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MULTICRITERIAL SUSTAINABILITY ASSESSMENT OF RESIDENTIAL BUILDINGS

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Abstract. A simple method for the assessment of sustainability of a residential building is proposed. The method consists of two steps. First, areas that influence sustainability level of the building (e.g. building architecture, design, in-built materials) are identified. For each area, several elements and corresponding indicators are determined. Depending on their nature, the indicators are expressed either in quantitative or qualitative terms. The impact areas and their corresponding elements influence all three aspects of sustainability. In the second step, the indicators are aggregated according to their influence on individual sustainability aspects. Special attention is placed to the determination of weights assigned to the indicators in order to make the assessment method relevant in the local context. Initially, the consensus-based method within the research team was used as a technique for aggregated indicators' weighting. Later, the open discourses among the developers and stakeholders, as well as surveys, were employed to determine the aggregated indicators' weights. The proposed method is applied to a selected sample building, and the analysis of the results is carried out. The results obtained show that the completeness and reliability of the input data is crucial for the reliability of the proposed assessment method. Subjectivity in evaluators' judgments required to score some indicators needs to be reduced by introducing adequate training of the assessors. The feedback from the potential users shows that the method has a potential for wider future implementation in practice.

Keywords: residential building, construction quality, assessment method, decision method, sustainability indicators, labelling.

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1. Introduction

Many factors, such as the apartment size and layout, age, size and location of the building, proximity to community and transport services (e.g. schools, bus stops) affect the quality of life of the residents (Lai and Yik 2009; Ozsoy *et al.* 1996; Maliene and Malys 2009). The selling price or the rent for an apartment is closely related to the perceived quality of life; therefore, these factors affect the market price, or the rent, of the residential units as well. In order to facilitate the market transactions, the ranking process used to determine the price (or rent, respectively) should be transparent and rational. However, this process is often disguised by additional ambiguous and implicit demands of potential buyers.

Overview of current practice in Slovenia shows that various informal rankings of multi-apartment buildings are used at selling or renting of apartments, mostly with no rational background. As a consequence, national and municipal housing funds, social housing associations, facility managers, real estate managers, consumers associations, the ministry responsible for residential policy as well as architects, contractors and investment companies expressed a demand for a rational method for the residential building quality assessment. The method should enhance the transparency of the ranking process, facilitate the ranking of the apartments and buildings, and consequently influence the real estate prices.

1.1. Scope of the paper

The paper presents the development of the methodology to be used in the assessment of the residential building stock quality adapted to local needs in Slovenia. The study is focused to the technical and functional aspects of quality, as opposed to the artistic and aesthetic aspects of the residential stock. In addition, as potential users indicated the need to include the sustainability aspects, the sustainability indicators were also taken into the account when developing the methodology.

1.2. Methods employed

Survey of the existing assessment approaches and methods was carried out in order to formulate the foundation of the proposed methodology. To obtain the criteria and other parameters that define the methodology applicable in Slovenia, expert group meetings and semi-structured interviews were used. The conceptual framework of quality labelling that is already established for construction products and services was adapted to sustainability assessment of residential buildings. The applicability of the methodology was tested for limited number of case studies, and analysis of the results was carried out.

2. Background

2.1. Survey of existing EU approaches

A new generation of buyers, aware of the importance of the sustainable built environment, has generated additional requirements for the apartments and buildings that should be taken into account in the method to be developed. These requirements are based on the perception of sustainable building, which has significantly changed over the last years. In the beginning, the assessment criteria employed in the sustainability assessment process were of technical nature, such as rational use of energy and limited resources, or reduction of the environmental impacts (Forsberg and Von Malmborg 2004; Šeduikytė and Bliūdžius 2005). Recently, the non-technical topics, i.e. economic and social sustainability, gained the importance and captured the public attention (Zavadskas and Antucheviciene 2006; Banaitiene *et al.* 2008; Viteikienė and Zavadskas 2007; Zavadskas *et al.* 2009). Successful German (Kuhndt and Liedtke 1999) and Danish (Olsen 2000) methodologies for building sustainability evaluation are reported, potentially applicable also in the above described context. Portuguese method for sustainability assessment LeaderA (Pinheiro 2007) is mainly based in environmental dimensions with elements of social sustainability. McDonald *et al.* (2009) reported a sustainability assessment method for communities, developed in UK, with a strong focus on evaluation of social aspect. Similar models that take into account all sustainability aspects have been developed for urban infrastructure as well (Ugwu *et al.* 2006a, b; Zavadskas *et al.* 2008b).

During the last decade, many internationally recognized methodologies were developed for holistic assessment of the building sustainability like LEED (Leadership in Energy and Environmental Design) (Humbert *et al.* 2007), BREEAM (Building Research Establishment Environmental Assessment Method) (BREEAM 2009), GBTOOL, SPEAR (Sustainable Project Appraisal Routine), DGNB (German certificate for sustainable buildings) (German ... 2009), LEnSE (Label for environmental, social and economic buildings) or EU eco label (for tourist accommodations). These methodologies take into account factors like the energy and CO_2 emissions, resource consumption, indoor environmental quality, health and comfort, life cycle costs (LCC), transport, sustainable materials use and many other sustainability issues (Erlandsson and Borg 2003). Some of the above methods (e.g. BREEAM, LEED) are also customized for different building types, in particular for apartment buildings.

