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Article

Ranking of Sustainability Indicators for Assessment of the New Housing Development Projects: Case of the Baltic States

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Abstract: Sustainable development is inconceivable without healthy real estate market. A housing project can be regarded as sustainable only when all the dimensions of sustainability (environmental, economic, and social) are dealt with. There has been an increased interest in using sustainability indicators for evaluating the impacts of the new development projects. Past and recent experiences have shown that sustainability indicators can be useful tools for measuring the outcomes of new construction, when used appropriately and adequately. The aim of this article is to propose an integrated, hierarchically structured system of sustainability indicators to be used for assessment of the new housing development projects in the Baltic States. This aim is achieved through accomplishing three objectives. First, based on a review of literature related to assessing building project performance and sustainable development in construction, the paper proposes a hierarchically structured system of sustainability indicators. Second, based on a survey of experts from the Baltic States, significances of criteria are estimated by the Analytic Hierarchy Process (AHP) method. Finally, paper proposes recommendations to government authorities and real estate developers as to how to enhance the performance of new residential projects according to the principles of sustainability.

Keywords: sustainability indicators; housing development; new projects; AHP; ranking

1. Introduction

In Brundtland's report [1], sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In general, sustainable development encompasses three interacting dimensions: environmental, economic and social.

It is widely accepted that the construction sector is one of the main contributors to sustainable development, and its role in encouraging environmental protection, economic growth, and social progress is undeniable [2]. Moreover, as Holmstedt et al. [3] claim, "urban sustainable development is today seen as one of the keys towards unlocking the quest for a sustainable world".

One of the key sectors in achieving sustainable development is residential construction. Traditionally housing development projects had mainly concentrated on the technical and financial feasibility. However, "the conversion to sustainable structures and urban communities ought to satisfy the complications posed by a variety of further environmental, social, and economic concerns; e.g., growing energy charges, resource exhaustion, and new regulatory requirements" [4].

From a social perspective, housing not only offers accommodation but also gives a sense of a secure future and strengthens local communities [5], [6]. From an economic perspective, houses are among the major investments that people make in their lifetimes [7]. However, from an environmental perspective, the housing sector in the European Union uses 40% of total final energy consumed (of which heating and cooling accounts around 70%) and releases about 36% of total CO_2 emissions [8]. Therefore, a housing project can be regarded as sustainable only when all the three dimensions of sustainability – environmental, economic and social – are taken into account. The various issues of sustainability are interrelated, and the interaction of a building with its environment has important ramifications [9]. Common considerations include those of the use of environmental friendly materials and water, reduction of energy consumption, ensuring healthy and comfortable indoor climate, reduction of pollution, cohesion of community, ensuring housing affordability, etc.

According to Mateus and Bragança [9], Zhang et al. [10] developing and using building sustainability measurement and benchmarking methods is one of the solutions that promote a more sustainable built environment. Moreover, a complete sustainability understanding also necessitates the consideration of environmental and ecological indicators related to the use of natural resources along with the ones associated with the society and economy as a whole [11].

Since the Rio Summit, many sustainability assessment indicators and frameworks were formulated to provide sustainability-related decision-making processes and have been widespread internationally [12]. The construction industry has a long history in developing and using of indicators, alongside of many general efforts to develop sustainable development indicators [13]. However, social and economic indicators are often neglected in the literature [2], [9], [14]. Moreover, Berardi [15] notes, that the social aspect is the most ignored dimension of sustainability.

There are many methods developed for sustainability assessment (e.g., LEED in the USA, BREEAM in the UK, CASBEE in Japan, GBTool in Canada), Life-cycle-based tools (e.g., Eco-Quantum in Netherlands, EcoEffect in Sweden, ENVEST in the UK, BEES in the USA, ATHENA in Canada, LCA House in Finland), however, "usually these methods ignore the economic and social aspects, and sustainable criteria are not prioritized for decision making facilitation" [14].

On the other hand, academics have developed numerous construction project evaluation methods, indicators and models for assessment of sustainability. Some of the studies deal with the housing projects. Ali and Al Nsairat [16] suggested green building assessment tool (SABA Green Building Rating System) for the Jordanian context. Alwaer and Clements-Croome [17] introduced a consensus-based model (Sustainable Built Environment Tool – SuBETool) for the sustainability assessment of intelligent buildings.

Study by Bragança et al. [18] intended to be the basis for the future development of an advanced residential building sustainability rating tool, especially suitable for Portuguese traditions, climate, society, and national standards. Afterwards, Mateus and Bragança [9] presented an innovative approach (SBToolPT–H) to assess the sustainability of existing, new and renovated residential buildings in urban areas, specifically in the Portuguese context. Bakar et al. [19] presented A Comprehensive Assessment System for Sustainable Housing (CASSH) for measuring sustainability in housing development to suit the Malaysian context. The formulated index considered the parameters in sustainable housing developed by various systems around the world.

Wallbaum et al. [13] proposed indicator based sustainability assessment tool for affordable housing construction technologies. Turcu [20] used a set of 26 sustainability indicators for evaluating social housing regeneration projects. Mulliner et al. [21] assessed sustainable housing affordability by COPRAS method in Liverpool (the UK).

A survey performed by Chandratilake and Dias [22] in Sri Lanka aimed to establish relative weights for various domains and aspects for a rating system in national context. Analytic Hierarchy Process (AHP) method was used, six domains (site, energy efficiency, water efficiency, materials, indoor environmental quality and waste and pollution) were considered. Alyami et al. [23] developed the sustainable building assessment scheme for Saudi Arabia by using Delphi consultation approach. Higham and Stephenson [24] proposed 17 sustainability factors that are categorised into standard, environmental, economic and social factors.

Yu et al. [25] developed an assessment method for green store buildings in China. The Expert Group Decision AHP method was used. The indicator system of the green store building rating included seven categories (landscape, energy efficiency, water efficiency, material and resources, indoor environment, construction management, and operation management).

Nilashi et al. [26] proposed a knowledge-based expert system to assess the performance level of a green building based on assessment criteria of building rating systems. AHP and fuzzy logic was applied for development of the system. Study by Preval et al. [27] evaluated the impact of the special housing areas on measures of environmental sustainability in New Zealand.

Abdul-Rahman et al. [14] developed a Fuzzy Weighted Hierarchy for Triquetrous Sustainability (FWH-TS) for integrating and ranking sustainability criteria for housing, in total 52 environmental, economic and social indicators were used.

Review of the academic research reveals that different sustainability indicators and systems are used for assessment of residential projects' sustainability in different countries. As noted by Mateus and Bragança [9], Ali and Al Nsairat [16], Bakar et al. [19], Chandratilake and Dias [22], Alyami et al. [23], particular indicators and their significances are highly dependent on the environmental, social and economic contexts of their use, therefore authors aim to develop national sustainability assessment systems. Academics also disagree on the nature and extent of the indicators to be measured, and "there exist significant conflicts between the models proposed regarding their detail, the measurement and evaluation approach, and the nature of their overarching features, so a suitable structured framework to assist project teams involved in the delivery of sustainable building projects is lacking" [28].

