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Characteristic of **Adaptability** - one of basic categories of the social aspect of sustainable housing construction

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**Abstract.** In the article the authors consider one of the basic aspects of sustainable construction regarding the social utility of a building. According to standard PN-EN 16309+A1:2014-12 during evaluating the social aspect should be assessed six categories: accessibility, adaptability, comfort and health, neighborhood, maintenance, safety and security. The authors present the evaluation criteria witch should be taken into account in the assessment of the second of them. Adaptability has been divided into three categories: The building’s ability to accomodate the change of user requirements, The building’s ability to accomodate technical changes, The building’s ability to accomodate the change of use. Each subcategory has been further elaborated by the criteria for which authors present proposal for the scale of assessments. The authors present a part of a work to construct a method for assessing the social characteristics of the residential buildings.

1. **Introduction**

Technical Committee CEN/TC 350 *Sustainability of construction Works* has developed a series of standards for sustainable development related to environmental, social and economic aspects [1]. Within the area of social characteristics of the building industry, three basic standards have appeared. The first one, the standard [2] provides general principles and requirements for the assessment of buildings in terms of environmental, social and economic performance taking into account technical characteristics and functionality of a building. In the next standard [3] are distinguished the following categories characterizing the social performance of sustainable construction:

- $K_1$ – accessibility;
- $K_2$ – adaptability;
- $K_3$ – health and comfort;
- $K_4$ – impact on the neighbourhood;
- $K_5$ – maintenance and maintainability;
- $K_6$ – safety and security.

For the assessment of the social aspect the most important is third standard [4] which provides methods and requirements for the assessment of social performance of a building while taking into account the building’s functionality and technical characteristics.

The above-mentioned standards provide guidelines for the assessment of the social properties of buildings. Those standards do not set the rules for how building assessment schemes may provide valuation methods. Nor do it prescribe levels, classes or benchmarks of performance. In this article has been made a full overview one of the basic categories highlighted in the standard [4] - $K_2$ – *Adaptability.*
The authors present a part of a work to construct a complex method for assessing the social characteristics of the residential buildings.

2. Characteristics of the category \( K_2 \) Adaptability

The concept of adaptation comes from Latin and means ‘to adapt’. In construction and architecture, adaptability is a feature that embodies spatial, structural, and service solutions to make changes to the building in response to time-varying requirements [5]. It usually involves adjusting an object to new requirements without changing its utility functions (e.g. by equipping the facilities with new technological solutions). The ability to adapt buildings is a condition of long-term use and contributes to delaying the aging process in technical and functional terms.

In the evaluated category should be assessed, among others, the building's spatial reserves, the load capacity of the structural components margins and the ease of access to the systems and facilities of the building. This group of features allows to evaluate the possibility of adaptive changes to the requirements of users of an entire or part of a building. Adaptability also contributes to the growth of the environmental aspect (e.g. change of building heating technology).

Table 1 shows the classification of the category \( K_2 \) Adaptability for three subcategories \( K_{21}, K_{22} \) and \( K_{23} \). The individual subcategories are evaluated by the criteria identified in the article with symbols \( K_{211} \div K_{233} \). For the evaluation of the considered factor (criterion) were adopted five-point discrete scale, where the best solution would be the highest value of 5.

Table 1. Breakdown of category \( K_2 \) into subcategories \( K_{21}, K_{22} \) and evaluation criteria \( K_{211} \div K_{233} \).

| \( K_{21} \) | The building’s ability to accommodate the change of user requirements |
| --- | --- |
| \( K_{211} \) | Optimization of internal load-bearing-elements (e.g. easy of demolition/ demountability of internal building elements), |
| \( K_{212} \) | Possibility to assemble equipment for the transport of people, including people with additional needs (e.g. lifts), |

| \( K_{22} \) | The building’s ability to accommodate technical changes |
| --- | --- |
| \( K_{221} \) | Accessibility and demountability of pipes and cables |
| \( K_{222} \) | Provision of space for additional pipes and cables for technical changes |

| \( K_{23} \) | The building’s ability to accommodate the change of use |
| --- | --- |
| \( K_{231} \) | Provide fire safety |
| \( K_{232} \) | Redundancy in load-bearing capacity |
| \( K_{233} \) | Ensuring hygienic-sanitary conditions and environmental protection |

3. Determining threshold values of criteria

3.1. Determining the scale of values of parameters characterizing the subcategory \( K_{21} \)

Subcategory \( K_{21} \) aims to assess the ability of an object to adapt to changing user requirements. It refers to both functional and spatial solutions for the common parts of the entire building as well as the interiors of individual dwellings. It should be also assessed the possibility of installation of new equipment to improve the movement of the building e.g. lifts, chairs "on handrails" or the installation systems improving the functioning of in which the object is (not) equipped.