The building sustainability is assessed through the environmental, economic and social aspects. The assessment methods define various indicators describing the sustainability elements. As the building assessment process is based on the application of multiple attributes, the decision-making, as a part of the process of optimization of building sustainability, is carried out by the multi-criteria analysis (Zavadskas *et al.* 2008 a, b).

According to the Agenda 21 on sustainable construction (1999), the strategies for sustainable construction should be compatible with the climate, the culture, building traditions, the level of industrial development and the nature of the building stock. Building sustainability can, therefore, be evaluated only in relation to the local conditions and, consequently, specific national criteria are required.

Research project COST C8 Sustainable Urban Infrastructure summarized (Lahti *et al.* 2006) state-of-the-art in methods, indicators and criteria for the evaluation of sustainability, aiming to support the decision-makers in local authorities. An overview of different approaches to the evaluation of urban infrastructure sustainability is presented. Lahti et al. (2006) considers the urban infrastructure to be composed of transportation, energy, water, sewage and information networks as well as waste management and blue-green infrastructure, in terms of supply and demand side, i.e. including the buildings that define the demand to be covered by the infrastructural networks. Best practice projects in sustainable urban infrastructure are collected, summarized and illustrated by an overview of selected case studies. The research was focused predominantly to the technical view of infrastructure, although social and economic aspects were not neglected.

In addition, the FP6 project PETUS (The Practical Evaluation Tools for Urban Sustainability) (Jones 2005) aims at giving a complete survey of tools for the evaluation of urban sustainability, with respect to the particular scope and level of the analysis. PETUS project contributes to bridge the existing gap between theoretical frameworks and practical approaches applied in everyday practice to evaluate urban sustainability when building and managing urban technical infrastructure down to the building level.

COST C25 Sustainability of Construction is promoting science-based developments of the sustainable construction in Europe through collection and collaborative analysis of scientific results concerning life time structural engineering, and especially integration of environmental assessment methods and tools, advanced materials and technologies as well as construction processes, both for new constructions and the rehabilitation of the existing ones. Braganca (Braganca *et al.* 2007) evaluated the state-of-the art in sustainability assessment of a whole building indicating the necessity to upgrade the early methods based on summing up the components' assessment with a performance based decision-making tool for building sustainability assessment.

2.2. Development of the Slovenian sustainability assessment methodology for buildings

A successful building design is a result of a fruitful communication among all stakeholders. Traditionally, in Slovenian practice, architects, engineers and clients (developers or public bodies) are involved in the design stage, while the end-user (buyers or tenants) have very low influence on the parameters of the building. The traditional building process also limits the innovation level in the design of residential buildings, mainly because the clients wish to reduce the costs both at design and construction phase by using already proved solutions. When the apartments are placed to the market, they are often groundlessly described as high standard flats, promising high quality building, healthy environment, ecological materials and exceptional comfort.

As a consequence, the residential building stakeholders have recognized the need for quality assessment of buildings, established on well defined criteria. Identification, selection and weight determination of explicit criteria is the first step of this process that would enable the potential tenants and buyers of apartments to expect an adequate value for the money paid for the flats. As a successful scheme of national labelling of construction products and services already existed, an idea to transfer this already established concept to the building assessment emerged.

Although clients, designers, engineers, end-users and other stakeholders aim at using the building products with positive economic, environmental and/or social impact, there is currently a lack of reliable criteria for distinguishing among different buildings products available on the market.

In order to support sustainable decision in selection of the building products, the "Quality label in building and civil engineering" (ZKG label) was introduced in Slovenia in 1997. ZKG is a voluntary quality-labelling national scheme, supported by the Slovenian Ministry of Environment and Spatial Planning, Ministry of Economy and Ministry of Science. Quality labels are awarded to building products that pass the pre-defined threshold (i.e. receive sufficient number of points) and also rank among top 15% in the relevant category. Quality assessment criteria used in the selection process are developed and updated regularly based on relevant current R&D findings by a group of independent experts in the domain. Today, this labelling scheme is well established on the Slovenian market. The producers have recognized the competitive advantage associated with the label and submit their products to the assessment, when the technical quality and sustainability of the building product has to be demonstrated. Since 1997, more than 100 building products and services were awarded with the ZKG quality label.

