# Housing Quality Assessment Model Based on the Spatial Characteristics of an Apartment

**Brkanić Mihić, Ivana**

buildings

MDPI

*Article*

# Housing Quality Assessment Model Based on the Spatial Characteristics of an Apartment

**Ivana Brkanić Mihić**

Faculty of Civil Engineering and Architecture Osijek, Josip Juraj Strossmayer University of Osijek, Ulica Vladimira Preloga 3, 31000 Osijek, Croatia; ibrkanic@gfos.hr

**Abstract:** Today more than ever, people are demanding higher-quality housing, and therefore, there is an increasing need for scientifically sound methods of systematic housing assessment that are capable of addressing multiple, conflicting, and irreconcilable aspects in both qualitative and quantitative terms. Existing studies and models often use a relatively small number of indicators and consider housing quality from a single perspective. This paper presents a methodology used to develop a model for assessing the quality of multiple conflicting spatial characteristics of an apartment. Through a literature review and a survey of 12 architects, 24 spatial indicators were identified and then classified into five categories: (i) additional rooms, (ii) room size, (iii) window orientation and ventilation, (iv) circulation, and (v) spatial organization. Finally, the overall rating of the apartment is calculated as the sum of the ratings of all indicator categories, where the share of each category in the overall rating and desirable characteristics of the apartment is determined by the user. The model was tested on the example of two apartments in the city of Osijek, Croatia.

**Keywords:** housing evaluation; quality assessment; housing quality; apartment spatial characteristics; housing quality indicators; users' perspective



**Citation:** Brkanić Mihić, I. Housing Quality Assessment Model Based on the Spatial Characteristics of an Apartment. *Buildings* **2023**, *13*, 2181. https://doi.org/10.3390/buildings13092181

Academic Editors: Pierfrancesco De Paola and Konstantina Vasilakopoulou

Received: 8 June 2023
Revised: 17 July 2023
Accepted: 22 August 2023
Published: 28 August 2023



## 1. Introduction

For most people, a house or an apartment is the most expensive item they will buy in their lifetime and is a crucial factor in subjective well-being [1]. It represents a status symbol, a part of a person's identity [2], and a major element of material living standards [3]. Since we spend a large part of our lives in a house or an apartment, it must meet various housing needs. The housing dimension has a substantial influence on the quality of life [4], and the housing unit should therefore be adapted to its users. Quality housing plays a significant role in healthy living, affects childhood development [3], leads to improved productivity [5], provides a comfortable space, and reduces psychological distress [6]. According to Natividade–Jesus et al. [7], the purchase of a home is usually a decision made on the basis of less detailed information than the purchase of a car, and this is explained by the fact that there is no multidisciplinary and specialized knowledge that could be included in the assessment of housing. Today, more than ever, people are demanding a superior quality of housing; therefore, there is an increasing need for more scientifically sound methods to conduct systematic housing assessment that are capable of addressing multiple, conflicting, and irreconcilable aspects, both qualitative and quantitative, and of addressing the concerns of various stakeholders (developers, consumers, government agencies, municipalities, etc.) [7]. Moreover, because potential users belong to different economic strata, live in different countries, climates, and cultures, and have different perceptions of housing quality, a single, unified assessment tool may not be appropriate. Finally, personal characteristics, such as age and gender [8], stage of life, income, education, family structure [9], and family needs [10], generate different housing expectations. Therefore, the characteristics, attitudes, needs, and desires of individual users should be included in the housing assessment.

Housing quality is a broad concept that encompasses many housing aspects and has both an objective and subjective dimension [11]. It encompasses many factors, including the physical condition of the building and other facilities and services that make living in a particular area pleasant, as well as the characteristics of the occupants [12]. Tibesigwa et al. [12] assert that spatial characteristics are fundamental quality parameters, including the organization of space, hierarchy, aesthetics, relationship with spatial functions, and flexibility of space. Previous research has also confirmed that improved spatial quality contributes to the attractiveness and public image of a building, as well as the users well-being [13].

A large amount of research defines the quality of housing through user satisfaction with housing conditions. Housing satisfaction is a dynamic process [14] as well as a multi-dimensional and complex construct [15] and can be defined as the perceived gap between respondents' needs and preferences and the reality of the current housing environment [3]. So far, housing satisfaction has been studied on the basis of different users (students [5], young population [16], older adults [1]), different housing types (multifamily housing [9], public housing [17], large housing estates [15], affordable housing [12], rental housing [18]), and different participants in the construction and sales process [19] in different parts of the world. Some of the conclusions of previous research that are significant for this research are: residential satisfaction in Europe is driven first by housing-specific characteristics, followed by neighborhood conditions and individual/household characteristics [20]; building characteristics are one of the important factors in tenant residential satisfaction [9]; dwelling size is shown to be a strong determinant of residential satisfaction; nice and helpful amenities in the apartment are a source of residential comfort [15]; an important component in the measure of quality in housing is the quality of the apartment unit design characteristics and features [21]. In addition, the personal satisfaction aspects of housing quality are generally associated with the personal characteristics of households, such as the occupant's age, income, level of education, preference, etc. [21].

Parallel to the studies on housing satisfaction, various methodologies and models for housing quality assessment were developed. These methodologies and models assess the quality of housing through many dimensions (for example, through the dimension of apartment, building, location, neighborhood, socio-economic dimension, etc.), where one dimension is often determined by only a few different indicators, which cannot give a realistic assessment of a certain dimension. Some of them are presented below.

The French Qualitel Association established in 1974 a set of seven indicators that are rated on a scale of 1 to 5, with 1 being the minimum standard and 5 being a comprehensive design solution. The Qualitel profile is simple, straightforward, and easy to understand, even by people who are not experts in the field of housing [22].

The Housing Quality Indicator (HQI) system, designed in the United Kingdom in 1998, is a tool for evaluating existing housing schemes on the basis of quality rather than simply cost [23]. There are 10 indicators related to: quality of the location; site ((i) visual impact; layout and landscaping; (ii) open space; (iii) routes and movement); permanent units ((i) size; (ii) layout; (iii) noise, light, services, and adaptability; (iv) accessibility within the unit; and (v) sustainability); and the external environment [24]. Each indicator includes a series of questions and receives one tenth of the total possible score. HQI users also have the option to change the weightings applied to each indicator. Failure to meet suitable levels of, for example, security or noise control may render a place so uninhabitable that other factors cannot compensate. However, this does not imply that these indicators should be more heavily weighted than other factors; merely that failure to meet a certain level is unacceptable for these indicators [25]. Scores are presented numerically and graphically to show the strengths and weaknesses of a project and how the overall score is composed. In March 2023, the HQI system was withdrawn because it was no longer current [23].

In 1999, also in the UK, the Construction Industry Council addressed the issue of poor-quality design in buildings through the development of the design quality indicator (DQI) [26]. The DQI can be used by all stakeholders involved in the production and use of buildings (public and private clients, developers, financiers, design firms, contractors, building managers, and occupants) [27]. Participants work through the DQI's structured questionnaire, which covers the three main quality principles (functionality, build quality, and impact) in 10 more focused sections. The DQI has two types of weighting; the first allows results to be distorted depending on how the respondents judge the success of various aspects of the building. Other, separate types of weighting can be applied, indicating whether aspects are fundamental relating to factors that the building must achieve in order to fulfill its purpose, added value relating to factors that will enhance the building's usefulness and pleasure value, or excellence relating to factors that make good design [27]. Results are presented graphically to highlight comparisons between different groups of respondents.

Système d'evaluation de logements (SEL) is a Swiss tool developed to help design, rate, and compare housing. It consists of 25 indicators and measures the quality of the building through three dimensions: (i) location in the settlement, (ii) building lot and building, and (iii) apartment. Each of the indicators is assigned between 0 and 4 points, and the sum of the final results determines the usable value of the apartment, which in total can reach 100 points [28].

In the mid-2000s, a housing performance evaluation model (HPEM) for multi-family residential buildings in Korea was developed. This model is intended to encourage initiatives toward achieving better housing performance and to support a homebuyer's decision-making on housing comparison and selection [29]. The model has 41 indicators divided into three dimensions (housing environment, housing function, and housing comfort). The overall score of housing performance for residential buildings depends on the aggregate of indicators' respective performance scores, which result from multiplying the numerical values (2–5) of the evaluated performance grades by the credits allocated for the indicators [29]. For easier application, an assessment program has been developed that allows the user to define the points for the indicators to reflect their own value for housing performance for the assessment.

A model of housing quality determinants (HQD) was developed in Pakistan for evaluating affordable housing. Twenty-four quality determinants marked as HQD were grouped into seven sections (housing site and planning; architectural design; structure and construction; building services; user comfort; maintenance; and sustainability) [30].

