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Model for assessing "accessibility" – the basic category in the evaluation of social performance of buildings according to standards PN-EN 16309+A1:2014-12

Model oceny kategorii „dostępność" – podstawowego czynnika w ocenie socjalnych właściwości użytkowych budynków wg normy PN-EN 16309+A1:2014-12

Abstract

The paper considers the assessment model of the category Accessibility, which is a basic element of the social aspect of sustainable construction. The model takes into account the standard PN-EN 16309+A1:2014-12, which generally provides methods and requirements for assessing the social performance of buildings. The authors, for the purposes of the model particularise the scope of the assessment category and set threshold values and the weight of particular social indicators. The model is treated as a contribution to developing a method for comprehensive assessment of the social characteristics of buildings.

Keywords: Technical Committee CEN / TC 350, the social aspect, accessibility, model

Streszczenie

W artykule rozpatrywany jest model oceny kategorii Dostępność będącej podstawowym elementem aspektu socjalnego zrównoważonego budownictwa. Model uwzględnia normę PN-EN 16309+A1:2014-12, która w sposób ogólny podaje metody i wymagania dotyczące oceny socjalnych właściwości użytkowych budynków. Autorzy dla potrzeb modelu uszczegóławiają zakres oceny rozpatrywanej kategorii oraz ustalają progowe wartości oraz wagi poszczególnych wskaźników społecznych modelu. Model traktowany jest jako przyczynek do opracowania metody umożliwiającej kompleksową ocenę socjalnych właściwości budynku.

Słowa kluczowe: Komitet Techniczny CEN/TC 350, aspekt socjalny, dostępność, model

1. Introduction

One of the basic standards developed by the Technical Committee CEN/TC 350 *Sustainability of construction Works* [3, p. 2010–2023] regarding the social aspect of sustainable development is the PN-EN 16309+A1:2014-12 Sustainability of construction works – Assessment of social performance of buildings – Calculation methodology published in English. In this standard six categories have been distinguished, which are used to assess the social performance of buildings: K_1 – *accessibility*; K_2 – *adaptability*; K_3 – *health and comfort*; K_4 – *impacts on the neighbourhood*; K_5 – *maintenance and maintainability*; K_6 – *safety and security*. The standard also includes methods and requirements for assessing social performance in buildings by taking into account the technical characteristics and functionality of the building. It should be noted that the standard [8] provides guidance for the assessment of the building, but does not include threshold values or weights of individual social indicators (category).

In this paper, the authors present a mathematical model for the assessment of the first category of social performance in buildings K_1 *Accessibility*. The authors treat the model as a contribution to the development of a model to enable a comprehensive assessment of the social characteristics of the building.

2. Assumptions for model

The proposed method, designed to assess the category *Accessibility*, covers the comparison of the solution features of the building tested (in terms of access to the building) with the characteristics of the reference object. The reference building is a hypothetical building designed according to current standards and practice with the same technological, structural and functional parameters as the building being evaluated. The reference building serves as a base of all possible theoretical analyses and is associated with a set of data defining the assess object. More information about the reference building is contained, among others, in paper [7].

In the constructed model, only the basic, in the authors' opinion, most important elements related to the categories $K_i (i = 1, 2, ..., m)$ describing the system (object) are included. In order to clarify the scope of given category *Ki* subcategories K_{ij} $(j = 1, 2, ..., n_i, i = 1, 2, ..., m)$ were specified that particularise K_i $(i = 1, 2, ..., m)$. Each of the subcategories is judged by the criteria K_{ijk} $(k = 1, 2, ..., n_{ij}, j = 1, 2, ..., n_i, i = 1, 2, ..., m)$. In order to formally describe the evaluation of the category K_i with components (subcategories) assessed by n_{ij} criteria shall be introduced the following scoring matrix $\mathbf{O}^i$:

$$\mathbf{O}^i = [o^i_{j,1}, o^i_{j,2}, ..., o^i_{j,n_{i,j}}] \text{ for } i=1, 2, ..., m; j=1, 2, ..., n_i \tag{1}$$

wherein the values $o^i_{j,n_{i,j}}$ for last $n'_{ij} - n_{ij}$ places will be zero, where:

n_{ij} limiting values for the index k, $n'_{ij} = \max_{1 \le j \le n_i} n_{ij}$;

n_i limiting values for the index j, $n'_i = \max_{1 \le i \le m} n_i$;

The values of ratings criteria are determined on the basis of expert knowledge [5, p. 73-78].

For the evaluation of the considered factor (criterion), depending on finding the existing state, a discrete scale consisting of 1 ÷ p levels for p = 5 p with levels with the following meaning were adopted:

5 – *very good condition,*
4 – *good condition,*
3 – *satisfactory state,*
2 – *poor condition,*
1 – *very poor condition.*

The proposed scale enables the influence of factors that are difficult to measure to be taken into account.

