A New Stakeholder Opinion-based Rapid Sustainability Assessment Method (RSAM) for Existing Residential Buildings

Abstract

In many developing countries, several strategies and programs have been established to support the green building initiative, but overall progress is too slow to keep up with the global advances. To accelerate progress in building sustainability as well as to aid the decision-making process of different parties involved, a tailored quantification method for the sustainability performance of buildings is needed. The study presents a Rapid Sustainability Assessment Method (RSAM) – a fast and easy-to-implement system developed using indicators and their respective weights obtained from stakeholders and an assessment approach based on residents' responses. It was then applied to measure the sustainability performance of several residential buildings (from eras: before 1991, from 1991-1998, and after 1998) in the capital of Kazakhstan's, Nur-Sultan (formerly Astana). Results differentiated well between the buildings of different era, revealing that even new buildings certified via international green building rating systems do not entirely satisfy the vision of sustainability of the capital's residents. Although the resident's opinion-based method was developed for existing residential buildings, it is flexible enough to accommodate future changes e.g. including data obtained from other stakeholders (e.g. building management) and assessing non-residential buildings. RSAM is further applicable to residential buildings constructed after 1950s in other similar regions including post-Soviet and Eastern Bloc countries.

Keywords: Central Asia; developing countries; green building; householder opinion; Kazakhstan; sustainability assessment tools; sustainability ranking; sustainability rating

1 Introduction

The increasing number of environmental disasters between 1950s and 1970s has raised public concerns about the environmental impact of anthropogenic activities. This forced governments to take action and, as a result, they pushed for sustainable development initiatives in various areas including construction which accounts globally for 34% of energy use (IIASA 2012), 19% of greenhouse gas emissions (IPCC 2014), and along with the demolition of buildings 36% of waste production (UNEP 2015). After first attempts to build sustainably, it was clear that some sort of measurement is required to evaluate the level of success in achieving sustainability goals. An ability to quantify the sustainability performance of given structures aids the decision-making process and limits arbitrary choices on the path to achieve a desired level of sustainability (AlWaer et al. 2008, Yudelson 2008). The best method for assessing the sustainability level of different structures, including buildings, is to use sustainability rating systems (Haapio and Viitaniemi 2008). There are currently numerous sustainability assessment tools developed worldwide to address this challenge, and a review of some of these methods is provided in the following section. In Kazakhstan, several strategies, concepts, and memorandums aim to support the sustainability and these initiatives have also led to the establishment of Kazakhstan's Green Building Council (KazGBC) – a member of World Global Building Council (WGBC). KazGBC, in cooperation with the United Nations Development Programme (UNDP), aims to introduce green construction standards and to motivate construction companies to certify buildings under BREEAM and LEED systems. Although the number of certified buildings is growing, the certification rate is too low to meet the 2030 target set by KazGBC (ITE Build & Interiors 2016). The progress by the green building initiative in Kazakhstan is relatively low due to following reasons: inadequate consideration given to green building principles by the outdated construction standards and regulations, a limited participation among construction industry members in green projects mostly due to their overall higher cost, and insufficient academic and research background on the sustainable buildings in the context of Kazakhstan. These root causes of overall poor sustainability practices, among others, are related to a lack of respective policies and regulations, guidelines, methodologies, practical examples, and technologies as well as low levels of awareness among the general public and the construction industry (UNDP 2013). Moreover, all certified buildings have only been constructed within the last decade which comprises only a small portion of the whole building stock in the country, whereas the sustainability of the existing buildings remains unassessed. In order to have a better understanding of the situation regarding these buildings, there is a need to develop a quick and effective sustainability assessment method tailored to Kazakhstan's context which would be used for numerous types of buildings while at the same time without inquiring large resources.

Including the stakeholders in the development process of an assessment methodology is key for achieving solutions that are environmentally, functionally, aesthetically, and economically viable for all involved (Bal et al. 2013, Stephan and Menassa 2015). In general, the stakeholders are defined as people who have interests in, can influence, or be influenced by a company or organization (Freeman 1984, Freeman et al. 2007, Freeman et al. 2010). A few studies assert the importance of stakeholders' engagement in construction (Mathur et al. 2008, Bal et al. 2013, Herazo and Lizarralde 2016). In particular, Mathur et al. (2008) pointed out three distinct approaches for conceptualizing stakeholder engagement in construction projects which relate to viewing stakeholder engagement as a management technique, an ethical requirement, or a forum for dialogue to facilitate mutual social learning. The benefits of using all these methods are clear and the opinions of stakeholders are critical in the proper assessment and analysis of requirements (Bryson 2004, Boecker et al. 2009, Gan et al. 2015). The involvement of multiple stakeholders plays a pivotal role in achieving sustainability goals.