In 2016, Le et al. [31] developed a system of indicators to measure the quality of social housing in Vietnam, which is useful not only for investors and consultants but also for ordinary citizens to make a better decision about buying a home. They proposed three major quality dimensions: location, master plan of the building, and architecture, which include 12 indicators with 55 specific component factors that cover almost all aspects of Vietnamese social housing. There are 4 levels of satisfaction: good (100%), fair (75%), pass (50%), and fail, and points would be rounded to 0.25 [31]. The total score is calculated based on the individual scores of components within each indicator.

The housing evaluation methodology for evaluating housing quality in a situation of social poverty designed in Mexico contains 51 indicators divided into four dimensions: social, physical, spatial, and urban environment. The attributes of the indicator system were mathematically weighted to quantify and evaluate the level of satisfaction, and once the users of the homes rated these and the level of satisfaction of the different dimensions was established through the Likert survey, the data obtained were treated statistically through a numerical stratification of values and satisfaction level [32].

In addition to the ones presented, there are many other different models and methodologies that deal with the assessment of different aspects of housing, such as: estimation algorithm for predicting the performance of private apartment buildings in Hong Kong [33], matrix of affordable housing assessment that design variables set in a survey tool with a Likert scale to evaluate user satisfaction levels with the designs of their respective buildings [34]; various different green building assessment tools that evaluate environmental performance of buildings including the residential ones such as BREEAM [35] or LEED [36], Assessment of Housing Quality method with 47 factors for assessing the quality of housing which are scored from 1 (not important) to 5 (extremely important) and where data was statistically processed in SPSS 9.0 software [37], etc.

In summary, previous studies have evaluated housing quality using different dimensions and indicators, as well as different assessment systems. Based on the indicators used, they can be mainly divided into two categories: (i) those that have developed indicators for housing quality assessment; or (ii) those that use existing quality indicators for different applications, including direct assessment of housing quality, assessment of comfort, satisfaction, safety, or health of residents, or measurement of energy efficiency of dwellings [38]. According to Wimalasena et al. [38], the three most represented indicator categories are: architectural features and characteristics of the housing unit (25%), user comfort (22%), and location and neighborhood of the dwelling (20%). Since climate, culture, urbanization level, technological progress, and socioeconomic progress influence the perception of housing quality standards, there is no universal definition of quality, and the tools developed for housing quality assessment should consider a flexible/adaptable system for indicator selection [21].

The question of where and how to live and under what physical, spatial, social, and urban conditions has become very important for millions of families around the world due to the confinement caused by the pandemic of COVID-19 [32]. Now more than ever, people are demanding a higher quality of life when buying or renting a home. Therefore, there is an increasing need for scientifically sound methods for the systematic assessment of housing that are able to take into account multiple, contradictory, and incompatible aspects [7].

The main objective of this research is to present a developed methodology for assessing measurable spatial characteristics of an apartment (SCA), which could be used in the future to develop a more comprehensive housing quality assessment model. An additional objective is to show how the model for assessing the spatial characteristics of an apartment works on the example of two apartments within the same residential building. Although the model is applicable to any micro-location, it will be tested on the example of two apartments in the same building in Osijek, Croatia. This location was chosen because it was the area of previous research [39,40] regarding housing policies and apartment characteristics in relation to those housing policy periods. In addition, Osijek was chosen as a research location because the issue of housing quality in Osijek has never been studied on this scale before and, as the fourth largest city in Croatia, the city has a representative building stock.

The term model refers to the entire system for evaluating the spatial characteristics of an apartment with all its necessary components, i.e., its graphic and mathematical representation. The term user is used to refer to a person who, in the case of this research, evaluates an apartment either with the intention of defining its level of quality, to obtain general information on a specific apartment, or to compare and purchase a specific apartment.

This section presented the problem and objective of the research, issues of housing quality and user satisfaction with housing, and an overview of existing methods and models that address housing quality. In the following section, a model for user assessment of the spatial characteristics of the apartment is presented in terms of the preliminary work required for its operation as well as its graphical and mathematical representation. The fourth section shows how the model works, using the example of a comparison of two apartments within the same residential building. The final two sections are the discussion and conclusions.

## 2. Materials and Methods

The model was developed through several stages, as shown in Figure 1. The starting point of the research was the analysis of existing literature on housing satisfaction, housing quality, housing design guidelines, and previously developed methods and models for evaluating housing quality (Step 1, in Figure 1) [41]. Based on the available literature, various indicators for housing quality were identified (Step 2, in Figure 1) [41]. The indicators were divided into four categories: (i) apartment unit quality; (ii) apartment building quality; (iii) neighborhood quality; and (iv) social and economic indicators (Step 3, in Figure 1) [41]. Due to the large number of identified indicators, only measurable spatial characteristics from the category of apartment quality indicators were selected for the first phase of the development of the housing quality assessment model presented in this paper.

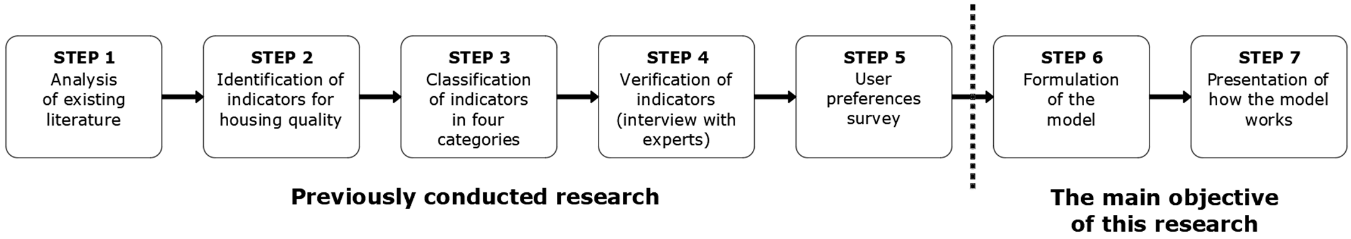



**Figure 1.** Steps of model development.

In the further course of the study, the significance of the spatial indicators was verified by interviewing experts: 12 architects with an average professional experience of 18.5 years in the design of residential buildings (Step 4, in Figure 1) [42]. The results of the architects' interviews served as the basis for the development of a structured questionnaire designed to elicit user preferences regarding specific apartment characteristics. This questionnaire is part of one of the preparatory actions, as it provides input data for the functioning of the model. Each of the questions is related to one of the indicators of the quality of the apartment. The questionnaire was tested on 130 apartment users between the ages of 18 and 82 (Step 5, in Figure 1) [42]. After examining the views of architects and testing questionnaires with users, the final questionnaire that will be used in the third pre-phase was defined. Further steps in the formulation of the model (Step 6 in Figure 1) and the presentation of how the model works (Step 7 in Figure 1) are the main focus of the research presented in this paper.

Table 1 shows five indicator categories: (i) existence of additional rooms, (ii) room size (square footage), (iii) window orientation (in relation to the insolation) and ventilation, (iv) circulation (communication between rooms/traffic pattern), and (v) spatial organization [41] with 24 indicators and the questions from the questionnaire corresponding to each of the indicators. The user answers the questions based on the offered answers by ranking them, either by choosing the most preferred answer or using a Likert scale. An example of the answers to each survey question can be seen in Appendix A.

The impact of a certain indicator category on the final apartment rating is defined through paired comparison analysis (PCA). PCA is used when there is no objective data or when different subjective criteria need to be compared. It is particularly useful when priorities are not clear, when options are completely different, and when trying to define the importance of each criterion. This method provides a framework for comparing each option to all the others and helps to show the relative importance of each option [43]. This study used a customized PCA method in which the surveyed user must not only select the most important indicator but also indicate the extent to which this indicator is more important to him than the others. Along with the letter of the indicator most important to them, they were also asked to write a number (from 1 to 5) indicating how important this indicator is to them compared to the others. The number 1 next to the letter means that the indicator is minimally more important, while the number 5 indicates that the indicator is much more important (Figure 2).