Although international literature is rich in residential projects' sustainability assessments, studies in the context of the Baltic States are very limited. There are only few researches to be mentioned. In Lithuania Viteikiene and Zavadskas [29] used COPRAS method to rank residential areas according to the overall sustainability performance, which was indexed based on 22 indicators related to sustainable development. More recently Zavadskas et al. [30] assessed 21 neighbourhoods in Vilnius, Lithuania in the context of a healthy and safe built environment in view of the principles of sustainable development. Multiple criteria decision making (MCDM) methods were used for this purpose; neighbourhoods were assessed according to 15 environmental, economic and social indicators.

In the study by Brizga [31] sustainable development integration in Latvia's environmental policy, focusing on assessment and analysis of normative, organizational and procedural policy integration instruments was analysed. Author concluded that there is no formal policy integration process in place and main integration barriers are lack of integration procedures, conflicting interests of stakeholders and organizational fragmentation. Zilans and Abolina [32] studied a methodology for assessing urban sustainability according to Aalborg commitments in Riga, Latvia. Geipele et al. [33] analysed interaction of socio-economic factors and real estate market in the context of sustainable urban development in Latvia comparing to other Baltic States. Nuuter et al. [34] used COPRAS method for comparison of housing market sustainability in European countries, including Estonia, Lithuania and Latvia.

Sustainable development is in specific interest of Lithuanian Real Estate Developers Association. Each year the competition for sustainable development is organized [35]. Lithuania's real estate developers are encouraged to take an active part in the contest of the best projects, with a strong focus on the ideas of sustainable development. The projects are evaluated by experts according to 8 criteria: adequateness of the object to sustainable urban development aims (renovation of existing residential areas or buildings, multi-functionality, access to public transport and other public infrastructure, adjustment of environmental, economic and social tasks); architectural, urban and building quality; respect to nature and cultural heritage values; energy saving according to 2009/28/ES;2010/31/ES; 2012/27/ES directives; innovativeness and

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non-traditional solutions; use of local production for the project; organization's image in society and business ethics.

Latvian Sustainable Building Council (LSBC) [36] was founded at the end of 2010 as a private sector initiative to increase the sustainability of the built environment in Latvia. It provides practical support to sustainable project development. With this aim in mind, LSBC has been instrumental in providing the local market with a set of sustainable building criteria for new commercial developments (buildings) – an adapted version of BREEAM.

The Estonian Green Building Council (Eesti GBC) [37] promotes the highest quality levels in planning, design, construction and operation for energy and real estate. Its members provide excellence, expertise and outstanding professionalism. Eesti GBC encourages certification of the buildings according to the BREEM and LEED standards.

In summary, there are sustainability promotion initiatives in the Baltic States and some of the previous research investigations have examined building sustainability assessment methods based on quantitative and qualitative criteria (indicators), however, to the best knowledge of authors, none of the previous studies presented the sustainability assessment framework for new residential projects. This publication aims to fill this gap and to propose an integrated, hierarchically structured system of sustainability indicators to be used for assessment of the new housing development projects in the Baltic States.

2. Materials and Methods

The methodology of research is presented in Figure 1.

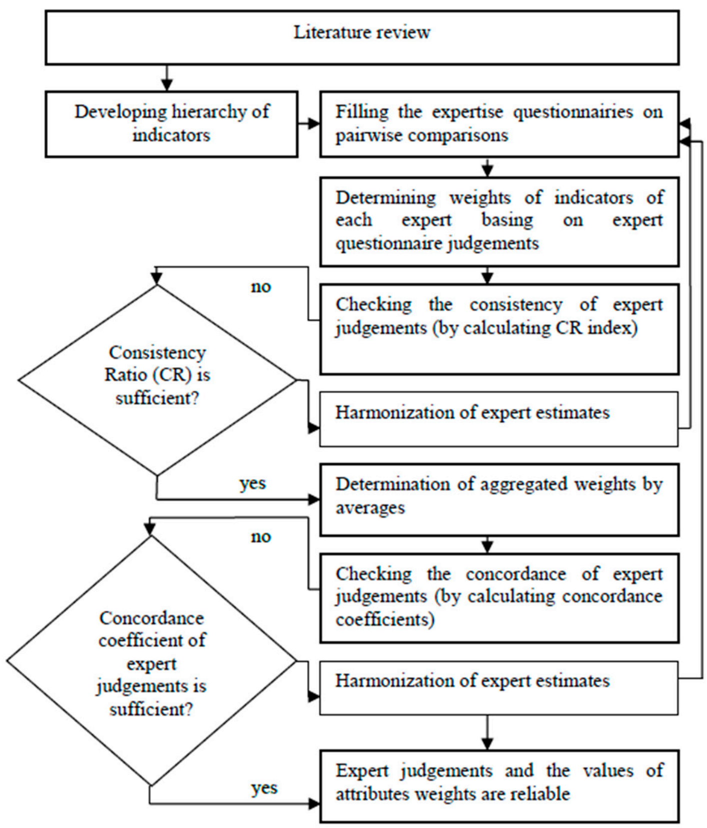

Figure 1. Research methodology.

Research started with the state-of-the-art review of similar studies and analysis of sustainability indicators proposed by the other authors as well as sustainability rating systems (i.e. BREEM, LEED, CASBEE, etc.). Unsurprisingly, enormous amount of sustainability indicators in the literature was

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found. Therefore, the main challenge was not the lack of indicators, but the selection of the most suitable indicators for assessment of the new residential projects. To solve this problem the panel of experts, consisting of professionals and academics from the three Baltic States was established. Profile of experts is provided in Table 1.

Table 1. Profile of experts.

No	Country	Specialty	Work experience	Expertise in sustainability issues
E1	Lithuania	Civil engineer	10	Consultant in buildings' certification according to the BREEM system
E2	Lithuania	Academic (Dr., Assoc. Prof.)	11	Teaches subject "Sustainable development of territories", took internship in the Lithuanian Real Estate Developers Association
E3	Lithuania	Analyst	15	Works in State Enterprise Centre of Registers, prepares market reviews that consider sustainability issues
E4	Latvia	Surveyor	20	Consults clients on sustainability issues
E5	Latvia	Academic (Dr., Assoc. Prof.)	18	Teaches subject "Sustainable urban development", participates in international projects
E6	Latvia	Architect	10	Designs passive houses
E7	Estonia	Real estate developer	12	Develops innovative residential projects
E8	Estonia	Valuator	10	Valuates real estate
E9	Estonia	Academic (Dr., Assoc. Prof.)	32	Researches housing sustainability issues, participates in international projects

Initial review of literature has provided extensive list of indicators – in total 246 indicators were retrieved. Each expert was asked to select the most important indicators, assuming that indicators must be relevant to the three dimensions of sustainability, measurable, clear, and adaptable to the assessment of the new residential projects in the Baltic context. Selected indicators were discussed during on-line meetings, categorised and finalised. Finally the hierarchically structured system of 53 indicators was developed (see Table 2).