Evaluation of the subcategory \( K_{21} \) for individual apartments is based on an analysis of their ability to adapt to user requirements such as the size of the flat, the number of rooms, the space of individual rooms, used of the functional and structural solutions, or the possibility of interior arrangement, etc. It is necessary to assess the possibility of adapting the dwelling to the needs of its occupants e.g. small children, elderly people, including the disabled people. The evaluated features also apply to the parameters of the corridors, the size of the door openings, the height of the thresholds, the bathroom adaptability, etc.

3.1.1. Criterion \( K_{211} \) Optimization of internal load-bearing-elements (e.g. easy of demolition/ demountability of internal building elements). An important feature to consider in the evaluation of the
apartment is the ability to easily change the room layout. The impact on this have factors such as: the character of the user's work, family size, the requirements of people with special needs, etc. Changing the layout of the rooms in practice consists in changing the location of partition walls. In systems of panel construction such changes can be carried out in a very limited extent. In buildings erected by traditional technology, there is much more freedom in changing the location of partition walls. In the case where in static calculations the load from partition walls was assumed to be "evenly distributed", change the layout does not constitute significant difficulties. If in the static calculations the load (walls) was taken in the form of concentrated forces then the decision of the new (planned) location of partition walls must be taken after analysis of the structural solutions of the slab.

In the case of buildings where the load-bearing walls are brick-built, depending on the stocks in their loads, it is possible to make holes in these walls, even of considerable width, which undoubtedly allows to make some changes in communication and the layout of the rooms.

Table 2 shows the proposed evaluation of the criterion $K_{211}$.

| Scale | Buildings constructed in traditional technology | Buildings in prefabricated large panel technology |
|-------|---------------------------------------------|-----------------------------------------------|
| 5     | Load from wall partition: substitute         |                                               |
| 4     | Load from wall partition: focused           |                                               |
| 3     | Masonry bearing walls (with the possibility of making holes) | X                                             |
| 2     | Slab-and-column structure                   |                                               |
| 1     |                                               | X                                             |

3.1.2. Criterion $K_{212}$ Provisions for possible future equipment e.g. lifts. An important role in the use of a residential building plays transport, more precisely: horizontal and vertical transport means. The lack of elevators in five- and four-storey buildings and their maladaptation for people with additional needs makes that transport to the higher floors is difficult for elderly and impossible for disabled people [6].

In existing buildings, the assembly of lifting equipment intended for the people movement, including the elderly and the disabled persons, is difficult. This is related to technical difficulties and high costs.

Figure 1. Examples of assembly of lifting equipment; a) inside building b) outside building, c) stairs chair.

In practice, the assembly of lifting equipment (passenger lifts) is carried out according to the following solutions:

- assembly inside the building; often located inside the "soul of the stairway" – Figure 1a),
installation outside the building – Figure 1b),

- use of stairlifts - these are lifting devices intended for the transport of the elderly and the disabled (with slight movement disorder) up the stairs - Figure 1c).

According to data in publications [7], [8] in multi-storey buildings where lifts are installed, most of the existing passenger lifts are not adapted for disabled people, including wheelchair users, people who are blind or deaf. After examining the construction of lift shafts, it is concluded that in large part, in the cases described above, it is possible to adapt them (lifts) to the requirements of users (people with disabilities) while maintaining the standard requirements.

The proposed rating scale for criterion \( K_{212} \) is presented in Table 3.

**Table 3.** The grading scale criterion \( K_{212} \) Provisions for possible future equipment e.g. lifts.

| Scale |
|-------|
| 5     |
| 4     |
| 3     |
| 2     |
| 1     |

| Assembly technology of personal lift | Adaptation of existing lifts | No adaptability |
|-------------------------------------|-----------------------------|-----------------|
| Outside the building                | X                           |                 |
| Inside the building                 | X                           |                 |
| Stair chair                         | X                           |                 |

3.2. **Subcategory \( K_{22} \) The building’s ability to accommodate technical changes**

3.2.1. **Criterion \( K_{221} \) Accessibility / demountability of pipes and cables.** Elements of the building's technical infrastructure (plumbing, gas, ventilation, electrical installations, TV, etc.) are degraded more quickly than building components. They are exchanged in the building's life cycle 2-4 times. Such frequent exchanges are determined not only by the degradation process, but also by economic and environmental considerations. Technological progress makes, that elements of the newer generation infrastructure are more durable, reliable, safe, have higher efficiency and their production and exploitation is more environmentally friendly. During the evaluation of this subcategory should be taken into account the ease of access to these devices – if the repair is necessary and if replacement of parts is required. Figure 2 show an example of difficult access to a water system and Figure 3 shows an easy access to an electrical installation.

**Figure 2.** View of difficult access to water installation.  
**Figure 3.** View of easy access to the electrical installation.