**Table 1.** Relationship between the questions in the survey and the indicators in the model.

| Indicator Category | Indicator | Survey Question |
|---|---|---|
| Additional rooms (ar) | The existence of several storage rooms | How desirable is it for the apartment to have more than one storage room (e.g., pantry, wardrobe)? |
| | The existence of outdoor space | How desirable is it for the apartment to have an outdoor space (balcony, loggia, terrace)? |
| | The existence of additional toilet | How desirable is it for the apartment to have an additional WC in addition to the bathroom? |
| Room size (rs) | Living room | In your opinion, what should be the minimum area ($m^3$) for you to feel comfortable in the following rooms? |
| | Living room with dining area | |
| | Kitchen | |
| | Kitchen with dining area | |
| | Parents' bedroom | |
| | Bedroom for two children | |
| | Bedroom for one child | |
| | High ceiling | How desirable is it for the apartment to have a high ceiling (a room higher than 3.00 m)? |
| Window orientation and ventilation (wo) | Living room orientation | What is the most desirable orientation of the windows of the following rooms? |
| | Kitchen orientation | |
| | Bedroom orientation | |
| | Kitchen with window | How important is it that the kitchen has a window? |
| | Bathroom with window | How important is it that the bathroom has a window? |
| | Two-sided orientation | How important is the two-sided orientation of the apartment? |
| Circulation (ci) | Communication between rooms | What is the most convenient way to connect the rooms in the apartment? |
| | Kitchen-living room Connection | What is the preferred connection between the kitchen and the living room? |
| | Indoor-outdoor connection | From which room is it best to go outside (balcony, loggia, terrace)? |
| | Bedroom-living room connection | How desirable is it to enter the bedroom through the living room? |
| Spatial organization (so) | Dining table location | What is the most desirable room for placing a dining table? |
| | Bedroom area-entrance area connection | How desirable is it to enter the bedroom area from a separate corridor connected directly to the entrance area? |
| | Apartment flexibility [1] | How desirable is it that the apartment can be reorganized with little construction work? |

[1] An apartment is defined as flexible if it can be changed according to changes in the family, such as adding a bedroom, dividing one room into two, and similar.

When indicators for which there are multiple spatial options are evaluated within indicator categories, the following scoring system was developed. In the model, the number of points assigned to each indicator within an indicator category depends on the user's answers in the questionnaire. There are three different ways to assign points to a particular indicator that are correlated with the question types:

1. For questions answered with a Likert scale (1 undesirable; 5 desirable), 1 point is awarded if the user rated a particular indicator as 4 or 5 and the rated apartment has

that characteristic. If the apartment does not have this characteristic, it is awarded 0 points. If, on the other hand, the user has assigned 1 or 2 to the indicator and the apartment has the characteristic, it is awarded 0 points or 1 point if it does not have the characteristic. If the user marked the characteristic of the apartment with 3, it means that this characteristic is neither important nor unimportant for him; therefore, it does not affect the rating, and this indicator is removed from the rating system;

2. In the questions about the sizes of certain rooms, users chose the interval in which they think the minimal area of a certain room should be. If the area of the room in the observed apartment is within the interval or higher, 1 point is awarded; if it is smaller, 0 points are awarded;
3. Since each spatial feature of the apartment can be designed in several different ways, i.e., has several possible variants, the user must be able to evaluate the desirability and quality of each of these variants in the model. For this reason, a scoring system was developed for the spatial features of the apartment, for which there are several different solutions. Indicators with three possibilities are assigned 0, 0.5, or 1 point; indicators with four possibilities are assigned 0, 0.33, 0.67, or 1 point; and indicators with five possibilities are assigned 0, 0.25, 0.5, 0.75, or 1 point.

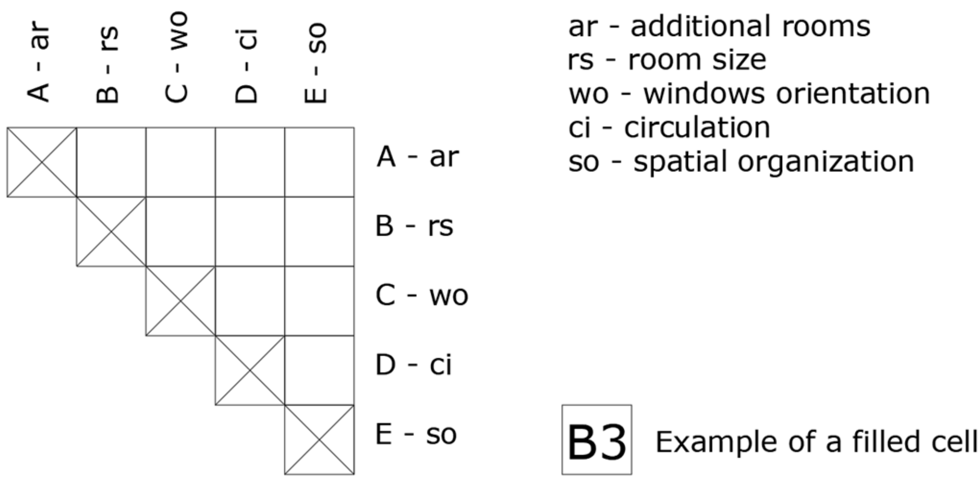



**Figure 2.** Example of PCA questionnaire.

In the continuation, the model is represented graphically by identifying and recording all the steps and actions necessary for its operation. Then, a mathematical representation of the model is given, based on which the Excel spreadsheet for calculating the score was programmed.

The procedure for user assessment of the spatial characteristics of the apartment consists of three preparatory actions and seven steps:

Preparatory actions:

1. Collecting general data on apartments and defining the spatial characteristics of the observed apartments based on the project documentation;
2. Application of the paired comparison analysis to five categories of indicators to determine the importance of each category;
3. Completing a questionnaire that identifies the importance of certain spatial features (indicators) of the apartment.

Steps:

1. Entering general apartment information into the model;
2. Entering data on the importance of each category of indicators into the model;
3. The model calculates the share of the indicator categories in the overall rating;
4. Data entry on the importance of each indicator within each indicator category;
5. The model awards points for each indicator;

6. The model calculates a rating for each indicator category;
7. The model defines the overall rating of the apartment.

The relationship between preparatory actions and steps is visible in Figure 3. The preparatory actions refer to the collection of information about the apartment and the user's preferences regarding apartment characteristics, while the steps refer to the input of information into the model and the processes that take place in the model.

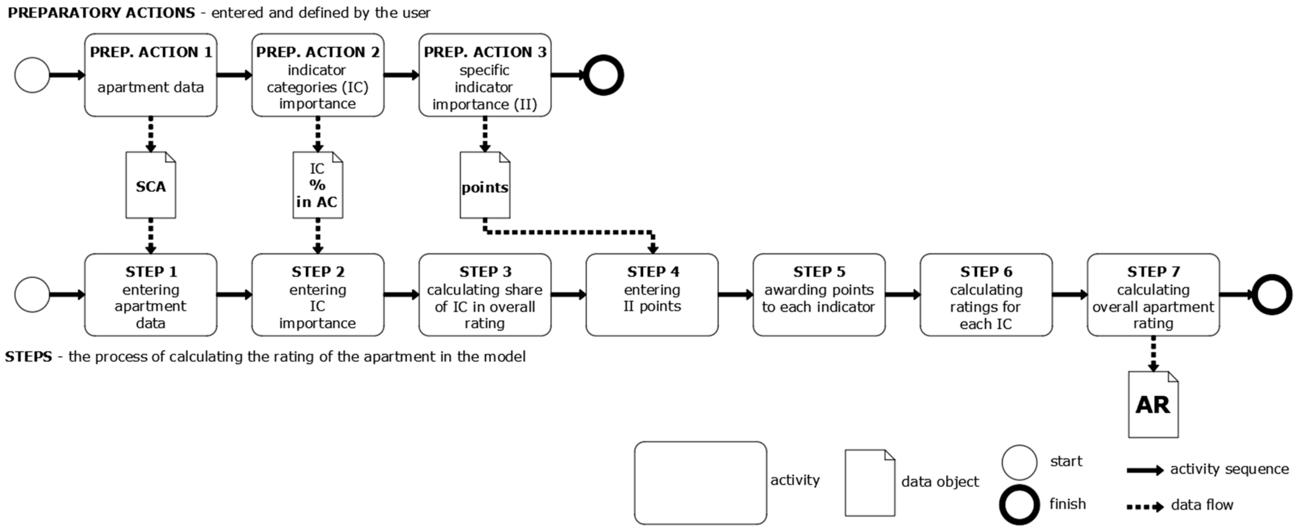



**Figure 3.** Graphical representation of the model.

The main premise of the model is that the overall apartment rating (AR) depends on the sum of the points in each indicator category. Equation (1) shows a simplified mathematical representation of the model. According to the equation, the overall apartment rating (AR) is equal to the sum of the ratings of the five indicator categories (ICR) used to evaluate the SCA.

$$AR = \sum_{j=1}^{5} ICR_j \tag{1}$$

The rating of the apartment (AR) depends on the rating of each indicator category of the SCA. Each indicator category of the SCA depends on the number of points achieved by each indicator within that indicator category, the number of indicators included in the assessment, and the share of the indicator category in the total score. The relationship between these elements and the overall rating of the apartment is represented by Equation (2).