The quality labelling of energy efficient windows is considered to be one of the ZKG's most successful projects (Šijanec Zavrl and Tomšič 2000). The 1999–2002 labelled windows were directly eligible for state subsidies for energy efficiency. The label is awarded to energy efficient windows, produced by companies concerned with the environmental aspect of their production and quality of their service. The evaluation scheme includes different criteria with relative weights that reflect their relevance to Slovenian situation. The criteria employed for the assessment of windows are:

- measurable technical criteria (U values, air-permeability, water tightness, mechanic characteristics),
- not measurable technical criteria (convenience of technical solution, functionality of the product)
- environmental criteria,
- efficiency and quality of production processes,
- satisfaction of buyers, fulfilment of the company's business plan,
- global impact on the society and the environment.

The residential buildings stakeholders acknowledged that extending the concept of ZKG quality label to residential buildings could influence the real-estate market priorities, improve the overall technical quality of the buildings and, consequently, contribute to the sustainable development of built environment. Potential users of the assessment methodology are end-users, i.e. buyers and tenants, clients (private and public), municipalities, architects, engineers, real estate agencies, building managers, the building industry and, last but not least, the ministry responsible for the strategic development plans in the residential domain.

Different evaluation methods for apartments and buildings were used in the past, mainly based on simple measurable criteria and aimed at ranking of rental flats or determination of the real estate value. None of the methods used so far in Slovenia has a broader scope, and does not take into account the behaviour and impacts of the building through all phases of the life cycle (Šijanec Zavrl and Gumilar 2003).

By extending the above-mentioned ZGK concept to the assessment of buildings, one should be aware that the task of developing the criteria for sustainable residential buildings describing all sustainability areas is far more complex than developing evaluation criteria for a particular building product. If the methodology is to be successfully implemented in practice, the criteria should be based on common views of the majority of stakeholders. The definition of these views upon sustainability indicators for a building represents, therefore, a challenging task.

3. Methodology for the assessment of building sustainability

The criteria for the evaluation of residential building quality were based on the three core principles of sustainability. The impact areas of building technical quality were defined and the associated list of measurable or descriptive elements was developed. The impact areas and their elements that influence environmental, economic and/or social aspect of sustainability were defined by the stakeholders from housing funds (social housing, investors and users), construction sector (engineers, contractors, consultants, researchers) and the ministry in charge of housing in a series of brainstorming sessions.

In the second step, the indicators, originally defined for a particular influencing element, were aggregated according to their impact to sustainability aspects.

3.1. Assumptions and limitations

The following assumptions and limitations were taken into the account.

Targeted product for the evaluation. The assessment methodology is planned to be used for the evaluation of recently built apartment buildings that passed the commissioning.

Aggregation level of criteria. The criteria should cover comprehensive and easily available information. The duplication of planners' work, regular quality control and commissioning during the evaluation process should be avoided in order to allow limited-in-time and affordable evaluation of the building technical quality. Quality assessment of a single product can be based mostly on very specific, measurable technical criteria. Applying the same principle to the building assessment shall create a need to analyze a large number of technical criteria. Wider and more complex criteria, with measurable and/or well descriptive character, that can be defined by a set of indicators, are therefore desired.

Evaluation process. The methodology shall allow self-evaluation based on the defined criteria. The client project team itself should be able to describe the key technical elements that contribute to the overall sustainability of the building. Based on this information together with building plans, site visit and discussion with the apartment owners and tenants, the assessment should be completed.

Expert group. The criteria should reflect the opinion and needs in the local Slovenian framework. Therefore, the expert group consists of established researchers from specific technical areas. In order to integrate the view of the stakeholders into the criteria, the experts from the building industry, planning and construction companies, major clients, consumers associations and municipal housing funds participate in the definition of evaluation criteria and in the sensitivity analysis of the assessment methodology on the pilot buildings.

3.2. Areas and elements influencing sustainability

Following the traditional structure and content of design documentation, the following impact areas have been considered: building architecture, urbanism, building structure, building materials, HVAC systems, electric installation and intelligent systems, building physics, functionality and maintenance. The selected structure of impact areas facilitates the later provision of building data needed for the assessment. A list of elements to be evaluated has been prepared for each of above-mentioned areas. Table 1 presents selected examples of the evaluation elements (e.g. when the area is building physics, possible evaluation elements are thermal insulation of envelope, daylighting – visual comfort, acoustic comfort, energy efficiency etc).

Table 1. Impact areas and examples of elements that influence building sustainability

No.	Impact area	Elements (examples)
1	Building architecture	Functionality of apartments Parking places LCC maintenance and repair costs etc.
2	Urbanism	Functional independence of a settlement Accessibility of public transport etc.
3	Building structure	Effectiveness of structure for earthquake load Economy of structure in life cycle etc.
4	Materials	Embedded energy Re-use and recycling etc.
5	Building physics	Thermal insulation of envelope Daylighting – visual comfort Acoustic comfort Energy efficiency of building etc.
6	HVAC systems	Hot water preparation – RES CO_2 emission etc.
7	Electric installation	Intelligent systems Energy saving bulbs etc.