Since the hierarchy was developed, next important step was determining significances of indicators. Due to large number of indicators and hierarchical nature of the system, Analytic Hierarchy Process (AHP) method by T.L. Saaty [53] was selected.

AHP method was proved as efficient and was widely used by many authors for different sustainability-related tasks solutions (see e.g. [14], [22], [25], [26], [54]–[59], etc.). Moreover, approximately 3000 papers concerning multi-criteria decision analysis (MCDA) in the environmental field were identified by Cegan et al. [60]. The results show a linear growth in the share of MCDA papers in environmental science across all application areas and reveal that AHP/ANP and MAUT/MAVT are the most frequently mentioned MCDA methods in the literature.

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Table 2. Hierarchically structured system of sustainability indicators for new residential projects.

Dimension	Category	Indicators	References
Environmental sustainability	***Land use considerations***	Appropriate site selection	[3], [9], [14], [16], [17], [18], [22], [23], [25], [26], [35], [38], [39–42].
		Developing damaged areas	[14], [23], [35], [38], [39], [43].
		Landscape design	[19], [22], [25], [40], [44].
		Ecosystem preservation	[9], [14], [16], [19], [23], [35], [38–40], [42], [44], [45].
		Quality of outdoor environment	[20], [21], [24], [25], [30], [35], [44] [46].
		Housing density	[9], [22], [23], [30].
		Infrastructure efficiency	[14], [22], [23], [35], [40], [42], [44], [47], [48].
	Water efficiency considerations	Quality of potable water	[9], [18], [26], [38], [40].
		Implementation of alternative water resources	[9], [14], [16], [18], [22], [23], [25], [26], [38], [39], [40].
		Water conservation	[17], [19], [20], [22], [26], [40], [42], [44].
	Energy and atmosphere considerations	Energy efficiency of housing	[3], [13], [14], [16], [19], [20], [21], [46], [22], [23], [24], [25], [26], [38], [39], [40].
		Lighting efficiency	[22], [23], [25], [26], [38], [40].
		Renewable energy use	[9], [14], [16–18], [22], [23], [25], [26], [35], [38–40], [44].
		Greenhouse gas emission	[17], [19], [22], [26], [39], [42].
	Materials and waste management	Use of materials with low environmental impact	[9], [13], [14], [17], [19], [22], [23], [25], [26], [38–40], [42–44], [49].
		Use of regional/local materials	[14], [22], [23], [26], [35], [39], [40–42], [49].
		Materials and products reused	[9], [22], [23], [26].
		Availability of waste management facilities	[3], [14], [16], [19–23], [39], [40], [42].
	Indoor environmental quality	Thermal comfort and control	[9], [14], [16], [18], [22], [23], [25], [26], [39], [40], [44], [45], [48], [50].
		Indoor air quality	[14], [16], [18], [19], [22], [23], [25], [26], [39], [40], [43], [44], [50].
		Lighting comfort	[9], [14], [22], [23], [25], [26], [38], [39], [44].
		Visual comfort	[14], [16], [18], [22], [23], [26], [42], [45], [50].
		Aural comfort	[9], [14], [16], [18], [22], [23], [25], [26], [30], [38], [39], [40],

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			[42], [44], [45], [50].
	External pollution	Pollution by NO2	[23], [30], [38], [44].
		Pollution by CO	[23], [38].
		Noise pollution	[23], [30], [42].
		Pollution reduction considerations	[14], [16], [40], [45].
	Innovation and design process considerations	Innovation in design	[4], [14], [23], [35], [40].
		Environmental friendly design	[14], [19], [22], [35], [51].
		Quality of facilities	[14], [48].
		Architectural heritage considerations	[14], [48].
		Architectural functionality, flexibility and adaptability	[14], [17], [35], [39], [52].
Social sustainability	***Accessibilities***	Distance to the city centre	[30]
		Access to public transportation	[3], [9], [14], [19], [20], [21], [46], [22], [23], [25], [26], [27], [30], [35], [38], [42].
		Access to employment opportunities	[14], [20], [21], [46], [26], [30].
		Access to educational institutions	[20], [21], [46], [30].
		Access to shops	[21], [46].
		Access to health care services	[20], [21], [46], [30].
		Access to child care	[21], [46], [30].
		Access to leisure facilities	[21], [46], [30].
		Access to open green public space	[21], [46].
		Car parking capacity	[21], [46].
	Neighbourhood /community considerations	Safety (crime rate)	[14], [19], [20], [21], [46], [24], [30], [42].
		Neighbourhood reputation	[21], [46], [24].
		Population density	[27], [30].
		Community cohesion	[19], [20], [23], [24], [26].
		Privacy	[26], [38].
Economic sustainability		Costs of construction	[9], [14], [16], [18], [23], [26], [39], [42].
		Housing affordability	[17], [20], [21], [46], [30].
		Mortgage interest rates	[21], [46].
		Value stability	[14], [17], [18], [23].
		Added value	[14], [20], [30], [35], [41], [42].
		Satisfaction of demand	[19], [24], [26], [41].

In AHP, experts were asked for pair-wise comparisons of indicators. For example, in evaluating of sustainability dimensions, the typical question was: "Of the two criteria, environmental or social sustainability, which one is you consider more important, and by how many times, with respect to

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sustainability of the new residential projects?" Experts gave their judgments based on the judgment scale (see Table 3).

Table 3. Saaty's scale of measurement in pair-wise comparison [53].

Intensity of importance	Definition	Explanation
1	Equal importance	Two indicators contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one to another
5	Strong importance	Experience and judgment strongly favour one to another
7	Very strong importance	An indicator is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The importance of one over another affirmed on the highest possible order
2,4,6,8	Intermediate values	Used to represent compromise between the priorities listed above
Reciprocals of above non-zero numbers		If indicator *i* has one of the above non-zero numbers assigned to it when compared with indicator *j* , then *j* has the reciprocal value when compared with *i*

The questionnaires of judgment matrices where prepared and provided to experts. Judgment matrices, filled by experts were used for the calculations of determinants' significances, according to the formulas [53]:

$$q_i = \frac{\left(\prod_{j=1}^{m} c_{ij}\right)^{1/m}}{\sum_{k=1}^{m}\left(\prod_{j=1}^{m} c_{kj}\right)^{1/m}}, \tag{1}$$

and

$$\lambda_{max} = \sum_{i=1}^{m}\left\{\left(\sum_{j=1}^{m} c_{ij}\right) \times q_i\right\}, \tag{2}$$

where: k – number of experts; m – number of indicators; c_i – i^{th} determinant; q_i – significance (weight) of the i^{th} indicator; λ – eigenvalue.