$$AR = \sum_{j=1}^{5} \left( \sum_{i=1}^{n} I_{(IC)i} \times \frac{S_{(IC)}}{NI_{(IC)}} \right)_j \tag{2}$$

AR—overall apartment rating
$I_{(IC)i}$—the number of points achieved by the indicator within a certain indicator category
$S_{(IC)}$—share of the indicator category in the total score
$NI_{(IC)}$—number of indicators within an indicator category
$n$—the number of criteria within each SCA indicator category

It is important to note that each category of indicators contains a different number of indicators for evaluating the SCA; a more detailed distribution of points within each category is presented later. A further breakdown of the equation showing the system included in the model is presented in Equation (3) below.

$$\mathrm{AR} = \left(\sum_{i=1}^{3} \mathrm{I}_{(\mathrm{ar})i} \times \frac{\mathrm{S}_{(\mathrm{ar})}}{\mathrm{NI}_{(\mathrm{ar})}}\right) + \left(\sum_{i=1}^{n} \mathrm{I}_{(\mathrm{rs})i} \times \frac{\mathrm{S}_{(\mathrm{rs})}}{\mathrm{NI}_{(\mathrm{rs})}}\right) + \left(\sum_{i=1}^{m} \mathrm{I}_{(\mathrm{wo})i} \times \frac{\mathrm{S}_{(\mathrm{wo})}}{\mathrm{NI}_{(\mathrm{wo})}}\right) + \left(\sum_{i=1}^{4} \mathrm{I}_{(\mathrm{ci})i} \times \frac{\mathrm{S}_{(\mathrm{ci})}}{\mathrm{NI}_{(\mathrm{ci})}}\right) + \left(\sum_{i=1}^{3} \mathrm{I}_{(\mathrm{so})i} \times \frac{\mathrm{S}_{(\mathrm{so})}}{\mathrm{NI}_{(\mathrm{so})}}\right) \quad (3)$$

(ar)—additional rooms
(rs)—room size
(wo)—windows orientation and ventilation
(ci)—circulation
(so)—spatial organization
*n* and *m*—change and depend on the number of rooms in the evaluated apartment

In this equation, each of the brackets indicates the sum of the points obtained within a certain indicator category. The number of indicators within the categories of room size and window orientation depends on the number of rooms in the evaluated apartment.

If the apartment meets all the user's conditions, the total rating is 100; if some of the conditions are not met, the apartment rating is lower. The overall rating of the apartment is the foundation on which two different apartments can be compared and by which it can be determined which is better for a particular future user/buyer.

## 3. Results

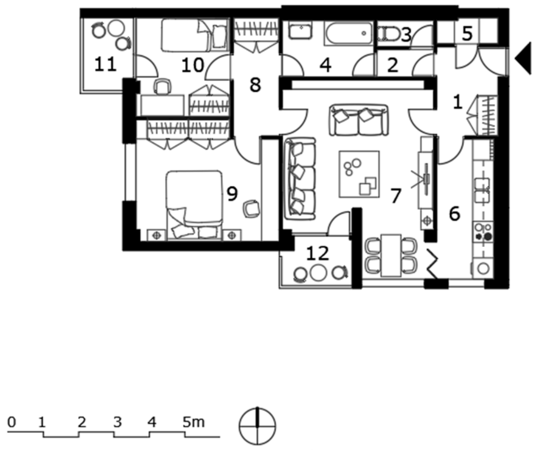
In the continuation of this section, the model is presented through its five segments, which refer to a specific category of indicators. The input data on the users' attitudes was taken from one of the surveys in the user question-testing procedure from the person who at that moment was looking for a new apartment for his family of three; the same person also filled out the additional PCA form. The users' responses can be found in Appendices A and B. The model was tested on the example of two apartments in the city of Osijek, Croatia.

### 3.1. Evaluated Apartments

In order for all conditions related to the location of the apartment in the apartment building and the location of the building within the settlement to be the same, two apartments located in the same apartment building on the same floor in the residential complex Sjenjak in the city of Osijek were selected for testing the model. Considering the preferences of the survey participant, two apartments with a living room and two bedrooms were selected for testing. The apartments are located in a twelve-story building with 106 apartments built in 1974. The floor plans of the apartments being evaluated, as well as the square footage of their rooms, are shown in Figure 4. The floor plans were redrawn based on project documents from the Croatian State Archives in Osijek.

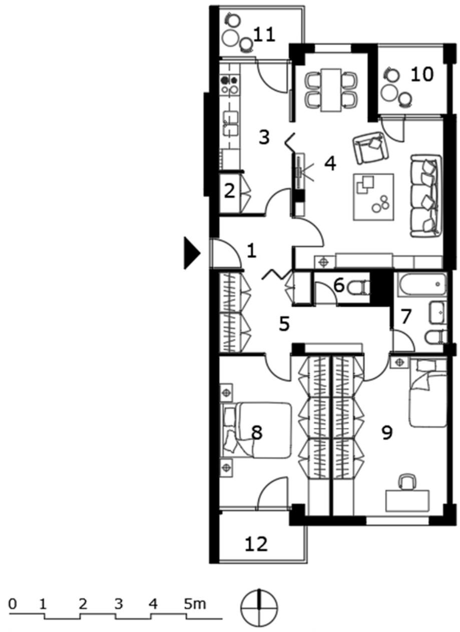
### 3.2. Assessment of the Presence of Additional Rooms (ar)

In the first category of indicators, three spatial characteristics of the apartment were evaluated. Every apartment, with the exception of the studio, contains the minimum required number of rooms: an entrance hall, a bathroom, a kitchen, and bedrooms. In this indicator category, additional rooms (storage areas such as a pantry or a wardrobe, outdoor space, and an additional toilet) that the apartment may contain are evaluated. According to the results of the PCA method, this category has a 19.05% share in the overall rating of the apartment for the user. For the user, it is desirable that the apartment have more than one storage room, and it is important that the apartment have an outdoor area and an additional toilet. Based on user preferences for the SCA in this category, points for each indicator for both apartments are shown in Table 2.



| room: | neto area: | room: | neto area: |
|---|---|---|---|
| 1 entrance area | 4.49m² | 7 living and dining | 20.74m² |
| 2 bathroom entry | 1.28m² | 8 wardrobe | 4.06m² |
| 3 toilet | 1.35m² | 9 bedroom | 13.13m² |
| 4 bath | 4.88m² | 10 bedroom | 7.28m² |
| 5 pantry | 1.47m² | 11 loggia | 2.88m² |
| 6 kitchen | 6.53m² | 12 loggia | 2.80m² |
| | | **total area:** | **70.89m²** |

(**a**)



| room: | neto area: | room: | neto area: |
|---|---|---|---|
| 1 entrance area | 2.72m² | 7 bathroom | 3.72m² |
| 2 pantry | 0.60m² | 8 bedroom | 13.05m² |
| 3 kitchen | 7.25m² | 9 bedroom | 11.60m² |
| 4 living and dining | 21.77m² | 10 loggia | 3.83m² |
| 5 wardrobe | 7.86m² | 11 loggia | 2.80m² |
| 6 wc | 1.35m² | 12 loggia | 2.80m² |
| | | **total area:** | **79.35m²** |

(**b**)

**Figure 4.** Evaluated apartments: (**a**) Apartment 1; (**b**) Apartment 2.

**Table 2.** Indicators, user preferences and apartment characteristics in the category of additional rooms (ar).

| Indicator | The Existence of Several Storage Rooms | The Existence of Outdoor Space | The Existence of Additional Toilet |
|---|---|---|---|
| **Indicator points** | 0/1 | 0/1 | 0/1 |
| **User preferences** | 4 [1] | 5 [1] | 4 [1] |
| **Apartment 1 characteristics**<br>Achieved points | yes<br>1.0 | yes<br>1.0 | no<br>0 |
| | | | Σ = 2 |
| **Apartment 2 characteristic**<br>Achieved points | yes<br>1.0 | yes<br>1.0 | yes<br>1.0 |
| | | | Σ = 3 |

[1] Likert scale 1–5 (1 = least desirable; 5 = most desirable).