Each evaluation element is followed by one or more specific criteria, describing the element's relevance to evaluation, and by one or more detailed indicators for its appraisal (Table 2). Each criterion may be described either with (a) several measurable indicators, (b) several descriptive indicators, (c) with a single measurable indicator or (d) with a single descriptive indicator. The indicators are, therefore, either measurable or descriptive, depending on the nature of the criterion.

Table 2. Example of criteria described with (a) several measurable indicators, (b) several descriptive indicators, (c) with a single measurable indicator and (d) with a single descriptive indicator

AREA	ELEMENT	CRITERIUM	INDICATOR(S)					
Building physics	Thermal insulation of building envelope	(a) U value	U value of wall, roof, windows, overall specific heat losses					
			THRESHOLD	POOR	AVERAGE	EXPECTED	DESIRED	TARGET
			Regulation	0.4 0.2 1.7 0.5	0.4 0.2 1.5 0.5	0.3 0.18 1.3 0.45	0.25 0.17 1.1 0.4	0.17 0.15 0,9 0.3
Building architecture	Parking places	(b) Availability, accessibility, safety	Number of parking places and safety level					
			THRESHOLD	POOR	AVERAGE	EXPECTED	DESIRED	TARGET
			Regulation	< 1 per apartment	Min. 1 per ap. + some for visitors, min 1 on the ground level	Min. 2 per ap. , security control		Min. 2 per ap. + 1 per ap. for visits, closed, private area
HVAC systems	Hot water preparation	(c) Participation of renewables	Percentage of RES used for hot water preparation					
			THRESHOLD	POOR	AVERAGE	EXPECTED	DESIRED	TARGET
			0%	0%	0%	50%	75%	100%
Materials	Embedded energy	(d) Acceptability of building material in respect of grey energy	Level of acceptability					
			THRESHOLD	LOW	AVERAGE	EXPECTED	DESIRED	TARGET
			No requirements	Steel	Concrete	Brick masonry	Adobe bricks	Wood

3.3. Indicators

In general, one or more criteria can be assigned to the element under consideration. Each criterion is further described by one or more indicators, as shown in part a) of the Table 2, where the specific heat losses expressed by the U value are identified separately for walls, roof, windows and the overall building. The quality level of the element under consideration is expressed by its utility score with respect to the selected criterion. The score is selected from the list of indicators.

The indicators allow up to five levels ranking of technical quality. The compliance with the minimum technical requirements defined in the national regulation is assumed as a threshold for further evaluation. Up to five additional quality levels are defined, from poor performance (low, but still acceptable quality) via average (business as usual), expected (additional effort mobilised) and desired performance (involves new technologies and additional costs) to target performance (i.e. corresponding to the sustainable apartment buildings integrating state-of-the-art technologies and solutions) (Šijanec Zavrl and Gumilar 2003). The quality levels are converted into numeric values, i.e. points finally assigned to criteria and/or indicators, where 0 points correspond to threshold, 1 to 5 points are given to other levels from poor to target level.

3.4. Weighting of sustainability indicators

The indicators are assigned to a particular criterion as presented in Table 2. The criteria differ according to their relative impact to the influencing element. Therefore, weighting was introduced in order to reflect the national context of the building sustainability.

To increase the reliability of the weights, in the first step, a consensus-based method was selected as a technique for weighting of aggregated indicators of particular criterion. An open discourse among the developers and participating stakeholders was used for the determination of aggregated indicators' weights. The concordance of the experts' opinions may also be evaluated by calculating the concordance degree (Ginevičius *et al.* 2008).

More recently, the poll was introduced in order to evaluate the stakeholders' opinion about the relevance of particular criteria to the building quality. The polls were carried out on a test sample of 30 stakeholders closely linked to the Residential Chamber of Slovenia. The questionnaire was distributed to the representatives of municipal housing funds, facility managers, investors and contractors specialised on high-rise residential buildings and they were then asked to indicate their perception of importance for individual criteria and relevance of these criteria to building sustainability.

An overview of criteria within "Energy efficiency" element of the area "Building physics" and criteria within "Functional characteristics of apartment building" element of the area "Architecture" is available in Table 3 and Table 4, respectively. The results of the poll for the "Energy efficiency" element that belongs to the area "Building physics" are presented in Fig. 1, and results for "Functional characteristics of apartment building" element belonging to the area "Architecture" in Fig. 2. It can be seen that for the Building physics – Energy efficiency area, the stakeholders place a lot of importance to low U values of envelope and low

CO_2 emissions due to energy use, while in case of Architecture – Functional characteristics of apartment building the most influencing criteria are functionality of flats and parking places. The weights for particular evaluation criteria in the area "Architecture", the field "Functional characteristics of apartment building" are determined on the basis of the poll results as shown in Table 5.