To simplify the survey and calculations, an open source BPMSG AHP Online System [61], was used. Weights and ranks, determined by each expert are provided in Supplementary materials (Tables S1–S3).

The consistency ratio (CR) of each matrix was checked according to the formula [53]:

$$CR = \frac{CI}{RI}, \tag{3}$$

where: RI – random consistency index and CI – consistency index calculated as follows [53]:

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$$CI = \frac{(\lambda_{max} - m)}{(m-1)}. \quad (4)$$

T.L. Saaty [53] has set the acceptable *CR* values for the different matrices' sizes: the CR value is 0.05 for a 3–by–3 matrix; 0.08 for a 4–by–4 matrix and 0.1 for larger matrices.

Further significances provided by each of the experts were aggregated and assumed as distribution and the averages of these distributions were calculated in order to determine the final significances of indicators.

Reliability of the data was expressed by the coefficient of concordance (agreement) of the experts' opinions by describing the extent to proximity of individual views. For this purpose Kendall's coefficient of concordance [62] was used:

$$W = \frac{12S}{r^2(m^3 - m) - r\sum_{k=1}^{r} T_k}; W \in [0; 1], \quad (5)$$

where S is the total square deviation of the rankings of each attribute; T_k – the index of reiterated ranks in the r rank, k – the number of respondents and m – the number of indicators.

However, the calculated value W is stochastic; and therefore, the significance of the concordance coefficient was calculated. Kendall [62] has proved that, when $m > 7$, the significance of the concordance coefficient can be calculated by χ^2 criterion which has a distribution with degree of freedom $\upsilon = m - 1$. It has been proved that if the calculated value χ^2 is larger than the critical tabular value χ^2_{crit} for the pre-selected level of significance (e.g. $\alpha = 0.05$), then the hypothesis about the agreement of independent experts' 'judgments' is not rejected.

The significance χ^2 of the concordance coefficient was calculated as follows [62]:

$$\chi^2_{\alpha,\upsilon} = Wr(m-1) = \frac{12S}{rm(m+1) - \frac{1}{m-1}\sum_{k=1}^{r} T_k}. \quad (6)$$

If the $\chi^2_{\alpha,\upsilon} > \chi^2_{crit}$ the significance of concordance coefficient exists on α level, then the agreement of experts' opinions is satisfactory and group opinion is established. Otherwise, when $\chi^2_{\alpha,\upsilon} < \chi^2_{crit}$ is obtained, the respondents' opinions are not in agreement, which implies that they differ substantially and the hypothesis on the rank's correlation cannot be accepted.

If number of attributes m is from 3 to 7 ($3 \leq m \leq 7$), the χ^2 distribution should be applied choicely. The obtained results on calculations are provided in Supplementary materials (Tables S1–S3). Calculations revealed that the opinions of experts are consistent, thus determined significances of criteria are valuable and can be used for further calculations. Results are provided in the next section.

3. Results and Discussion

The main criteria for sustainability assessment of the new housing development projects in the Baltic States were divided into three hierarchical levels: Sustainability dimensions, Categories and Indicators. Since the aim of this study was to establish the most applicable assessment categories and indicators for the Baltic States, some new categories and indicators had been developed by the research (see Figure 2) and discussed below.

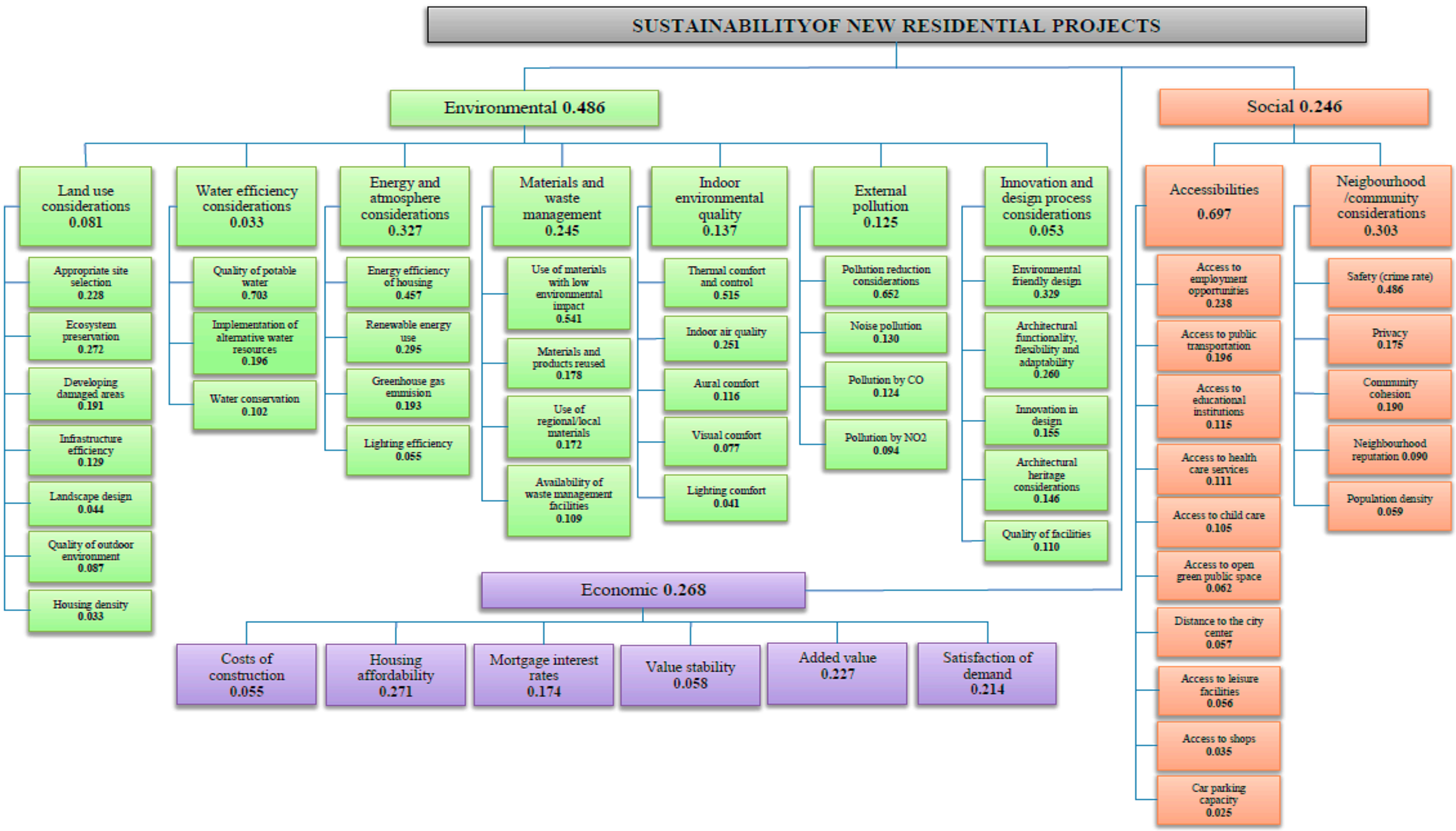

Figure 2. Hierarchical structure of sustainability indicators and their significances.