The proposed rating scale for criterion \( K_{221} \) is presented in Table 4.
| Scale | Possibility to repair | Possibility of exchange |
|-------|-----------------------|-------------------------|
|       | pipes | cables | pipes | cables |
| 5     | +     | +      | +     | +      |
| 4     | +     | +      | +     | -      |
| 3     | +     | +      | -     | +      |
| 2     | +     | +      | -     | -      |
| 1     | +     | -      | -     | -      |
|       | -     | +      | -     | -      |
| +     | the operation under consideration is feasible, |
| -     | the operation under consideration is not feasible. |

3.2.2. **Criterion $K_{222}$ Provision of space for additional pipes and cables required for technical changes.**
The technical progress in building infrastructure, the widespread use of electronics and information systems, environmental standards (e.g. resignation of the local boilers) and climate change necessitates the need for modernization of existing installations, as well as the installation of completely new systems such as fiber optic telecommunication, air conditioning. For example: currently the vast majority of new building connections are already being implemented in FTTH (Fiber To The Home) and FTTB (Fiber To The Building) technologies, in addition, the existing copper connections are increasingly being exchanged. Execution of the above operations, assembly of new systems (e.g. fiber or air conditioning), are related to the need to find the necessary additional space. However, during the replacement of old systems with new ones generally there is no need to. An example is the refurbishment of old sewage pipes and approaches to appliances that are usually made of cast iron and replacing them with new ones made of plastic, several times lighter and also have smaller dimensions.

The proposed rating scale for criterion $K_{222}$ is presented in Table 5.

| Scale | Ease of installation the pipes | Ease of installation the cables | Installing pipes with difficulties | Installing cables with difficulties |
|-------|--------------------------------|--------------------------------|----------------------------------|----------------------------------|
| 5     | +                              | +                              | +                                | +                                |
| 4     | +                              | -                              | -                                | +                                |
| 3     | -                              | +                              | +                                | -                                |
| 2     | -                              | -                              | +                                | +                                |
| 1     | +                              | -                              | -                                | -                                |
|       | -                              | +                              | -                                | -                                |
| +     | the operation under consideration is feasible, |
| -     | the operation under consideration is not feasible. |

3.3. **Subcategory $K_{23}$ The building's ability to accommodate the change of use**
According to article 71 par. 1 pt. 2 of the Act of 7 july 1994 – Construction Law [9], by change in the use of building or part of it is understood in particular the taking or abandonment of a building or part of it an activity changing conditions: fire, flood, work, health, hygiene and sanitation safety, environmental protection or size or system of load.
3.3.1. Criterion $K_{231}$ Provide fire safety. According to the Regulation [10], the building and its associated equipment should be designed and constructed in such a way that in case of fire:

- bearing capacity of the structure by the time resulting from regulation,
- limiting the spread of fire and smoke in the building,
- limiting the spread of fire to neighboring buildings,
- the possibility of evacuation of people.

Assessment of the criterion $K_{231}$ consists in expressing the opinion by an appraiser whether will meet fireproof class specified for the particular use of the building and whether the requirements for evacuation routes are met.

Particular elements of a building belonging to the appropriate fireproof class shall meet the requirements in the form of the required fire resistance class, as well as the conditions of the degree of spread of fire [10].

The proposed rating scale for criterion $K_{231}$ is presented in Table 6.

| Scale | The building fire resistance | Emergency exit requirements |
|-------|-----------------------------|-----------------------------|
|       | Fulfilled | Possible to implement | Fulfilled | Possible to implement |
| 5     | +         |                     | +         |                     |
| 4     | +         | -                   | +         |                     |
| 3     | -         | +                   | -         | +                   |
| 2     | -         | +                   | -         | +                   |
| 1     | -         | -                   | -         | +                   |

3.3.2. Criterion $K_{232}$ Redundancy in load-bearing capacity. During the change of use often we have to deal with the situation of changing the usage load to larger than the previous ones. In this case, for the new load size, the structural safety of the building should be checked [11]. It consists in ensuring that the limits of load capacity and serviceability limits are not exceeded throughout the building and in each of its components.

In the assessment of the structural safety the following elements are taken into account: slabs, walls and columns and foundations. As a result of the static analysis, it may be that in all the structural elements of the building there is no exceeding of the limit load capacity, but it is also possible that in some parts of the building e.g. in the walls or foundations, there are some reserves of load capacity, while in others e.g. slabs should be reinforced or replaced.

