving energy savings and thermal insulation, noise protection and sustainable use of natural resources. Therefore, for the elements on which the improvement of these requirements is dependent, i.e. $i = 1,2,3,4,7,11,12,13,14$ the assumption of $z_i \geq 4.5$ pts was made. For the remaining elements, the assumption was made that they should be repaired at least to the average condition, i.e. $z_i \geq 3$ pts. The results of the calculations are presented in Table 5.

Table 5. Selected repairs and the cost of their execution for the assumed values of building elements.

| Number of element $i$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|-----------------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|
| Assumed value $z_i$ [pts] | 4.5 | 4.5 | 4.5 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
| Obtained value $p_i$ [pts] | 4.6 | 5 | 5 | 5 | 3 | 34 | 5 | 5 | 3 | 67 | 3 | 67 | 3 | 67 |
| Repair number $r$ [pts] | 2 | 3 | 4 | 10 | 9 | 14 | 11 | 18 | 13 | 17 | 10 | 18 | 10 | 18 |
| Renovation cost $C$ [PLN] |   | 1 386 000 |   |   |   |   |   |   |   |    |    |    |    |    |
| WUB [pts] |   | 4.36 |   |   |   |   |   |   |   |    |    |    |    |    |
Next, calculations were carried out according to the optimization criterion, i.e. maximization of the increase in the value of element assessments with the assumed financial constraint. Calculations were carried out for one renovation-modernization scenario, which aims to improve the assessment of the building in terms of the following requirements: construction safety, energy saving and thermal insulation, noise protection, sustainable use of natural resources. The improvement of the assessment values of the above requirements involves the application of repairs in the following elements \( i = 1, 2, 3, 4, 11, 12, 13, 14 \).

**Table 6.** Repairs and the cost of their execution for the assumed values of building elements.

| Number of element \( i \) | 1 | 2 | 3 | 4 | 11 | 12 | 13 | 14 |
|----------------------------|---|---|---|---|----|----|----|----|
| Budget \( B \) [PLN]       | 600 000 |
| Element assessment \( p_i \) [pts] | 4.6 | 4 | 2.8 | 2 | 5 | 5 | 5 | 5 |
| Repair number \( r \) [pts] | 2, 3 | 4 | 5 | 14 | 19 | 21, 22 | 23 | 24 |
| Renovation cost \( C \) [PLN] | 586 000 |
| WUB [pts]                   | 2,974 |

The results presented in tables 3, 4 and 5 were obtained thanks to the application of optimization measures, the aim of which was to find the cheapest variants of the renovation meeting the assumptions of the element assessment values (defined in three renovations and modernization scenarios). In the first case, for the adopted assumption that assessment of at least good for all elements, a renovation variant consisting of 13 repairs was selected, for which an increase in the building utility value to 2.6 points at the cost of execution of 1 016 000 pln was obtained. The values of assessments obtained in this case significantly exceed the assumed minimum. This is due to a very limited set of proposed repairs, which does not ensure a good fit. For the second variant of renovation and modernization, the main objective of which was to improve the safety of use and accessibility for the disabled, the optimal renovation variant included 12 repairs, for which an increase in the utility value of the building of 2.26 points was obtained at a cost of 1 123 000 pln. The implementation of the objective of the third variant of renovation and modernization aimed at improvement of thermal and acoustic insulation and sustainable use of natural resources requires 16 repairs, the total cost of which amounts to 1 386 000 with an increase in utility value of 3.49 points. The implementation of the last fourth renovation and modernization scenario assuming the maximum increase in the assessment of elements for the assumed budget of 600,000 to improve structural safety, thermal and acoustic insulation and sustainable use of natural resources made it possible to identify a renovation variant consisting of 10 repairs at the total cost of 586,000.

4. Conclusion

An analysis of the cost-effectiveness and possibility of carrying out renovation and modernization activities in a public building allows to improve the maintenance process of the building. However, it is a rather complex and toilsome calculation problem. The first major issue to be solved was to determine the way the building was to be assessed. Therefore, seven baseline requirements for newly designed buildings have been adopted for the assessment of the established building element and a simple scoring system has been developed. The next step was to develop a model to support the selection of the most advantageous renovation variant. This required the use of appropriate calculation tools to solve the tasks at each stage of the renovation. The presented model is a multistage approach, in which the utility value of the building is assessed in one of the stages by means of a fuzzy application system. Its operation is based on fuzzy rules, for the generation of which the neuron-fuzzy ANFIS system was used. The selection of the most beneficial repairs and modernization is carried out as a result of optimization actions for which linear programming with the use of BINTPROG Matlab solver was applied. Other tools and methods for solving particular tasks in the model were also used.
The results of the optimization activities presented in the paper allowed to identify the most advantageous solutions from the point of view of the adopted objectives, assumptions and limitations. The analysis of various repair scenarios with the adopted optimization assumptions makes it possible to assess the legitimacy and purposefulness of their application.

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