In this category, Apartment 1 received two points due to the lack of an additional toilet, while Apartment 2 received a maximum of three points. The share of the category rating depends on the result of the PCA method, the number of indicators, and the individual points obtained for each indicator. For the user, this category makes up 19.05% of the total rating. Since the category contains three indicators, Apartment 1 received 12,70% of the ratings for 2 points, while Apartment 2 reached the maximum rating of 19.05% because all indicators correspond to the user's preferences. The calculation of the rating for Apartment 1 is shown in Equation (4) and for Apartment 2 in Equation (5).

$$AR_{(ar)}1 = \sum_{i=1}^{3} I_{(ar)i} \times \frac{S_{(ar)}}{NI_{(ar)}} = 2 \times \frac{19.05}{3} = 12.70 \quad (4)$$

$$AR_{(ar)}2 = \sum_{i=1}^{3} I_{(ar)i} \times \frac{S_{(ar)}}{NI_{(ar)}} = 3 \times \frac{19.05}{3} = 19.05 \quad (5)$$

*3.3. Assessment of Room Size (rs)*

The second category of indicators evaluates the spatial dimensions of the apartment: the square footage and the height of the rooms. The number of indicators in this category depends on the number of bedrooms in the apartment. Since apartments with a living room and two bedrooms (the parents' bedroom and one child's bedroom) were evaluated, the total number of indicators in this category is five. User preferences regarding each indicator and the points they received for both apartments are shown in Table 3.

**Table 3.** Indicators, user preferences and apartment characteristics in the category of room size (rs).

| **Indicator** | **Living Room ($m^2$)** | | **Kitchen ($m^2$)** | | **Bedroom ($m^2$)** | | | **High Ceiling (above 3.0 m)** |
|---|---|---|---|---|---|---|---|---|
| | **Without Dining** | **With Dining** | **Without Dining** | **With Dining** | **Parents' Bedroom** | **2 Persons Bedroom** | **1-Person Bedroom** | |
| **Indicator points** | 0/1 | 0/1 | 0/1 | 0/1 | 0/1 | 0/1 | 0/1 | 0/1 |
| **User preferences** | 15–20 | 20–25 | 6–9 | 12–16 | 10–15 | no | 5–10 | 1 [1] |
| **Apartment 1 characteristics** | no | 20.74 | 6.53 | no | 13.13 | - | 7.28 | no |
| Achieved points | - | 1.0 | 1.0 | - | 1.0 | | 1.0 | 1.0 |
| | | | | | | | | Σ = 5 |
| **Apartment 2 characteristic** | no | 21.77 | 7.25 | no | 13.05 | - | 11.60 | no |
| Achieved points | - | 1.0 | 1.0 | - | 1.0 | | 1.0 | 1.0 |
| | | | | | | | | Σ = 5 |

[1] Likert scale 1–5 (1 = least desirable; 5 = most desirable).

In this category, both apartments received 1 point for all indicators and thereby achieved the maximum number of points within the category. For the user, this category makes up 42.86% of the total rating. The calculations of the rating for Apartment 1 are shown in Equation (6) and for Apartment 2 in Equation (7).

$$AR_{(rs)}1 = \sum_{i=1}^{5} I_{(rs)i} \times \frac{S_{(rs)}}{NI_{(rs)}} = 5 \times \frac{42.86}{5} = 42.86 \quad (6)$$

$$AR_{(rs)}2 = \sum_{i=1}^{5} I_{(rs)i} \times \frac{S_{(rs)}}{NI_{(rs)}} = 5 \times \frac{42.86}{5} = 42.86 \quad (7)$$

*3.4. Assessment of Window Orientation and Ventilation (wo)*

Since apartments with a living room and two bedrooms were evaluated, the total number of indicators in this category is seven: orientation of windows in the living room, kitchen, and two bedrooms; presence of windows in the kitchen and bathroom; and two-sided orientation of the apartment. User preferences and the points for each indicator for both apartments are shown in Table 4.

**Table 4.** Indicators, user preferences and apartment characteristics in the category window orientation and ventilation (wo).

| Indicator | Living Room | Kitchen | Bedroom 1 | Bedroom 2 | Kitchen with Window | Bathroom with Window | Two-Sided Orientation |
|---|---|---|---|---|---|---|---|
| **Indicator points** | 0/0.33/0.67/1 [1] | | | | 0/1 | 0/1 | 0/1 |
| **User preferences** | 1 south<br>2 east<br>3 west<br>4 north | 1 north<br>2 east<br>3 south<br>4 west | 1 east<br>2 south<br>3 north<br>4 west | | 5 [2] | 3 [3] | 4 [2] |
| **Apartment 1 characteristics** | south | south | west | west | yes | not relevant | yes |
| Achieved points | 1.0 | 0.33 | 0 | 0 | 1.0 | for user | 1.0 |
| | | | | | | | Σ = 3.33 |
| **Apartment 2 characteristic** | north | north | south | south | yes | not relevant | yes |
| Achieved points | 0 | 1.0 | 0.67 | 0.67 | 1.0 | for user | 1.0 |
| | | | | | | | Σ = 4.34 |

[1] If the apartment has a characteristic ranked under 1, it receives 1 point, for the other places, the score is reduced by one third of the point; [2] Likert scale 1–5 (1 = least desirable; 5 = most desirable); [3] The user has rated this indicator as 3 (neither important nor unimportant), therefore the indicator has no influence on the rating and is excluded from the assessment.

Indicators of room orientation depend on the preferences of users regarding the orientation of a particular room. Apartment 1 has only a living room, while Apartment 2 has a kitchen oriented according to the user's preferences, and for these two indicators, both apartments received 1 point each. Other rooms have a less desirable orientation and therefore received fewer points. It should be noted that the indicator for the presence of a window in the bathroom was excluded from the overall assessment, as this indicator has neither a positive nor a negative impact on the user, so this feature of the apartment does not affect the quality of the apartment in the opinion of the user. Therefore, 6 out of a maximum of 7 indicators were used to evaluate apartments for this user in this category. For the user, the importance of this category is 4.76% of the total rating of the apartment. The method of calculating the rating of this category of apartment is shown in Equations (8) and (9).

$$AR_{(wo)}1 = \sum_{i=1}^{6} I_{(wo)i} \times \frac{S_{(wo)}}{NI_{(wo)}} = 3.33 \times \frac{4.76}{6} = 2.64 \quad (8)$$

$$AR_{(wo)}2 = \sum_{i=1}^{6} I_{(wo)i} \times \frac{S_{(wo)}}{NI_{(wo)}} = 4.34 \times \frac{4.76}{6} = 3.44 \quad (9)$$

### 3.5. Assessment of Apartments Circulation (ci)

The category contains indicators related to the way rooms within the apartment are connected. The category contains four indicators that evaluate the connection of rooms at the level of the entire apartment: the way communication was established between the living room and kitchen, indoor and outdoor spaces, and between the living room and bedrooms. It should be noted that in the indicator of the connection of indoor and outdoor spaces, only one outdoor space was considered, as this is most often the case. For assessed apartments that have two or three outdoor spaces, the one that has the most favorable impact on the rating would be included in the evaluation. User preferences regarding each indicator and the points for all indicators for both apartments are shown in Table 5.

**Table 5.** Indicators, user preferences and apartment characteristics in the category of circulation (ci).

| Indicator | Communication between Rooms | Kitchen-Living Room Connection | Indoor-Outdoor Connection | Bedroom-Living Room Connection |
|---|---|---|---|---|
| **Indicator points** | 0/0.25/0.5/0.75/1 [1] | 0/0.5/1 [2] | 0/0.5/1 [2] | 0/1 |
| **User preferences** | 1 zoning<br>2 circular connection<br>3 via corridor<br>4 central living room<br>5 direct room to room connection | 1 connected by a door<br>2 separate rooms<br>3 in the same space | 1 living room<br>2 kitchen<br>3 bedroom | 1 [1] |
| **Apartment 1 characteristics**<br>Achieved points | circular connection<br>0.75 | connected by a door<br>1.0 | living room<br>1.0 | yes<br>0 |
| | | | | Σ = 2.75 |
| **Apartment 2 characteristic**<br>Achieved points | zoning<br>1.0 | connected by a door<br>1.0 | living room<br>1.0 | no<br>1.0 |
| | | | | Σ = 4 |

[1] If the apartment has a characteristic ranked under 1, it receives 1 point, for the other places, the score is reduced by one quarter of a point. [2] If the apartment has a characteristic ranked under 1, it receives 1 point; for the other places, the score is reduced by one half of a point.

Considering the points for each indicator and the share of this category in the total score, Equations (10) and (11) show the scores achieved by apartments 1 and 2 in this category. For the user, this category makes up 9.52% of the total rating.

$$AR_{(ci)}1 = \sum_{i=1}^{4} I_{(ci)i} \times \frac{S_{(ci)}}{NI_{(ci)}} = 2.75 \times \frac{9.52}{4} = 6.55 \quad (10)$$

$$AR_{(ci)}2 = \sum_{i=1}^{4} I_{(ci)i} \times \frac{S_{(ci)}}{NI_{(ci)}} = 4 \times \frac{9.52}{4} = 9.52 \quad (11)$$

### *3.6. Assessment of Apartments Spatial Organizations (so)*

The last indicator category evaluates the SCA that was not represented in the other categories and refers to the arrangement of rooms within the apartment. This category includes three indicators shown in Table 6 that evaluate the location of the dining area, the presence of a hallway that groups intimate spaces (bedrooms and bathrooms) and separates them from the entrance area, and the apartment's flexibility.