Table 3. Overview of criteria within "Functional characteristics of apartment building" element of the area "Architecture", as used in the poll

Area – "Architecture"				
Element – "Functional characteristics of apartment building"		Element	…	Element
Criterion *j* = 1	Main entrance (size, functionality, security)			
Criterion *j* = 2	Common storage room for bicycles			
Criterion *j* = 3	Common storage room for carriages			
Criterion *j* = 4	Common storage room for cleaning and maintenance service			
Criterion *j* = 5	Number of parking places, accessibility, security			
Criterion *j* = 6	Flexibility of flats			
Criterion *j* = 7	Elevator in the buildings			

Table 4. Overview of criteria within "Energy efficiency" element of the area "Building physics" as used in the poll

Area – "Building physics"				
Element – "Energy efficiency of building"		Element	…	Element
Criterion *j* = 1	Low U values of envelope			
Criterion *j* = 2	Low heat demand for space heating			
Criterion *j* = 3	Low final energy use			
Criterion *j* = 4	Low CO_2 emissions due to energy demand			

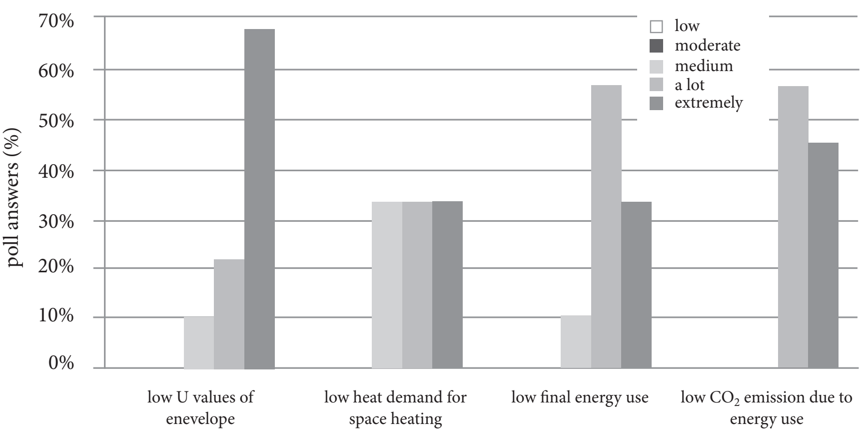

Fig. 1. Relative importance of criteria within "Energy efficiency" element from the area "Building physics" as determined by the poll

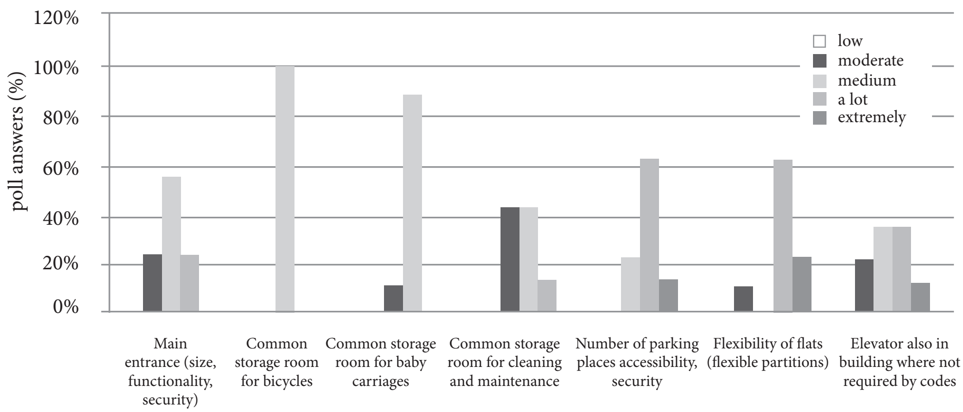

Fig. 2. Relative importance of criteria within "Functional characteristics of apartment building" element from the area "Architecture" as determined by the poll

Table 5. Weights for some evaluation elements based on the answers from test poll among stakeholders

Importance of element		**Importance of particular elements of "Functional characteristics of apartment building" field within the area "Architecture" and determination of weights Relative number of responses obtained in test poll among stakeholders**				
Descriptive	Numeric	Common storage room for baby carriages, bicycles	Common storage room for cleaning and maintenance	Number of parking places accessibility, security	Flexibility of flats (flexible partitions)	Elevator also in building where not required by codes
	w_i	a_{i1}	a_{i2}	a_{i3}	a_{i4}	a_{i5}
Low	1	0%	0%	0%	0%	0%
Moderate	2	11%	44%	0%	11%	22%
Medium	3	89%	44%	22%	0%	33%
A lot	4	0%	11%	67%	67%	33%
Extremely	5	0%	0%	11%	22%	11%
Weight $W_j = \Sigma\, w_i\, a_{ij}$	[–]	2.89	2.67	3.89	4.00	3.33

3.5. Aggregation of indicators for sustainability assessment

Once the experts evaluating particular technical area provide the descriptive and numerical values of indicators, the corresponding score for each indicator is converted into a numeric value (0 – threshold, 1 – poor, 2 – average, 3 – expected, 4 – desired, 5 – target) and weighted according to the importance of criterion determined by the experts and other stakeholders.