In the multi-criteria analyses [1], and these we are dealing with, an important problem is the unequal validity of the criteria adopted, in varying degrees of fragmentation characteristics of the object (criteria), and including this in the assessment algorithm. For this purpose weights should be entered (hierarchical coefficients, standardized with regard to individual vectors of state assessment) which are correction values according to the preferences expressed by an expert:

$$\lambda_{ijk} \in [0,1] \quad \text{where} \sum_{i=1}^{m} \lambda_{ijk} = 1 \quad \text{dla} \quad j = 1, 2, ..., n_i, \; k = 1, 2, ..., n_{ij} \qquad (2)$$

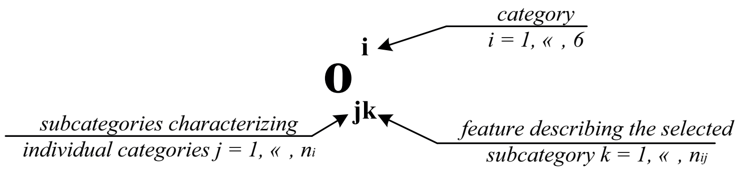
The model assumes the scale of weights from 0.1 to 1.0 (0.1 – little important, ..., 1.0 - very important) [4, p. 4236–4240].

3. Construction of the model

In a complex system which a building is, a clear proposition of the evaluation index is extremely difficult, so the authors propose to deal with a qualified assessment. Using the qualified evaluation o_{jk}, for $j = 1, ..., n_i$; $k = 1, ..., n_{ij}$ we receive a rating matrix of category $\mathbf{O}^i$ and assigned to it the matrix of weights $\mathbf{\Lambda}^i$:

$$\mathbf{O}^i = \begin{bmatrix} O^i_{1,1} & \cdots & O^i_{1,n_{ij}} \\ \vdots & \ddots & \vdots \\ O^i_{n_i,1} & \cdots & O^i_{n_i,n_{ij}} \end{bmatrix} \qquad \mathbf{\Lambda}^i = \begin{bmatrix} \lambda^i_{1,1} & \cdots & \lambda^i_{1,n_{ij}} \\ \vdots & \ddots & \vdots \\ \lambda^i_{n_i,1} & \cdots & \lambda^i_{n_i,n_{ij}} \end{bmatrix} \qquad (3)$$

where:



In the present case for K_1 *Accessibility* two subcategories K_{11} and K_{12} and the criteria by which they are assessed are specified. The tree of the assessment for category K_1 is shown in Fig. 1.

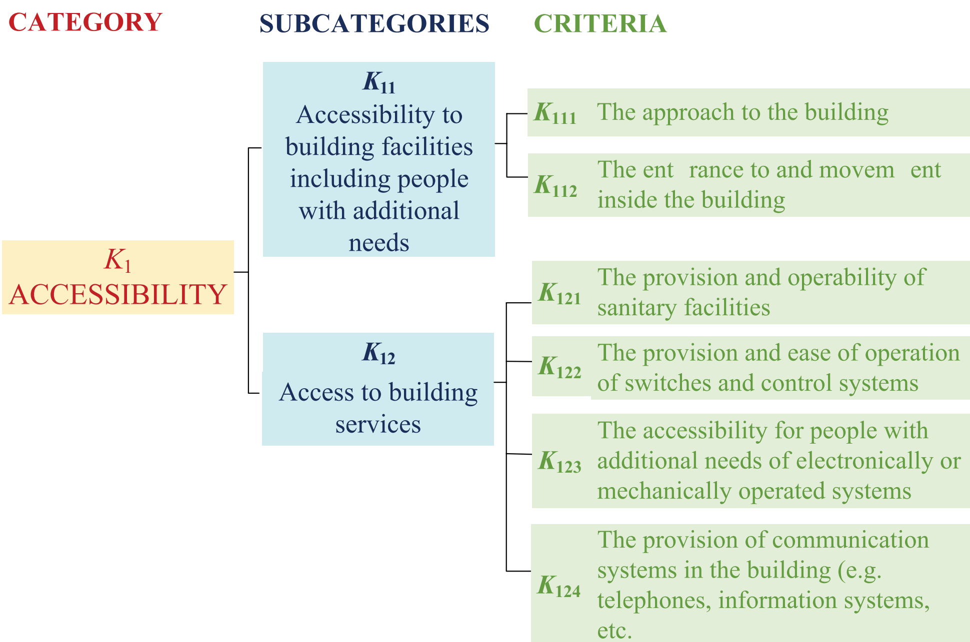


Fig. 1. Assessment tree of category K_1 *Accessibility*

Indexes for category K_1 *Accessibility* will take the following values (Fig. 1):
– n_i index values j: for $i = 1$, $n_i = 2$,
– n_{ij} index values k (when $i = 1$) for $j = 1{:}n_{1j} = 2$; for $j = 2{:}n_{1j} = 4$;