**Table 6.** Indicators, user preferences and apartment characteristics in the category of spatial organization (so).

| Indicator | Dining Table Location | Bedroom Area-Entrance Area Connection | Apartment Flexibility |
|---|---|---|---|
| **Indicator points** | 0/0.5/1 [1] | 0/1 | 0/1 |
| **User preferences** | 1 living room<br>2 kitchen<br>3 dining room | 4 [2] | 4 [2] |
| **Apartment 1 characteristics**<br>Achieved points | living room<br>1.0 | no<br>0 | no<br>0 |
| | | | Σ = 1 |
| **Apartment 2 characteristic**<br>Achieved points | living room<br>1.0 | yes<br>1.0 | no<br>0 |
| | | | Σ = 2 |

[1] If the apartment has a characteristic ranked under 1, it receives 1 point, for the other places the score is reduced by one half of the point; [2] Likert scale 1–5 (1 = least desirable; 5 = most desirable).

Both apartments have a dining area in the living room, so both apartments received one point each for these indicators. In Apartment 1, access to the sleeping area is through the living room, for which it received 0 points, while Apartment 2 received 1 point due to access to the sleeping area through the corridor connected to the entrance area. Due to the low flexibility caused by the location of the windows and the load-bearing structure, both apartments received 0 points for this indicator. For the user, the importance of this category is 23.81% of the total apartment rating. The overall score for this category is derived from Equation (12) for Apartment 1 and Equation (13) for Apartment 2.

$$AR_{(so)}1 = \sum\nolimits_{i=1}^{3} I_{(so)i} \times \frac{S_{(so)}}{NI_{(so)}} = 1 \times \frac{23.81}{3} = 7.94 \quad (12)$$

$$AR_{(so)}2 = \sum\nolimits_{i=1}^{3} I_{(so)i} \times \frac{S_{(so)}}{NI_{(so)}} = 2 \times \frac{23.81}{3} = 15.87 \quad (13)$$

### *3.7. Overal Apartments Ratings*

Based on the ratings for each category, the apartments achieved the overall ratings shown in Table 7.

**Table 7.** Overall apartments ratings.

| Indicator Category | Additional Rooms | Room Size | Windows Orientation and Ventilation | Circulation | Spatial Organization | Σ |
|---|---|---|---|---|---|---|
| | (ar) | (rs) | (wo) | (ci) | (so) | |
| **Apartment 1** | 12.70 | 42.86 | 2.64 | 6.55 | 7.94 | **72.69** |
| **Apartment 2** | 19.05 | 42.86 | 3.44 | 9.52 | 15.87 | **90.74** |

## 4. Discussion

The question of housing quality is one that researchers have been dealing with for many years and from many different angles. The quality of housing is of paramount importance not only for the professionals involved in housing construction (investors, architects, engineers of various professions, developers, real estate agents, etc.), but above all for the people who will be its buyers, or rather, the end users—their tenants. Since buying a home is the biggest investment of most people's lives [21], this also increases the responsibility of professionals to ensure the highest possible design and construction quality [2]. A high-quality living space not only plays a major role in a person's identity but is also of greatest importance for his or her quality of life and physical and psychological well-being [3]. With globalization and computerization leading to an increase in home-based work as well as the COVID pandemic impacting changes in people's lives and work, more is expected of homes today than in the past. A well-designed space is expected to, in addition to the usual functions and comfort of living, now provide the framework for many other functions.

Existing studies and models often look at housing quality from one perspective and use a relatively small number of indicators per category. FQA, for example, has only seven indicators [22]. Other methods do have more indicators, going as far as 55 in research from Vietnam [31]. The aim of this research was to develop a methodology that could enable a comprehensive assessment and comparison of quality criteria for different apartments and that would later allow us to develop a comprehensive housing quality assessment model that includes the assessment of apartments, residential buildings, settlements, and various social and economic aspects of housing. This paper therefore presents the development of a methodology and a model that evaluate the quality of the spatial characteristics of an apartment. The indicators used to evaluate the quality of apartment spatial characteristics were grouped into five categories: (i) additional rooms;

(ii) room size; (iii) window orientation and ventilation; (iv) circulation; and (v) spatial organization.

Since both needs and perceptions of housing quality vary from person to person and depend on personal characteristics and the environment in which they live, it is not possible to measure housing quality with a universal tool. Therefore, it is necessary to develop a tool that takes these circumstances into account. To achieve this, the wishes and attitudes of future users were considered when evaluating the apartment. This was achieved in two different ways:

(1) In most previous studies, all indicator categories often had the same proportion of the total score (only HQI [24] and HPEM [29] have the ability to change the weightings), which is not the reality from the perspective of the vast majority of users. In this model, each category has a different impact on the overall housing quality score, so each user defines the importance of each category for himself through the PCA method;

(2) Each user uses a questionnaire to determine which housing characteristics are important to them and to what extent, and what characteristics an apartment must have to be good for them and meet their criteria.

An assessment defined in this way allows a broader use of the model but also provides more accurate assessment results for a larger number of different users. The goal is not to provide a universal model for apartment assessment but to define a model that allows individual users to accurately evaluate the quality of different apartments in relation to their own needs and desires at the time of purchase.

The proposed model can be used to evaluate apartments that have a living room, a bathroom, a kitchen, and at least one bedroom. For the assessment of a studio apartment, the model must be redesigned to exclude questions about the square footage of the bedroom and its orientation from the assessment. This can be achieved by specifying the number of rooms in the apartment at the first stage of the assessment, whereupon the automatically determined indicators for small apartments are excluded; i.e., for larger apartments, a larger number of bedrooms is added.

Since the model is intended to be adapted to different users, it would be good to leave the possibility to add additional indicators that are important for a particular user. This would mean that before starting to evaluate the apartments, the user must enter the indicator in the model, as well as the number of points that the user thinks this characteristic, if present in the apartment, should achieve.

In evaluating the two apartments shown, the question of the size of the rooms arose. In the questionnaire, and therefore in the model itself, the minimum dimensions of the rooms that make up a quality apartment were defined. In Apartment 2, the bedroom for the child is larger than the minimum size indicated by the users. It is necessary to either: (i) define the interval of optimal square footage of rooms within the questionnaire so that all rooms within this interval receive points and all rooms smaller or larger do not receive points; or (ii) include in the questionnaire a question about how much larger square footage is acceptable so that the rooms of the apartment are evaluated accordingly. If this question were phrased differently, the rating of Apartment 2 according to the size of the room category could be different depending on the user's view.

Using the example of the rating indicators within the window orientation and ventilation category, it can be seen that a particular feature of the apartment that is not important to the user does not factor into the overall rating of the apartment, because regardless of whether the apartment has this feature or not, it does not play a decisive role in the overall rating of the apartment.

For indicators related to room orientation and other questions that offer multiple answer choices that the users rank from desirable (1) to least desirable (5), points are determined based on the number of answers (if there are four answer choices, such as room orientation, the minimum score is 0.25, and each higher-scoring attribute is scored 0.25 points higher). The points were defined in this way in a survey of experts in order to create a simpler scoring system. Further research needs to determine, through model validation with users:

(1) how much a different distribution of points would affect the overall score if the user defined the number of points for each answer, and
(2) how much more complicated the questionnaire would be if it contained such questions, and how much longer the entire assessment process would take.

In addition, the validation of the model should consider whether there is a difference in the assessment of orientation between bedrooms and whether the orientation of the master bedroom should be assessed separately from the children's bedrooms.

Based on the presented methodology, the future comprehensive model will be able to be used not only by users but also by various professionals. Depending on the data entered into the model (opinions of architects, various experts, or the public), and by adding or excluding individual indicators or categories of indicators, the model will be able to be used not only for the assessment of individual apartments but also for the assessment of housing quality in general.

What sets this model apart from previous research is the ability of the user to add value to both indicators and categories. The user can choose whether one category is more important to him than the other and by how much. One user might value room size five times more than window orientation, while the other might value it only three times more. Additionally, within each category, the user can assign ratings to those indicators he finds more suitable to his lifestyle preferences. For example, one user might prefer having the dining room table in the living room, while the other might prefer it in the kitchen. The model as it is presented allows for both of them to not only choose one or the other but also to rank them in order of importance. No previous research identified in the literature review process has had this level of adaptability to users' preferences.