The proposed rating scale for criterion $K_{232}$ is presented in Table 7.

| Scale | Foundations | Horizontal elements (slabs, joists) | Vertical Elements (walls, columns) |
|-------|-------------|-------------------------------------|---------------------------------|
| 5     | +           | +                                   | +                               |
| 4     | +           | +                                   | -                               |
| 3     | +           | -                                   | +                               |
| 2     | -           | +                                   | -                               |
| 1     | -           | -                                   | +                               |

+ - element satisfies safety,
- - element does not meet the safety condition.
3.3.3. Criterion K\textsubscript{233} Ensuring the health and hygienic-sanitary conditions and environmental protection. Changing of use of a residential building entails some kind of threat in ensuring the comfort of the building occupants and the environment protection. In the considered criterion K\textsubscript{233}, the following factors were taken into account in its assessment:
- noise,
- vibrations,
- the presence of harmful dusts and fumes in the air.

The scale of evaluation of criterion K\textsubscript{233} is shown in Table 8.

### Table 8. The grading scale criterion K\textsubscript{233} Ensuring the hygienic-sanitary conditions and environmental protection.

| Scale | Noise | Vibrations | Harmful dust and fumes |
|-------|-------|------------|------------------------|
| 5     | +     | +          | +                      |
| 4     | -     | +          | +                      |
| 3     | +     | -          | +                      |
| 2     | -     | +          | -                      |
| 1     | +     | -          | -                      |

+ - proposed change of use meets the standard conditions,
- - proposed change of use does not meet the standard conditions.

4. Assessment of the social aspect of sustainable housing in the category K\textsubscript{2}

Assessment of category K\textsubscript{2} Adaptability is proposed to rate by qualified assessment [12], [13]. Qualified assessment based on the indicative ratings. For each criterion, we assume the same scale of change of the criteria parameters from the highest standard (upper value) and ending at a certain fixed lower level. To merge these ratings in subcategories, weight should be assigned to them.

The matrix of assessment for Adaptability and the matrix of weights assigned to it will have the form:

\[
O^2 = \begin{bmatrix}
  o_{1,1}^2 & o_{1,2}^2 & 0 \\
  o_{2,1}^2 & o_{2,2}^2 & 0 \\
  o_{3,1}^2 & o_{3,2}^2 & 0 \\
\end{bmatrix}, \quad \Lambda^2 = \begin{bmatrix}
  \lambda_{1,1}^2 & \lambda_{1,2}^2 & 0 \\
  \lambda_{2,1}^2 & \lambda_{2,2}^2 & 0 \\
  \lambda_{3,1}^2 & \lambda_{3,2}^2 & \lambda_{3,3}^2 \\
\end{bmatrix}
\]

where \( o_{i,j}^k \) for \( i \) - category: \( i = 2; j \) - subcategory: \( j = 1,2,3 \) and \( k \) - criterion: \( k = 1,2,3 \)

Taking into account evaluation vectors that can be extracted from the matrix (4) by applying the adjusted index of summation, a partial score is calculated for each of the three subcategories listed:

\[
dla K_{21}: \quad O_1^2 = \sum_{k=1}^{3} o_{1,k}^2 \lambda_{1,k}^2 = o_{1,1}^2 \lambda_{1,1}^2 + o_{1,2}^2 \lambda_{1,2}^2 + o_{1,3}^2 \lambda_{1,3}^2
\]

\[
dla K_{22}: \quad O_2^2 = \sum_{k=1}^{3} o_{2,k}^2 \lambda_{2,k}^2 = o_{2,1}^2 \lambda_{2,1}^2 + o_{2,2}^2 \lambda_{2,2}^2 + o_{2,3}^2 \lambda_{2,3}^2
\]

\[
dla K_{23}: \quad O_3^2 = \sum_{k=1}^{3} o_{3,k}^2 \lambda_{3,k}^2 = o_{3,1}^2 \lambda_{3,1}^2 + o_{3,2}^2 \lambda_{3,2}^2 + o_{3,3}^2 \lambda_{3,3}^2
\]

The next stage is to determine the adjusted index of summation for the vector value received in the previous calculation: \( O_j^2 = [O_1^2, O_2^2, O_3^2] \). In addition, for each of three subcategories a weight vector has also been designated (by survey):
\[ L_j^2 = \left[ L_1^2, L_2^2, L_3^2 \right]^T. \]

For such a set value we calculate:

\[ O_C^2 = \sum_{j=1}^{3} O_j^2 \ast L_j^2 = O_1^2 \ast L_1^2 + O_2^2 \ast L_2^2 + O_3^2 \ast L_3^2 \]  

\[ (6) \]

5. Summary
The method of standardization of category ratings proposed on the example of K2 Adaptability is a contribution to the harmonization of the social evaluation of the performance of sustainable construction. The established threshold values, the proposed scale of assessments of the considered criteria and the weights assigned to each criterion and subcategory are largely based on expert research.

The presented method of assessing the social aspect of sustainable housing on the example of category K2 makes possible to compare, in terms of adaptability, between the examined building and the reference object, as well as between buildings made in different technologies. In the longer term, it will allow to determine the scope of the projected renovation / refurbishment of the building, and may also be helpful in real estate valuation.

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