Finally, the indicators with their corresponding weighted values are aggregated in eight groups according to their impact to three sustainability aspects (Fig. 3). During the application of the method, every indicator from the impact area has to be assigned:
- the corresponding weight (W_j),
- its corresponding score in numeric value (0–5 points), obtained during evaluation process (s_j),
- affiliation with one of eight groups of aggregated and weighted indicators influencing the sustainability areas.

Each of eight groups of indicators is presented with a final score from 1 to 5 points (where 0 to 1 point indicates non-compliancy with regulation). The final score S, which is determined for all eight groups of indicators, is obtained by normalizing the sum of weighted indicators' values by the maximum possible score:

$$S = \frac{\sum_{j=1}^{m} s_j W_j}{5m}.$$

m denotes the total number of indicators assigned to the particular group of aggregated and weighted indicators.

For the graphic presentation of sustainability assessment results, eight groups of aggregated indicators are nested around three main sustainability axes, i.e. economic, environmental and social sustainability (Table 6, Fig. 3). A multi-criteria presentation of the assessment results as presented in Fig. 3 is highly important in order to clearly present the sustainability information per area. Further aggregation of scores, however, should be avoided since the quality of information might be lost.

4. Case study

The presented method was used to assess the sustainability of a selected residential building built in the early 90s in Ljubljana. The building has 6 storeys with 128 flats, and it is accessible from six staircases. The results are presented in Fig. 4. The test evaluation showed good results in terms of economic indicators, since traditional cost effective solutions, normally applied in buildings to be sold on the market, were used. The building, however, could have reached better assessment in the environmental aspect, i.e. in terms of use of renewable energy sources and low carbon materials. Comfort indicators as well as architectural indicators are appropriate for new building design, and the structural efficiency was estimated to fulfil the expectations.

It should be noted that rather than validation of sustainability aspects, the scope of the case study analysis was to check if the evaluation of criteria and determination of indicators ranking was feasible with respect to the available data and competences of the involved actors as well as to identify the weak points in the procedure.