## 5. Conclusions

This research presents the development of a housing quality assessment model based on the spatial characteristics of an apartment. Previous research has already tackled the issue, but too broadly by comparing many categories with only a few indicators. This research focuses specifically on the spatial aspects of the apartment, such as the number and orientation of the rooms, internal communication, the existence of certain areas, etc., while for the time being disregarding other dimensions that were often included in the previous research, such as the location of the building in its surroundings, the size of the building, available services, housing comfort, etc. Those other dimensions are quite subjective and depend greatly not only on the opinions of the user but also on each specific macro-location, or rather city, and perhaps even the culture of living in the country or area. Of course, these dimensions are important to the final decision of which apartment the user should buy, and the model is designed to be able to be expanded with these dimensions and additional indicators.

An additional contribution of this research with regards to previous assessment models is its ability to weigh both indicator categories and individual indicators. For example, one user might favor the spatial organization of the apartment more than the size of individual rooms, or perhaps the orientation more than the communication between the rooms. Therefore, the user can place more emphasis on those indicators he values more than others.

The model, as it stands, does have certain limitations. In addition to only measuring one of the aspects related to housing quality, there might be other spatial characteristics that the user would like to score but that were not included in the model. For this reason, it could be possible in later iterations of the model for the user to add their own categories and indicators. Also, and much more likely, some of the characteristics of the apartment could have the same value (for example, a south- and east-facing bedroom could be equally important) and the same number of points. For now, for simplicity's sake and to make the questionnaire manageable and user-friendly, this variability was left out.

However, future research on this topic could easily address these limitations. The inclusion of other dimensions was planned ahead, and the model is designed to be able to be expanded to include more dimensions, indicator categories, and indicators. Also, the questionnaire could be redesigned to allow for specific user preferences to be included.

The housing quality assessment model presented in this paper fills in the gap identified in the literature by specifically focusing in depth on one of the most important sets of criteria when assessing the quality of housing, the apartment itself, and further builds upon previous assessment models by including the opportunity for each user to tailor the importance of each of the categories to their own preferences.

**Funding:** This research received no external funding.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The author declares no conflict of interest.

## Appendix A

**Table A1.** Relationship between the questions in the survey and the indicators in the model and user responses in regard to preferred apartment characteristics.

| Survey Question (Evaluation Method) | | Offered Answers | User Responses |
|---|---|---|---|
| How desirable is it for the apartment to have more than one storage room (e.g., pantry, wardrobe)? | | Likert scale 1–5 (1 = least desirable; 5 = most desirable) | 4 |
| How desirable is it for the apartment to have an outdoor space (balcony, loggia, terrace)? | | | 5 |
| How desirable is it for the apartment to have an additional WC in addition to the bathroom? | | | 4 |
| In your opinion, what should be the minimum area (m2) for you to feel comfortable in the following rooms? [1] | Living room | <10; 10–15; 15–20; 20–25; 25–30 | 15–20 |
| | Living room with dining area | 10–15; 15–20; 20–25; 25–30; 30–35 | 20–25 |
| | Kitchen | <3; 3–6; 6–9; 9–12; 12–15 | 6–9 |
| | Kitchen with dining area | 4–8; 8–12; 12–16; 16–20; 20–24 | 12–16 |
| | Parents' bedroom | 5–10; 10–15; 15–20; 20–25; 25–30 | 10–15 |
| | Bedroom for two children | 5–10; 10–15; 15–20; 20–25; 25–30 | 10–15 |
| | Bedroom for one child | <5; 5–10; 10–15; 15–20; 20–25 | 5–10 |
| How desirable is it for the apartment to have a high ceiling (a room higher than 3.00 m)? | | Likert scale 1–5 (1 = least desirable; 5 = most desirable) | 1 |
| What is the most desirable orientation of the windows of the following rooms? | Living room | Rank from 1 to 4 from most desirable to least desirable (east, west, north, south) | 1 south; 2 east; 3 west; 4 north |
| | Kitchen | | 1 north; 2 east; 3 south; 4 west |
| | Bedroom | | 1 east; 2 south; 3 north; 4 west |
| How important is it that the kitchen has a window? | | Likert scale 1–5 (1 = least desirable; 5 = most desirable) | 5 |
| How important is it that the bathroom has a window? | | | 3 |
| How important is the two-sided orientation of the apartment? | | | 4 |
| What is the most convenient way to connect the rooms in the apartment? | | Rank from 1 to 5 from most convenient to least convenient (circular connection, central living room, via corridor, zoning, direct room to room connection) | 1 zoning; 2 circular connection; 3 via corridor; 4 central living room; 5 direct room to room connection |

**Table A1.** *Cont.*

| Survey Question (Evaluation Method) | Offered Answers | User Responses |
|---|---|---|
| What is the desirable connection between the kitchen and the living room? | Rank from 1 to 3 from most desirable to least desirable (separate rooms, connected by a door, in the same space) | 1 connected by a door; 2 separate rooms; 3 in the same space |
| From which room is it best to go outside (balcony, loggia, terrace)? | Rank from 1 to 3 from most desirable to least desirable (kitchen, living room, bedroom) | 1 living room; 2 kitchen; 3 bedroom |
| How desirable is it to enter the bedroom through the living room? | Likert scale 1–5 (1 = least desirable; 5 = most desirable) | 1 |
| What is the most desirable room for placing a dining table? | Rank from 1 to 3 from most desirable to least desirable (kitchen, living room, dining room) | 1 living room; 2 kitchen; 3 dining room |
| How desirable is it to enter the bedroom area of the apartment from a separate corridor connected directly to the entrance area? | Likert scale 1–5 (1 = least desirable; 5 = most desirable) | 4 |
| How desirable is it that the apartment can be reorganized with little construction work? | | 4 |

[1] The response intervals were defined based on the analysis of the room dimensions of apartments from the housing stock of the city of Osijek [39] and interviews with architects.

## Appendix B

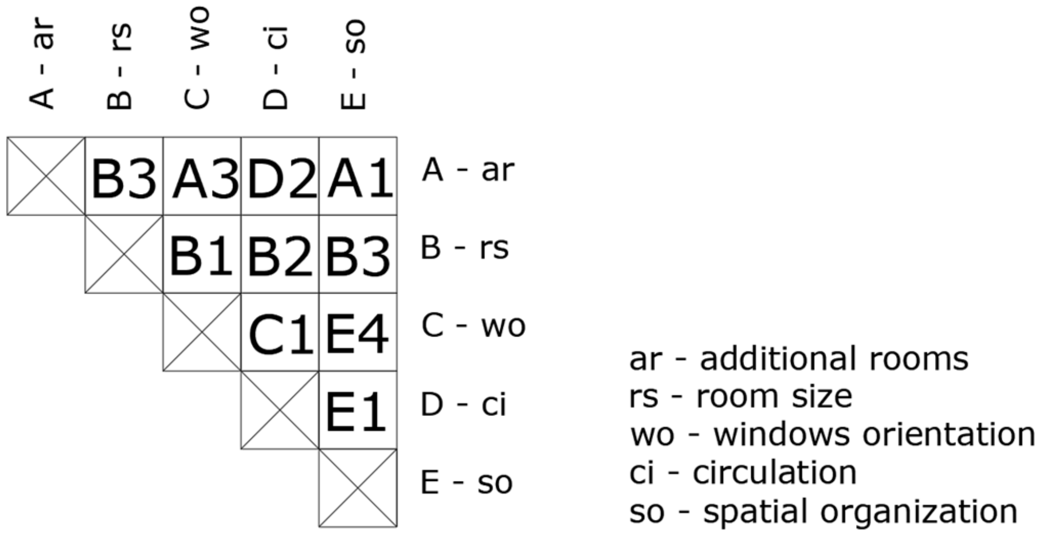



**Figure A1.** PCA results for a user who participated in the evaluation of apartments.

**Table A2.** Share of each category in the total rating of the apartment—according to PCA.

| **Indicator Category** | **Additional Rooms** | **Room Size** | **Windows Orientation and Ventilation** | **Circulation** | **Spatial Organization** | **Σ** |
|---|---|---|---|---|---|---|
| | **(ar)** | **(rs)** | **(wo)** | **(ci)** | **(so)** | |
| **PCA score** | 4 | 9 | 1 | 2 | 5 | 21 |
| **Share of the category in the final rating** | 19.05 | 42.86 | 4.76 | 9.52 | 23.81 | 100% |