In paper [6, p. 55–61] the characteristics of the elements of the "tree assessments" juxtaposed in Fig.1, including the matched rating scale, have been presented. The matrix of assessment for *Accessibility* and the matrix of weights assigned to it will have the form:

$$\mathrm{O}^1 = \begin{bmatrix} o_{1,1}^1 & o_{1,2}^1 & 0 & 0 \\ o_{2,1}^1 & o_{2,2}^1 & o_{2,3}^1 & o_{2,4}^1 \end{bmatrix} \quad \Lambda^1 = \begin{bmatrix} \lambda_{1,1}^1 & \lambda_{1,2}^1 & 0 & 0 \\ \lambda_{2,1}^1 & \lambda_{2,2}^1 & \lambda_{2,3}^1 & \lambda_{2,4}^1 \end{bmatrix} \tag{4}$$

Based on presented in [6, p. 55–61] subcategories and the criteria describing them can be extracted from the matrix (4) assessments vectors and weight vectors for individual characteristics (criteria):

$$o_{1k}^1 = [o_{1,1}^1, o_{1,2}^1] \quad \text{and} \quad o_{2k}^1 = [o_{2,1}^1, o_{2,2}^1, o_{2,3}^1, o_{2,4}^1] \tag{5}$$

$$\lambda_{1k}^1 = [\lambda_{1,1}^1, \lambda_{1,2}^1]^T \quad \text{and} \quad \lambda_{2k}^1 = [\lambda_{2,1}^1, \lambda_{2,2}^1, \lambda_{2,3}^1, \lambda_{2,4}^1]^T \tag{6}$$

Taking into account vectors (5) and (6), by applying the adjusted index of summation [2, p. 2010-2023], a partial assessment for each of the two separate subcategories should be calculated:

- for K_{11} *Accessibility to building facilities including people with additional needs we obtained*:

$$o_1^1 = \sum_{k=1}^{2} o_{1,k}^1 \cdot \lambda_{1,k}^1 = o_{1,1}^1 \cdot \lambda_{1,1}^1 + o_{1,2}^1 \cdot \lambda_{1,2}^1 \tag{7}$$

- for K_{12} *Access to building services* scalar function will have the form:

$$o_2^1 = \sum_{k=1}^{4} o_{2,k}^1 \cdot \lambda_{2,k}^1 = o_{2,1}^1 \cdot \lambda_{2,1}^1 + o_{2,2}^1 \cdot \lambda_{2,2}^1 + o_{2,3}^1 \cdot \lambda_{2,3}^1 + o_{2,4}^1 \cdot \lambda_{2,4}^1 \tag{8}$$

The next stage is to determine the adjusted index of summation for the vector value received in the previous calculation: $\mathbf{O}_j^1 = \left[O_1^1, O_2^1 \right]$. In addition, for each subcategory a weight vector in the form has also been designated (by survey):

$$\mathbf{L}_j^1 = \left[L_1^1, L_2^1 \right]^T \tag{9}$$

For such a set value we calculate:

$$O_C^1 = \sum_{j=1}^{2} \mathbf{O}_j^1 \cdot \mathbf{L}_j^1 = O_1^1 \cdot L_1^1 + O_2^1 \cdot L_2^1 \tag{10}$$

The evaluation of K_1 for the social aspect of sustainable construction obtained in the above calculation should be compared with the assessment, previously determined, for the reference object. The difference between the obtained assessments gives us information about the state of the analysed object in relation to the current requirements for the category *Accessibility*.

4. Example

4.1. Building characteristics

A residential unit located in multi-family building on the housing complex "Pod Fortem" in Kraków has been assessed. The building was constructed using mixed technologies: ceilings between storeys, basement walls and pillars on each floor are monolithic, the interior brick walls are made of silicate blocks, external walls are three-layer. Building dimensions: 53.10 x 15.45 x 10.60 m^3. The housing estate was erected in the years from 2006 to 2008 and together nineteen residential blocks were created. The building is triple-staircase, three-storey and basement. In the basement storey there are 13 parking places for cars. The estate is located on the outskirts of Kraków, it is fenced and has an internal road infrastructure and parking spaces for cars in its area. The premises shown are a three-bedroom apartment, located on the first floor. The layout and location of the apartment are presented in Figures 2 and 3.