The sustainability of buildings in Central Asia and in particular in Kazakhstan has yet to be studied in detail. To the authors' knowledge, the only published work on the subject covering the construction sector in Kazakhstan has been recently performed by Akhanova et al. (2020). The authors developed a Kazakhstan's Building Sustainability Assessment Framework (KBSAF) using the stepwise weight assessment ratio analysis (SWARA) technique for estimating weights of the system's categories and indicators, however; the framework focuses on assessing the sustainability performance of commercial buildings only, including office and retail buildings. Furthermore, the system involves a total number of 200 items to assess and requires extensive data collection for proper sustainability assessment, which the authors strive to achieve through BIM technologies. The method of data acquisitions along with the focus on the assessment of commercial buildings creates an approach to the evaluation of buildings' sustainability that is completely different from the one discussed in the present paper.

The present research aims to develop a systematic approach using stakeholders' perceptions and opinions for evaluating building sustainability: Rapid Sustainability Assessment Method (RSAM). It then specifically aims to obtain a snapshot of the current level of sustainability of existing residential buildings in Nur-Sultan (formerly Astana), Kazakhstan by the application of RSAM to selected buildings. RSAM can also be used for the assessment of buildings erected in the second half of the 20th century in other contexts directly (e.g. cities of post-Soviet and Eastern Bloc countries with very similar building characteristics and construction practices) as well as indirectly following minor modifications (e.g. cities of other developing countries).

1.2 Review of existing sustainability assessment methods

In the past, various sustainability tools with distinct goals and scopes have been introduced. These include environmental impact assessment (focusing on the impact of a project based on its localization on various modules of environment e.g. fauna, flora, communities, etc.), life cycle assessment/analysis (overall impact of a product over its lifetime), total quality assessment (focusing on all pillars of sustainability i.e. environmental, economic, and social), cumulative energy demand (focusing on energy consumption), and building assessment tools which is the focus of the following discussion. According to Reijnders and van Roekel (1999), the assessment tools can be roughly classified as either qualitative tools (that are based on criteria and scoring) and quantitative ones (which use life-cycle approach and quantitative input and output data of matter and energy flows). Two of the most commonly used qualitative tools are BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design), whereas tools based on life-cycle assessment (LCA) approach include EcoEffect, EcoQuantum, Environmental Load Profile (ELP), BEES (Building for Environmental and Economic Sustainability), BEAT (Building Environmental Assessment Tool, Denmark), and ITACA (Forsberg and von Malmborg 2004, Asdrubali et al. 2015). A similar classification as provided by Ali and Al Nsairat (2009) that classifies existing building assessment methods as either life-cycle assessment-based or multicriteria-based. The most notable multi-criteria rating systems that acquired worldwide recognition in the last decades include but are not limited to BREEAM (UK), LEED (USA), CASBEE (Comprehensive Assessment System for Built

Environment Efficiency, Japan), and Green Star (Australia, New Zealand, South Africa) (Zhang et al. 2017).

In BREEAM, the overall sustainability score of the building is calculated by evaluating the number of credits for each of its ten categories, multiplying them by weighting factor based on the category's importance, and summing them up (Gou and Xie 2017). LEED, on the contrary, awards points in its nine categories based on the number of requirements satisfied which are then added up to 110 total points (Castro-Lacouture et al. 2009). Green Star has adopted many of the features presented in LEED but has adjusted them to the regional context. CASBEE utilizes a completely different approach to score calculation: the system evaluates the building's sustainability performance using "Building Environmental Efficiency (BEE)" which is a ratio of "Building Environmental Quality and Performance (Q)" to "Building Environmental Loadings (LR)" (Banani et al. 2013). All of these sustainability assessment tools consider the building's various stages including its design, construction, and operation where CASBEE further investigates the deconstruction phase of the building's lifecycle.

Due to differing approaches these methods utilize, the same building might be given different performance scores depending on the rating system used. To address this issue, Asdrubali et al. (2015) proposed a methodology to normalize the overall sustainability performance scores which they apply to two buildings in Central Italy evaluated using LEED and ITACA, respectively. They identified the differences between the methods, established key categories (or "macro-areas") (site, water, energy, indoor environment quality, and materials) based on common indicators, reassigned new scores based on the new macro-areas, and compare the resultant values. A similar approach has been employed in the present study: a simplified normalization procedure of the four rating systems was performed to compare their agendas in sustainability performance evaluation (Figure

1) (JSBC 2005, GBCA 2009, USGBC 2009, BRE 2011). The present study established five key categories (“sustainable sites”, “energy”, “water”, “materials and resources”, and “indoor environment quality (IEQ)”) common to all of the examined sustainability assessment methods and the importance of each key category was determined in percentages. All discussed rating systems have distributed some credits outside of the identified key categories, but, for the sake of comparison, the credits attributed to these five key categories were assumed to comprise 100% of the total score.