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3.1. Environmental sustainability dimension

As it was previously observed, environmental dimension is mostly researched in the literature and extensively used in certification systems, therefore it involves large amount of indicators. In this research for this dimension seven categories of indicators were distinguished (see Figure 3).

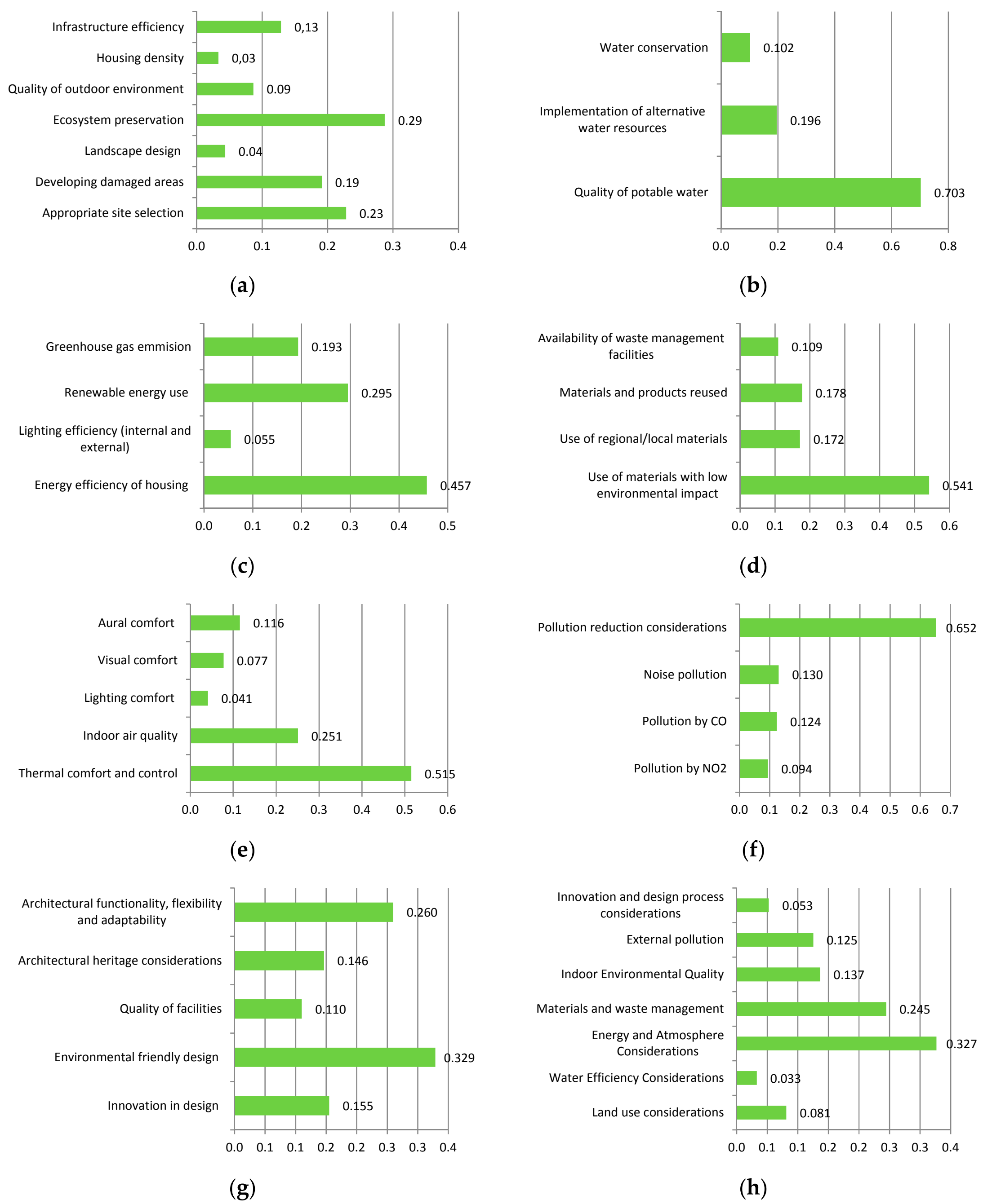

Figure 3. Rankings of environmental sustainability indicators: (**a**) Land use considerations; (**b**) Water efficiency considerations; (**c**) Energy and atmosphere considerations; (**d**) Materials and waste management; (**e**) Indoor environmental quality; (**f**) External pollution; (**g**) Innovation and design process considerations; (**h**) Categories of environmental indicators.

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3.1.1. Land use considerations

Sustainability of the new housing projects directly depends on appropriate land use, as land is limited recourse and has impact to the other categories of sustainability. Selection of the land site is associated with the location of building itself and its infrastructure. Seven indicators (see Figure 3a), according to experts, encourage sustainable development and promote developing of damaged areas, ecosystem preservation, sustainable landscape and quality of outdoor environment, housing density, whilst ensuring that buildings are adequately connected to basic infrastructure. The panel of experts gave priorities to 'ecosystem preservation' (0.287), 'appropriate site selection' (0.228) and 'infrastructure efficiency' (0.129).

These rankings correspond to the findings of other authors, e.g. research by Alyami et al. [23] revealed that site selection, transport links are among the most important sustainable land use indicators. Similarly study by Nilashi et al. [26] revealed that site design and transportation are the most important criteria in ratings of green buildings. Ali and Al Nsairat [16] also pointed the importance of infrastructure efficiency and land use in Jordan.

3.1.2. Water efficiency considerations

Water efficiency in this research was described by three indicators (see Figure 3b): quality of potable water and strategies (reuse of rain and grey water and water conservation) that have significant impact on reducing the overall water consumption. It is observed, however, that experts gave strong priority to the 'potable water quality' (0.703). Water resources are sufficient in the Baltic States, thus water conservation and reuse are not among priorities like in hot climate zones, for instance, Saudi Arabia [23] or Jordan [16].

3.1.3. Energy and atmosphere considerations

Indeed, energy efficiency is one of the most important categories in achieving sustainable development goals. It is prioritised in sustainability rating systems as BREEM [38], GBTool [39], LEED [40] and CASBEE [44]. In the Baltic States, like in other European countries, energy efficiency of buildings is assessed by the energy efficiency classes. In terms of energy performance, buildings are divided into the following 9 classes: A++, A+, A, B, C, D, E, F and G. The highest class A++ indicates that the building consumes almost no energy, whereas classes A+, A and B signify that buildings consume little energy. Energy efficiency class is determined according to properties of the building, e.g. building envelope performance, efficiency of HVAC system, windows, doors, etc. Moreover, renewable energy use and lighting efficiency is encouraged. Energy efficiency of the buildings directly contributes to reduction of greenhouse gas emission.