## References


1. Herbers, D.J.; Mulder, C.H. Housing and subjective well-being of older adults in Europe. *J. Hous. Built Environ.* **2017**, *32*, 533–558. [CrossRef]
2. Nahtigal, D.; Grum, B. Segmentation and the Value Frame of Buyers of Residential Apartments. *Geod. Vestn.* **2015**, *59*, 71–101. [CrossRef]
3. Streimikiene, D. Quality of Life and Housing. *Int. J. Inf. Educ. Technol.* **2015**, *5*, 140–145. [CrossRef]
4. Ibem, E.O.; Amole, D. Residential Satisfaction in Public Core Housing in Abeokuta, Ogun State, Nigeria. *Soc. Indic. Res.* **2013**, *113*, 563–581. [CrossRef]
5. Tajudeen, A.; David, T.; Basirat, M.-A.; Azeez, B. Comparative Assessment of Students' Satisfaction with Hostel Accommodation in Selected Private Universities in Ogun State, Nigeria. *Eur. Sci. J.* **2016**, *12*, 410. [CrossRef]
6. Li, L.W.; Liu, J.; Zhang, Z.; Xu, H. Late-life depression in Rural China: Do village infrastructure and availability of community resources matter? *Int. J. Geriatr. Psychiatry* **2015**, *30*, 729–736. [CrossRef]
7. Natividade-Jesus, E.; Coutinho-Rodrigues, J.; Antunes, C.H. A multicriteria decision support system for housing evaluation. *Decis. Support Syst.* **2007**, *43*, 779–790. [CrossRef]
8. Haddad, M.; Judeh, M.; Haddad, S.I. Factors Affecting Buying Behavior of an Apartment an Empirical Investigation in Amman, Jordan. *Res. J. Appl. Sci. Eng. Technol.* **2011**, *3*, 234–239.
9. James, R.N. Multifamily Housing Characteristics and Tenant Satisfaction. *J. Perform. Constr. Facil.* **2007**, *21*, 472–480. [CrossRef]
10. Chohan, A.H.; Irfan, A.; Awad, J. Development of Quality Indicators of Housing Design (QIHD), an Approach to Improve Design Quality of Affordable Housing. *Open House Int.* **2015**, *40*, 10–17. [CrossRef]
11. Elsinga, M.; Hoekstra, J. Homeownership and housing satisfaction. *J. Hous. Built Environ.* **2005**, *20*, 401–424. [CrossRef]
12. Tibesigwa, B.M.; Hao, L.; Karumuna, B.V. The concept of spatial quality and its challenges on exercised affordable housing design typology in Dar es Salaam—Tanzania. *Habitat Int.* **2017**, *59*, 44–59. [CrossRef]
13. Acre, F.; Wyckmans, A. Spatial quality determinants for residential building renovation: A methodological approach to the development of spatial quality assessment. *Int. J. Sustain. Build. Technol. Urban Dev.* **2014**, *5*, 183–204. [CrossRef]
14. Mohit, M.A.; Ibrahim, M.; Rashid, Y.R. Assessment of residential satisfaction in newly designed public low-cost housing in Kuala Lumpur, Malaysia. *Habitat Int.* **2010**, *34*, 18–27. [CrossRef]
15. Kabisch, S.; Poessneck, J.; Soeding, M.; Schlink, U. Measuring residential satisfaction over time: Results from a unique long-term study of a large housing estate. *Hous. Stud.* **2022**, *37*, 1858–1876. [CrossRef]
16. Milić, J.; Zhou, J. Residential satisfaction among young people in post-socialist countries: The case of Serbia. *J. Hous. Built Environ.* **2018**, *33*, 715–730. [CrossRef]
17. Tanaphoom, W.; Bart, D. An Overview of Public Housing Characteristics and Living Satisfactions: Old and New Public Housing Project in Bangkok. *Procedia Environ. Sci.* **2015**, *28*, 689–697. [CrossRef]
18. Li, J.; Li, D.; Ning, X.; Sun, J.; Du, H. Residential satisfaction among resettled tenants in public rental housing in Wuhan, China. *J. Hous. Built Environ.* **2019**, *34*, 1125–1148. [CrossRef]
19. Choi, J.; Cho, T. Comparing Perception Concerning the Importance of Apartment Complex Components Between Consumers and Housing Providers. *J. Asian Archit. Build. Eng.* **2014**, *13*, 109–116. [CrossRef]
20. Borgoni, R.; Michelangeli, A.; Pirola, F. *Residential Satisfaction for a Continuum of Households: Evidence from European Countries*; Global Labor Organization (GLO): Milan, Italy, 2018.
21. Sinha, R.C.; Sarkar, S.; Mandal, N.R. An Overview of Key Indicators and Evaluation Tools for Assessing Housing Quality: A Literature Review. *J. Inst. Eng. (India) Ser. A* **2017**, *98*, 337–347. [CrossRef]
22. Moreira da Costa, J.; Sampaio, M.F. User Information in the housing market. In Proceedings of the World Congress on Housing, Santander, Spain, 26–29 October 2010; pp. 1–8.
23. Homes and Communities Agency. Housing Quality Indicators. Available online: https://www.gov.uk/guidance/housing-quality-indicators (accessed on 2 April 2023).
24. The National Affordable Homes Agency. 721 Housing Quality Indicators (HQI) Form. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/366634/721_hqi_form_4_apr_08_update_20080820153028.pdf (accessed on 22 March 2023).
25. Harrison, A. Housing Quality Indicators. Available online: https://www.housingauthority.gov.hk/eng/events/conf/conferen/pdf/eandrew.pdf (accessed on 13 January 2023).
26. Design Quality Indicator. Available online: https://www.dqi.org.uk/ (accessed on 14 January 2023).
27. Rogers, P. CIC Design Quality Indicator Online. Available online: http://www.dqi.org.uk/dqi/Common/DQIOnline.pdf (accessed on 14 January 2023).
28. SEL. Available online: https://www.wbs.admin.ch/fr/application/methodologie (accessed on 2 April 2023).
29. Kim, S.-S.; Yang, I.; Yeo, M.; Kim, K.-w. Development of a housing performance evaluation model for multi-family residential buildings in Korea. *Build. Environ.* **2005**, *40*, 1103–1116. [CrossRef]
30. Chohan, A.; Che-Ani, A.; Shar, B.; Awad, J.; Jawaid, A.; Mohd Tawil, N. A Model of Housing Quality Determinants (HQD) for Affordable Housing. *J. Constr. Dev. Ctries.* **2015**, *20*, 117–136.
31. Le, L.H.; Ta, A.D.; Dang, H.Q. Building up a System of Indicators to Measure Social Housing Quality in Vietnam. *Procedia Eng.* **2016**, *142*, 116–123. [CrossRef]

32. Mercader-Moyano, P.; Morat-Pérez, O.; Muñoz-González, C. Housing Evaluation Methodology in a Situation of Social Poverty to Guarantee Sustainable Cities: The Satisfaction Dimension for the Case of Mexico. *Sustainability* **2021**, *13*, 11199. [CrossRef]
33. Yau, Y.; Ho, D.; Wing, C.K.; Lau, W.-y. Estimation algorithm for predicting the performance of private apartment buildings in Hong Kong. *Struct. Surv.* **2009**, *27*, 372–389. [CrossRef]
34. Chohan, A.H. Matrix of Affordable Housing Assessment: A Development Process. *Designs* **2022**, *6*, 4. [CrossRef]
35. BREEAM. Available online: https://bregroup.com/products/breeam/ (accessed on 2 April 2023).
36. LEED. Available online: https://www.usgbc.org/leed (accessed on 3 April 2023).
37. Kurian, S.M.; Thampuran, A. Assessment of Housing Quality. *Inst. Town Plan. India J.* **2011**, *8*, 74–85.
38. Wimalasena, N.N.; Chang-Richards, A.; Wang, K.; Dirks, K. Housing quality indicators: A systematic review. In Proceedings of the 10th World Construction Symposium, Colombo, Sri Lanka, 24–26 June 2022; pp. 531–544.
39. Brkanić, I.; Stober, D.; Mihić, M. A Comparative Analysis of the Spatial Configuration of Apartments Built in Osijek, Croatia, between 1930 and 2015. *J. Asian Archit. Build. Eng.* **2018**, *17*, 23–30. [CrossRef]
40. Brkanić, I.; Atanacković-Jeličić, J. Socialist Housing in Osijek. *Electron. J. Fac. Civ. Eng. Osijek e-GFOS* **2018**, *17*, 10. [CrossRef]
41. Brkanić, I. Housing Quality Assessment criteria. *Electron. J. Fac. Civ. Eng. Osijek e-GFOS* **2017**, *8*, 37–47. [CrossRef]
42. Brkanić, I. Comparison of Architects' and users' attitudes toward spatial characteristics of apartments. In Proceedings of the 5th International Academic Conference on Places and Technologies, Belgrade, Serbia, 26–27 April 2018; pp. 445–452.
43. Paired Comparison Analysis. Available online: https://www.nydi.org/images/cps-tools/focusing-tools/Paired_Comparison_Analysis.pdf (accessed on 4 April 2023).