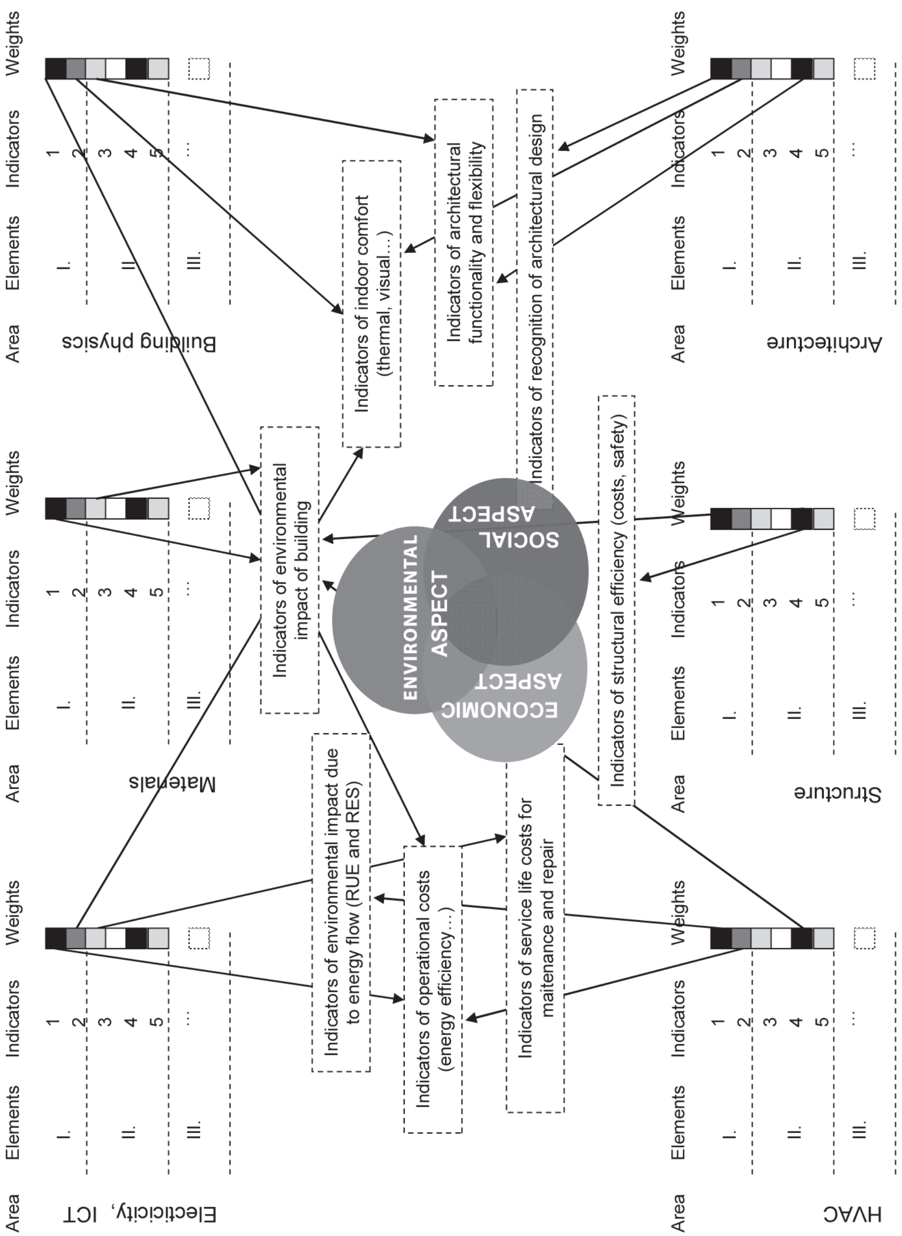

Fig. 3. Schematic presentation of aggregation of sustainability indicators in thematic groups related to building sustainability, i.e. assignment of indicators with one of eight groups of aggregated weighted indicators

Table 6. Eight groups of aggregated and weighted indicators and their influence on sustainability areas

Aggregated group of weighted indicators	**Influence on sustainaibility axis**		
	Environmental sustainability	**Social sustainability**	**Economic sustainability**
Indicators of environmental impact of building materials	xx	–	–
Indicators of indoor comfort	x	x	–
Indicators of architectural functionality and flexibility	–	xx	–
Indicators of recognition of architectural design	–	xx	–
Indicators of structural efficiency (safety and economy)	–	x	x
Indicators of service life costs for maintenance and repair	–	–	xx
Indicators of operational costs (energy efficiency)	–	–	xx
Indicators of environmental impacts due to energy flow (building energy efficiency and renewable energy use)	x	–	x

Legend:
xx strong impact
x moderate impact
– no impact

Preliminary conclusions are summarized as follows. First, it is clear that the reliability of the input data for evaluation is essential. The assessment is based as much as possible on the design and commissioning data; missing or unreliable information may lead to decreased reliability of the assessment. The data required for the evaluation are sometimes difficult to obtain, in spite of the fact that the indicators are defined and structured according to the information available in design phase (impact areas in Table 1). It may happen that due to an obsolete regulation, some analyses were not required at the design phase, so the necessary data are missing, while at the same time the client refuses to accept the additional required work load and costs. This problem will be reduced when the building regulation will be fully developed and as much as possible integrated in the definition of indicators.

5. Results and discussion

The presented method for the evaluation of building sustainability was initiated by a group of experts whose goal was to develop a method for identification of technical quality level of a building. Soon, it was concluded that the information about the technical quality of particular elements does not satisfy the end-users, as the maximum quality is not always

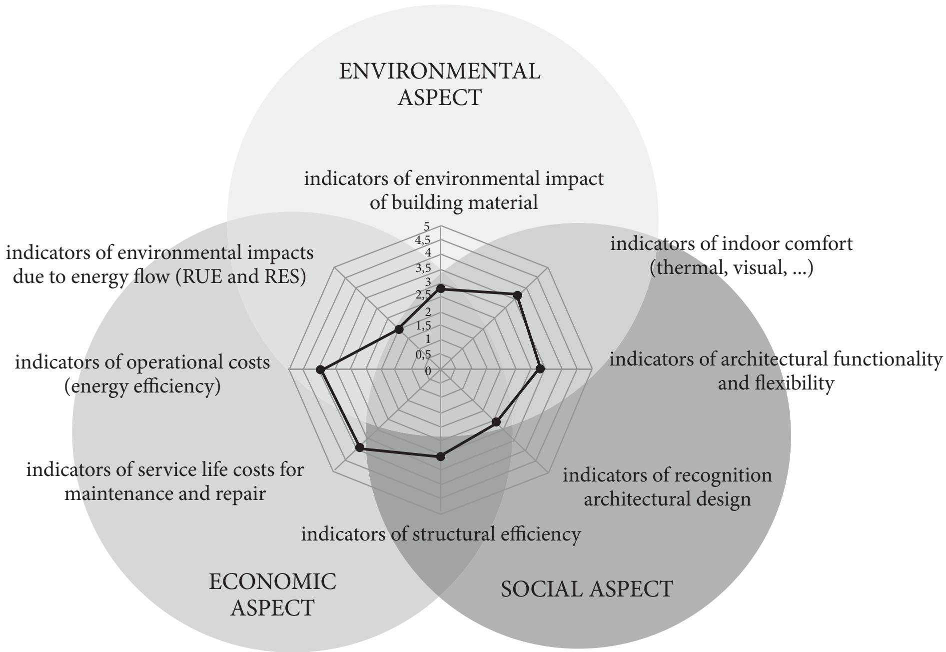

Fig. 4. Aggregated indicators of apartment building sustainability and their reference to the environmental, economic and social aspect of sustainability as obtained for a selected residential

the optimum for the end-user. Currently, the number of end-users who are looking for a building with balanced elements from economic, environmental and social aspect, i.e. for sustainable building, is increasing. Further development of the method should therefore be oriented towards the aggregation of indicators according to their relevance of particular sustainability areas.