The panel of experts gave priorities to 'energy efficiency of housing' (0.457), 'renewable energy use' (0.295) and 'greenhouse gas emission' (0.295). 'Lighting efficiency' was assessed as less important indicator (0.055) (see Figure 3c).

Importance of building envelope performance, efficiency of HVAC system, reduction of electricity use was also emphasised in studies of Alyami et al. [23] and Ali and Al Nsairat [16]. Similarly, study by Nilashi et al. [26] revealed that renewable energy and building envelope performance are the most important criteria in ratings of green buildings.

3.1.4. Materials and waste management

To enhance energy efficient design of the buildings, selection of appropriate materials is vitally important. According to Shen et al. [63], "the reduced use of and therefore depletion of both limited raw materials and long-cycle renewable materials by substituting them with instantly renewable materials is crucial in achieving sustainability of buildings".

Survey of experts revealed that the choice of materials with low environmental impact (0.541), reuse of materials and products in new construction projects (0.178) are the most important considerations in the Baltic States (see Figure 3d). The findings are in line with the study of Alyami et al. [23], where Delphi survey panel distinguished the choice of 'materials with low environmental

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impact' along with 'building fabric components' as the most important considerations. Similarly study by Nilashi et al. [26] revealed that environmental impact of materials, resource reuse and use of renewable materials are the most important criteria in ratings of green buildings.

The panel of experts also considered the 'use of regional/local materials' (0.172) as important indicator. According to Shen et al. [41] and Pearce et al. [49], implementation of regional materials contributes to the regional economy and reduces environmental effects from transportation. This indicator also was assessed as very important in study by Ali and Al Nsairat [16].

'Availability of waste management facilities' in this study was ranked as less important indicator as in the Baltic States all of the new housing projects must be equipped with appropriate waste management facilities, including recycling facilities.

3.1.5. Indoor environmental quality

Category of the 'indoor environmental quality' included five indicators (see Figure 3e) – thermal, aural, visual, lighting comfort and indoor air quality – that help ensuring the health and wellbeing of the occupants [43]. The panel of experts gave priorities to 'thermal comfort and control' (0.515), 'indoor air quality' (0.251) and 'aural comfort' (acoustics and noise protection) (0.116).

In the Baltic States, due to cold winters, appropriate heating strategies are among the most important considerations. Indoor air quality directly influences health of the occupants. Importance of thermal comfort and control was also emphasised in international studies of Mateus and Bragança [9], Abdul-Rahman et al. [14], Alyami et al. [23]; Yu et al. [25]; Nilashi et al. [26], Ceron-Palma et al. [48]; Lai et al. [50] as well as certification systems as GBTool [39], LEED [40], CASBEE [44].

To ensure high indoor air quality for occupants, controllability of systems (thermal, ventilation and lighting systems) should be implemented [43]. Similarly as in this research, study by Nilashi et al. [26] revealed indoor air performance among the most important criteria in ratings of green buildings.

Aural comfort, which focuses on ensuring that building walls and floor systems are designed with sufficient sound absorption capability to sustain suitable acoustical quality for occupants and neighbours [45], [50], is assumed to be important indicator as many of the occupants of new residential apartments comply for insufficient acoustical insulation and suffer from noise, as it was noted by experts from Lithuania.

The panel of experts assigned lower significances to 'visual comfort' (0.077) and 'lighting comfort' (0.041) as these indicators mostly depend on the actions of residents and usually new residential apartments in the Baltic States are sold with partial finishing.

3.1.6. External pollution

This category included four indicators (see Figure 3f). Pollution indicators (pollution by NO_2, CO and noise pollution) were assessed with similar importance, however, according to [40], [45] these indicators shall be investigated in each project. Indeed, experts gave priority to pollution reduction considerations (0.652) as manageable strategies, which "relate to efficient land use and actions taken to prevent land-based pollution" [14].

3.1.7. Innovation and design process considerations

In total five indicators were assessed by experts for innovation and design process considerations (see Figure 3g): 'innovation in design'; 'environmental friendly design'; 'quality of facilities'; 'architectural heritage considerations' and 'architectural functionality, flexibility and adaptability'.

Innovation in design offers design teams and project participants the opportunity to be awarded for performance above minimum requirements [51]. Moreover, it leads to environmental efficient design. "Eco-innovation does not necessarily mean expensive solutions, but rather ones that are technically robust, socially responsible, and financially viable" [4]; these also include provision of high quality facilities.

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Architectural heritage considerations focus on prevention of negative impact of project development on any kind of cultural heritage [14]. Moreover, buildings should provide proper functionality, flexibility and adaptability to residents' needs [14, 52].

In this research 'environmental friendly design' (0.329), 'architectural functionality, flexibility and adaptability' (0.260) and 'innovation in design' (0.155) were recognised as the most important indicators. These indicators are promoted by Lithuanian Real Estate Developers Association [35] and also are highlighted in studies by Georgiadou et al. [4], Abdul-Rahman et al. [14], AlWaer and Clements-Croome [17], Bakar et al. [19].

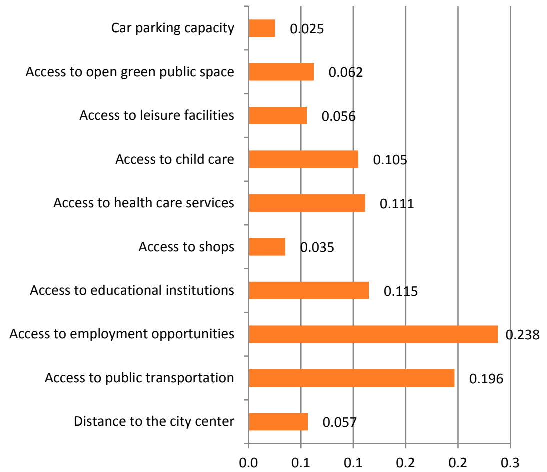
The panel of experts also ranked the categories of environmental sustainability (see Figure 3h). The judgement is that 'energy and atmosphere considerations' (0.327) and 'materials and waste management' (0.245) are the top priorities of the new residential projects in the Baltic States. 'Indoor environmental quality' (0.137) and 'external pollution' (0.125) were ranked as less significant, but still important indicators. These findings correspond to rankings of the mostly used sustainability rating systems, i.e. BREEM [38], CASBEE [44] and LEED [40]. Energy efficiency and use of environmental friendly materials was also distinguished as the most important in the Portuguese context [9] and sustainable social housing projects in the UK [28].

Lower significances were assigned to 'land use considerations' (0.081), 'innovation and design process considerations' (0.053) and 'water efficiency considerations' (0.033). Similar findings were achieved in raking of sustainability indicators in Portugal [9].