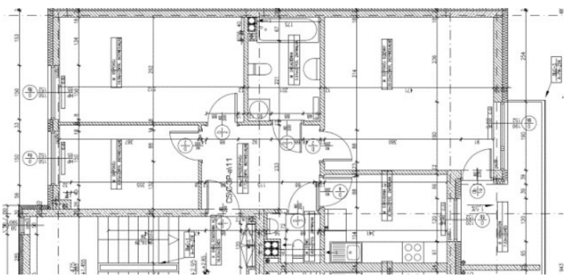


Fig. 2. Layout of assessed apartment

Fig. 3. View of housing estates on which the assessed apartment is situated

4.2. Determining the values of the criteria

After the local vision, the necessary information was collected from the occupants about the building and the surroundings and taking into account the rating scales proposed in paper [6, p. 55–61], the criteria characterizing the category K_1 *Accessibility* in the examined apartment were established. The results of the findings are presented in Table 1:

Table 1. The assessment of criteria characterizing the various subcategories

<table>
<tr><th colspan="2">Subcategories</th><th colspan="2">Criteria</th><th>Assessment o^1_{jk}</th></tr>
<tr><td rowspan="2">K_{11}</td><td rowspan="2">Accessibility to building facilities including people with additional needs</td><td>K_{111}</td><td>The approach to the building</td><td>5</td></tr>
<tr><td>K_{112}</td><td>The entrance to and movement inside the building</td><td>3</td></tr>
<tr><td rowspan="4">K_{12}</td><td rowspan="4">Access to building services</td><td>K_{121}</td><td>The provision and operability of sanitary facilities</td><td>5</td></tr>
<tr><td>K_{122}</td><td>The provision and ease of operation of switches and control systems</td><td>3</td></tr>
<tr><td>K_{123}</td><td>The accessibility for people with additional needs of electronically or mechanically operated systems</td><td>4</td></tr>
<tr><td>K_{124}</td><td>The provision of communication systems in the building (e.g. telephones, information systems, etc.)</td><td>5</td></tr>
</table>

The validity of the various criteria λ^1_{jk} established on the basis of expert preferences is shown in Table 2.

Table 2. Weights of each criteria (marking of subcategories and criteria according to Tab. 1)

Subcategories	Criteria	Weights λ^1_{jk}
K_{11}	K_{111}	0.559
	K_{112}	0.441
K_{12}	K_{121}	0.213
	K_{122}	0.246
	K_{123}	0.224
	K_{124}	0.317

Below are given the qualification data for evaluation of the *Accessibility* category in matrix form together with matrices assigned to the weights (determined on the basis of the survey):

$$O^1 = \begin{bmatrix} 5 & 3 & 0 & 0 \\ 5 & 3 & 4 & 5 \end{bmatrix}, \qquad \Lambda^1 = \begin{bmatrix} 0.559 & 0.441 & 0 & 0 \\ 0.213 & 0.246 & 0.224 & 0.317 \end{bmatrix} \tag{11}$$

$$L^1_j = \begin{bmatrix} 0.489 \\ 0.511 \end{bmatrix} \tag{12}$$

By multiplying the matrices (shown in paragraph 3) the vector of ratings was yielded:

$$\mathbf{O}_j^1 = \begin{bmatrix} 4.118 \\ 4.284 \end{bmatrix}$$

Then multiplying the vector of ratings by the vector of weight, were obtained the evaluation of category K_1 for the investigated object:

$$\mathbf{O}_c^1 = O_j^1 \cdot L_j^1 = 4.203$$

In parallel, an assessment of the reference object for this type of building () should be performed. Next we examine the difference in assessments of category K_1 of the tested object and the reference object:

$$\Delta\mathbf{O}_c^1 = \mathbf{O}_c^{1R} - \mathbf{O}_c^1 \tag{13}$$

and quotient:

$$\delta = \frac{\Delta\mathbf{O}_c^1}{\mathbf{O}_c^{1R}} \tag{14}$$

The indicator δ shows how big the difference is between the category of *Accessibility* for the particular building, and the value of *Accessibility* for the reference building, which takes into account the current technical and construction regulations, contemporary logistics of towns and housing estates, new technologies of erection, etc.

5. Conclusions

Assessment of the social performance of buildings is a quite difficult process. A part of the assessed elements may be quantified, compared with standard parameters, while others, such as logistics solutions in the object, the degree of implementation of modern electronic devices (BMS) is difficult to quantify. The proposed model is characterized by a comprehensive approach to assessing the social performance of the building. It can provide significant simplification in the evaluation of real estate and indicate the manager / owner the need and scope of refurbishment for the approach to the building and functional solutions inside the building.

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