The building documentation from design and construction phase does not always provide an adequate input for more advanced or targeted level of particular indicators, since solutions based on advanced design methods go beyond the regulation. The data provision problem may also occur if one of the indicators is out of scope of the (already old) building regulation. In such case the ranking is dependent on subjective judgement of the evaluator and agreement for additional analysis for the evaluation purposes. This subjectivity should be reduced by adequate training of the assessors. Further efforts shall be put in the sensitivity analysis of aggregated indicators weighting and the reliability as well as objectivity of the evaluation.

The potential users of the sustainability assessment method are real-estate companies, private developers and public housing funds investing in social housing that put the residential building on the market and are thus interested in presenting the achieved sustainability level to end-users, i.e. buyers of flats and tenants. The increasing environmental awareness creates more demanding buyers, who are looking for quality labels when buying the flat in order to reduce the risk of bad investment.

The opinion of potential users about the potential of the method was also investigated through their willingness to pay the service. The poll among stakeholders (integrated in the poll for determination of indicators' weights) showed that acceptable additional costs of evaluators working on the assessment of building were quite low, i.e. 25% of respondents support 20 EUR per apartment, and 37% (38%) consider 40 EUR (80 EUR) per apartment as acceptable costs. The opinion about the acceptable labour input for the preparation of data for assessment application (costs of real-estate company, private developer, public clients in social housing) and for the assessment itself (cost of the evaluator) showed similar status. 67% of clients are willing to accept 2–3 man days for the preparation of evaluation application, and 87% think the evaluators should not spend more than 2–3 days for evaluation of a medium sized building (10–25 flats). These conditions may seem discouraging at the moment. The EU environmental and energy directives, however, constantly require upgrading of the national building codes, which means that the sustainability assessment and associated indicators will in a due time become a part of routine designer's work.

6. Conclusions

The paper reports on a relatively simple and efficient method for the assessment of building quality, sustainability and building performance. The method is intended to be used by various stakeholders in residential construction market. The assessment results may emphasise the competitive advantages of a building in terms of sustainable buildings design. On the other hand, the end-users of the method are the future users of flats, either flat owners or tenants, who wish to support their decision-making by various aspects of building quality, sustainability and building performance.

Currently, there are many different building assessment schemes available, from the obligatory EPBD energy performance certification scheme to the recognized voluntary international schemes for green and/or sustainable building evaluation. These international methods, however, are not customized to relevant building types, construction tradition in the country and region specific expectations of end-users.

The proposed method for sustainability assessment is based on the poll in order to reflect the national context of sustainability, and it is customized for multi-apartment buildings. It reflects the experiences of Slovenian national voluntary quality labelling scheme ZKG and could be, therefore, introduced into regular Slovenian practice without major problems. The case study presented in this paper shows that the method is easy to apply and its results can be understood by the potential end-users of the apartments without additional information.

Although its application has been presented for a Slovenian case study, the method can be transferred into other regions/countries if adapted to the local requirements and practice by using criteria weights suitable for that region.

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DAUGIAKRITERINIS GYVENAMŲJŲ NAMŲ DARNOS VERTINIMAS

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Santrauka

Straipsnyje siūlomas paprastas gyvenamųjų namų darnos vertinimo metodas. Šiuo metodu skaičiuojama dviem etapais. Pirmuoju etapu nustatomi kriterijai, darantys įtaką pastato darnos lygiui (pavyzdžiui, pastato architektūra, konstrukcija, medžiagos). Nustatomi keli kiekvieną kriterijų apibūdinantys rodikliai. Priklausomai nuo pobūdžio jie gali būti kiekybiniai arba kokybiniai ir gali apibūdinti visus tris darnos aspektus. Antruoju etapu rodikliai sugrupuojami pagal jų įtaką atskiriems darnos aspektams. Ypatingas dėmesys skiriamas rodiklių reikšmingumų nustatymui. Tai vertinimo metodą daro tinkamą konkrečioms sąlygoms. Rodiklių reikšmingumai nustatomi grupės ekspertų nuomonių sutarimo metodu. Vėliau reikšmingumai tikslinami diskusijoje tarp susinteresuotų grupių narių. Pasiūlytas metodas pritaikytas pasirinktam tipiniam pastatui, atlikta gautų rezultatų analizė. Rezultatai atskleidė, jog pradinių duomenų išsamumas ir tikrumas daro lemiamą įtaką pasiūlyto vertinimo metodo patikimumui. Tinkamai apmokant vertintojus galima sumažinti kai kurių rodiklių vertinimo subjektyvumą. Potencialių vartotojų reakcija rodo, kad ateityje šis metodas gali būti plačiai taikomas.

Reikšminiai žodžiai: gyvenamasis namas, statybos kokybė, vertinimo metodas, sprendimo priėmimo metodas, darnos rodikliai, žymėjimas.

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