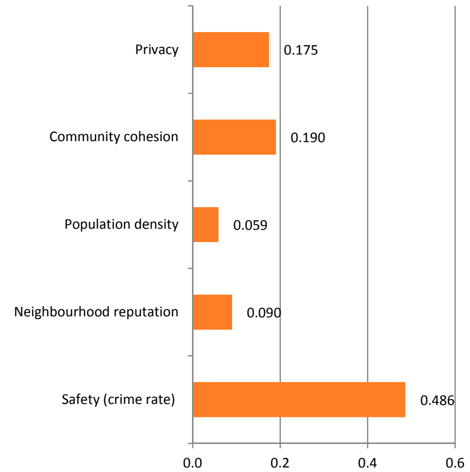
In the Baltic States land use for the new construction is restricted by local legal acts and land use regulations in general follow the principles of sustainable development. Innovation and design process considerations are related to other (according to expert judgments), more significant categories, i.e. energy and material use considerations. The quality of water is rather high in the living districts of the Baltic States; therefore indicator was estimated as being least significant. 'Water efficiency' and 'waste management cost' were also found as least important criteria in study by Ali and Al Nsairat [16].

3.2. Social sustainability dimension

Sustainable housing is characterized as being available, good quality, economical, ecological, comfortable and cosy. For communities to be sustainable, they must provide hospitals, schools, shops, good public transport, open public spaces and a clean and safe environment [30]. Therefore, social sustainability dimension was divided into two categories, namely 'accessibilities' and 'neighbourhood /community considerations' (see Figure 4).



(**a**)



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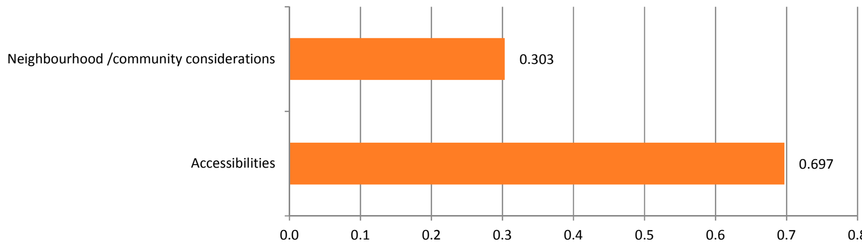

(**c**)

Figure 4. Rankings of social sustainability indicators: (**a**) Accessibilities; (**b**) Neighbourhood/community considerations; (**c**) Categories of social indicators.

3.2.1. Accessibilities

In the category of 'accessibilities' ten indicators were distinguished (see Figure 4a), including access to public transportation, urban amenities and employment opportunities. The top priority indicators, according to estimates of experts are 'access to employment opportunities' (0.238) and 'access to public transportation' (0.196). Similar findings were observed in study by Mulliner et al. [21], where 'access to employment opportunities' and 'public transport services' were top priority criteria among other accessibility indicators in assessment of sustainable housing affordability in the UK. Access to services was also in priority of the sustainability assessment of social housing regeneration projects in the UK [24].

Indeed, according to experts, availability of public transportation directly influences access to the most important public amenities: education institutions (0.115), health care services (0.111) and child care institutions (0.105). Less important indicators are 'distance to the city centre' (0.057), 'access to leisure facilities' (0.056), 'access to open green public space' (0.062) and 'car parking capacity' (0.025).

In survey by Turcu [20], over 60% of residents rated access to public transport, health services, jobs, green open spaces as "very important" (in the UK). Similarly study by Nilashi et al. [26] revealed that accessibility to urban amenities and public transportation are the most important criteria in ratings of green buildings, moreover, 'local employment opportunities' were evaluated as one of the most important externalities in social dimension. The same results were obtained in ranking of sustainability indicators in Portugal [9].

3.2.2. Neighbourhood /community considerations

Buildings ought to be designed, built, and maintained in a way which fulfils the various requirements of society to provide an appropriate environment, which promotes the development and advancement of individuals and communities [43]. In this research 'Neighbourhood /community considerations' included five indicators: 'safety', 'neighbourhood reputation', 'community cohesion', 'population density in living area' and 'privacy' (see Figure 4b).

Panel of experts assigned highest significance to 'safety (crime rate)' indicator (0.486). This finding corresponds to findings of many researches. For instance, according to Ceccato and Lukyte [64], "a sustainable community shall be a place free from the fear of crime, where a feeling of security underpins a wider sense of place attachment and place attractiveness". Cozens [65] noted that "such issues as crime and the fear of crime are not effectively represented within most sustainability agendas and require explicit inclusion". Research by Zavadskas et al. [30] indicated safety as the most important criterion in social dimension for assessment sustainability of Vilnius districts. In survey by Turcu [20] (the UK), over 80% of residents rated safety as "very important". Crime and cohesion indicators were also emphasised in the sustainability assessment of social housing regeneration projects in the UK [28].

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In the second place, according to judgment of experts, are indicators 'community cohesion' (0.190) and 'privacy' (0.175), although 'privacy' was ranked as the most important criterion of occupants' satisfaction in study by Nilashi et al. [26].

Indicators that were considered as less important are 'neighbourhood reputation' (0.09) and 'population density' (0.059). These indicators are directly related to the above mentioned indicators.

Among two categories of social sustainability, 'accessibilities' (0.697) were considered as more important than 'neighbourhood considerations' (0.303) (see Figure 4c).

3.3. Economic sustainability dimension

As it was previously noted, the developed hierarchical system of indicators for sustainability assessment is limited to new residential projects in the Baltic States, therefore maintenance and operational costs as well as life cycle assessments, considered by many authors, are not estimated. The panel of experts has chosen six economic indicators pertinent to new housing projects (see Figure 5).

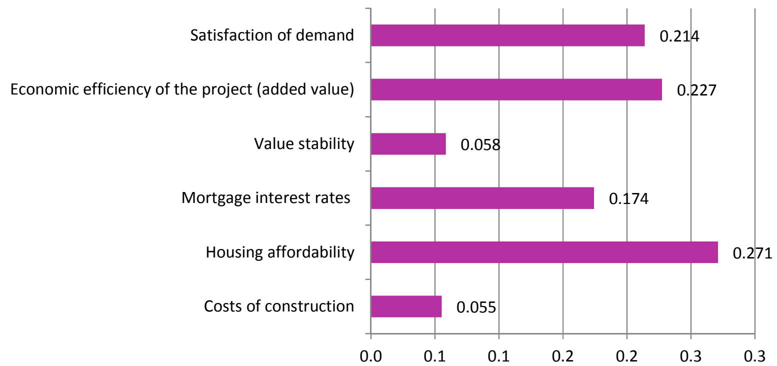

Figure 5. Ranking of economic sustainability indicators.

'Housing affordability' (price in relation to income) was ranked as the most significant (0.271) followed by 'added value of the project' (0.227), 'satisfaction of housing demand' (0.214) and 'mortgage interest rates' (0.174). 'Value stability' (0.058) and 'costs of construction' (0.055) were assumed as less significant.

According to Mulliner et al. [21], most importantly, "sustainable communities must provide decent homes at prices people can afford". Survey of experts done by Zavadskas et al. [30] revealed that housing price is the most important criterion in assessment of sustainable built environment in Vilnius districts. In survey by Turcu [20] (the UK), over 60% of residents rated housing affordability as "very important". The same findings were achieved in study by Mulliner et al. [21] where housing affordability was ranked as the most important criterion in assessment of sustainable housing affordability in the UK districts.

3.4. Ranking of sustainability dimensions

Finally experts were asked to rank three major sustainability dimensions (see Figure 6). These three elements are included in most studies which focus on sustainable development in the construction industry.

According to experts, in achieving sustainability of the new residential projects, environmental sustainability (0.486) is considered as more significant than the other two dimensions. Not surprisingly, higher rank is also assigned to economic dimension (0.268) as economic issues are among priorities in transitional countries as the Baltic States are. Notwithstanding, social dimension was also considered as important (0.246).

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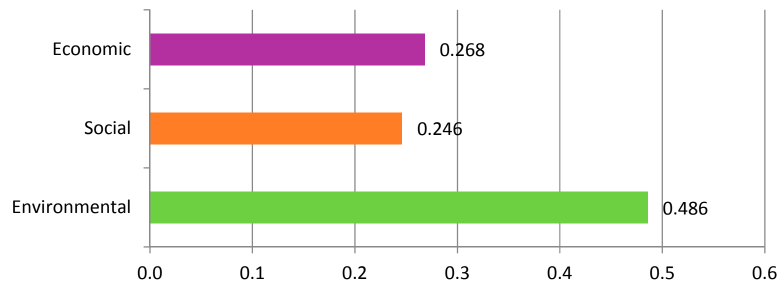

Figure 6. Ranking of sustainability dimensions.

Many of researchers found that environmental sustainability in similar studies is in the first place (e.g. [14], [26]). However, economic and social dimensions are ranked differently. In studies by Nilashi et al. [26] and Abdul-Rahman et al. [14], social dimension was ranked higher than economic. On the other hand Higham et al. [28] found that economic criteria are perceived as more important than the social or environmental factors in housing projects' feasibility stage investment decisions. Actually, as it was noted by Heravi et al. [2] and Shen et al. [57], the social dimension of sustainability is to some extent challenging. Although there is an agreement on indicators such as cultural effects, public related issues, as social ones, some of them such as employment, safety, and indoor air quality are considered sometimes as economic and environmental indicators [2].

3.5. Recommendations

This research suggests some recommendations that might be useful to government authorities and real estate developers as to how to enhance the performance of new housing development projects according to the principles of sustainability:

1. Research revealed that sustainable new housing development projects shall encompass three main sustainability dimensions: environmental, economic and social. This triangular sustainability shall be incorporated in local strategies and assessed according to substantial indicators. Developing such assessment framework shall be based on scientific research and practical knowledge. Experts, designers, developers and other stakeholders should be introduced as key participants in this process. As proposed by Scolobig and Lilliestam [66], "stakeholders' perspectives can be included in the shape of qualitative, quantitative, or mixed data, and often a translation of qualitative views into alternatives, technical options, models, or scenarios—including quantification efforts adds difficulty and complexity to the process, but can also enrich the final outcome".
2. Energy and atmosphere considerations, materials and waste management are among the top priorities of the new residential projects in the Baltic States. Therefore, developers are encouraged to build new energy efficient residential buildings from environmental friendly, reused and recycled materials. Moreover, from the economic point of view these projects shall be affordable and from the social perspective – infrastructure efficient in respect to public transportation and access to the most important public amenities (schools, kinder gardens, healthcare institutions, etc.).
3. To promote sustainable new residential projects, the national contests could be organised in Latvia and Estonia. Good practice example in this case is initiative of the Lithuanian Real Estate Developers Association.
4. As the findings of research were in line with the findings of the other authors, it is suggested that Baltic States can learn sustainability principles from the other countries' work, ideas, frameworks, and best practices; however, new sustainable residential projects shall suit the local context, depending on the culture, legislation, policy, stakeholders, practices and institutions.

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4. Conclusions

This publication aimed to propose an integrated, hierarchically structured system of sustainability indicators to be used for assessment of the new housing development projects in the Baltic States as no existing comprehensive framework including all three aspects of sustainability was found in practice and the literature.

The main criteria for sustainability assessment of the new housing development projects in the Baltic States were divided into three hierarchical levels: Sustainability dimensions, Categories and Indicators. Since the aim of this study was to establish the most applicable assessment categories and indicators for the Baltic States, some new categories and indicators had been developed by the research. Each category consisted of several indicators, a total of 53 indicators were addressed in. Selection of categories and indicators depended mainly on the ranking of the importance and relevance to the local situation.

Rankings of the sustainability indicators by the experts revealed that in dimension of environmental sustainability 'energy and atmosphere considerations', 'materials and waste management' are the top priorities of the new residential projects in the Baltic States. 'Indoor environmental quality' and 'external pollution' were ranked as less significant, but still important indicators.

In the social dimension 'accessibilities' were considered as more important than 'neighbourhood considerations'. In the category of 'accessibilities' the top priority indicators, according to estimates of experts, were 'access to employment opportunities' and 'access to public transportation'.

In the economic dimension 'housing affordability' indicator was ranked as the most significant followed by 'added value of the project', 'satisfaction of housing demand' and 'mortgage interest rates'.

According to experts, in achieving sustainability of the new residential projects, environmental sustainability is considered as more significant than the other two dimensions. Higher rank was assigned to economic dimension. Notwithstanding, social dimension was also considered as important.

In this research, some limitations exist, which need to be solved in further studies. First, there were a small number of experts in fulfilling the survey. Different groups of experts could participate in refining of the hierarchical system of criteria and determining the significances of indicators. Second, the proposed system of sustainability indicators is limited to assessment of the new residential development projects in the Baltic States. For assessment of the other types of projects in context of the other countries individual systems shall be developed. Third, the developed hierarchical system of indicators shall be tested in assessment of the real development projects; it will be accomplished in the ongoing authors' research. Forth, in the future studies, the significances of indicators may be obtained from other methods, such as expert ranking, Delphi or similar.

Supplementary Materials: The following are available online at www.mdpi.com/link, Table S1: Determining significances of indicators, Table S2: Determining significances of categories, Table S3: Determining significances of dimensions.

Author Contributions: Laura Tupenaite and Jurga Naimaviciene researched, summarised literature and designed the methodology; Irene Lill, Ineta Geipele and Jurga Naimaviciene performed the survey of experts in the Baltic States; Laura Tupenaite performed calculations; all of the authors contributed to discussion of results, conclusions and writing the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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