Although the sustainability assessment tools selected for the present discussion share a consensus on their basic structures, the approach to achieving sustainability goals in these categories that each rating system demonstrates is unique. For example, LEED and Green Star consider the key category as “energy”, awarding the highest amount of points – 40% and 33.3%, respectively. CASBEE, on the other hand, awards an equal amount of credits (28.5%) to both “energy” and “IEQ”, the former being the most essential category within “LR” and the latter being the lead key category of “Q”. Meanwhile, BREEAM chooses “materials and resources” category as the most essential one allocating 29.5% of the credits to this key category and only 22.5% to “energy” category. An agreement is observed between LEED, BREEAM, and Green Star for “IEQ” category as they award 19-21.3% of credits to this category, which is considerably less compared to CASBEE. The least significant key category in all rating systems is “water” category: Green Star – 13.3%, LEED – 13%, BREEAM – 10%, and CASBEE awarding the least number of points – 3%. There is also a discrepancy amidst the methods on how they approach “sustainable sites” category: whilst CASBEE awards as high as 21.5% in this category, LEED restricts the number of achievable credits to 12% of the maximum score. The basis of these four sustainability assessment tools is built upon the discussed five key categories, but the differences in importance levels these methods allocate to the key categories, not to mention the indicators left outside of the comparative (sensitivity) analysis, demonstrate a general lack of agreement on how the global building sector should approach sustainability.

Banani et al. (2013) performed a comparative analysis of five different SA tools including BREEAM, LEED, Green Star, and CASBEE; which shed a light on how the tools assess important indicators falling outside of the scope of five key categories. All four tools recognize the contribution of buildings to the global pollution problem; but BREEAM, Green Star, and CASBEE assess pollution as an individual category whereas LEED distributes restrictions to emissions across several other categories. In addition, BREEAM and Green Star consider management as well as transportation as separate categories whereas LEED and CASBEE choose to distribute these parameters across different assessment categories. Moreover, BREEAM, LEED, and Green Star reward innovative approaches in achieving sustainability goals, whereas CASBEE does not include this criterion in evaluation, instead choosing to consider region-specific parameters such as “earthquake resistance” and “restriction of wind damage”. This comparative analysis along with the differences between the key categories addressed here show that the discussed methods have a common perspective on components of sustainable building but approach the evaluation process in different fashions best fitting their country of origin.

Issues with the applicability of global sustainability assessment methods to certain regions has led to numerous studies attempting to adapt international tools such as LEED and BREEAM to country-specific conditions and to propose their own model for sustainability assessment. Ali and Al Nsairat (2009) developed a green building assessment tool for residential buildings in Jordan tailored to various domestic regions considering variances in climate and geography within the country. Al-Jebouri et al. (2017) proposed a sustainability assessment system which can be further customized for different types of buildings in Oman by reviewing existing international and regional sustainability rating systems, identifying categories and indicators distributed among five pillars of sustainability (environmental, economic, social, cultural, and governance), and evaluating their relative weights. They claim that Middle Eastern countries (UAE in particular) admit the importance of regional context and culture in achieving sustainability and therefore regard them as a fourth pillar and include these in their sustainability-rating systems known as UAE Estidama. Following the example of UAE in developing their own domestic system, Banani et al. (2016) compared five major green building assessment tools to establish a framework for sustainability assessment of non-residential buildings, despite the adoption of the U.S. LEED sustainability rating system by the Saudi Green Building Council as its official tool for sustainability performance evaluation. They claimed that, at that moment, the country lacked specific assessment methods that would address the unique economic, social, and cultural aspects of Saudi Arabia. Mahmoud et al. (2019) addressed the issue of the inapplicability of contemporary methods outside of their country of origin and developed a sustainability assessment tool for existing buildings with a weighting system based on Fuzzy Hierarchal Process Method that can be used globally while demonstrating how regional variations affect the sustainability assessment process. These studies acknowledge and confirm the need for substantial effort arising whenever a sustainability rating tool is adapted to the country-specific conditions.

Although existing buildings provide multiple challenges regarding urban sustainability, the sustainability assessment tools designed for them are limited. Amidst all phases of the building’s lifecycle (i.e. raw materials extraction and processing, production of construction materials, construction of the building, operation, maintenance, and demolition), the operation and maintenance stage (involving: electricity use in the outlets, HVAC and lighting, heat in ventilation and conduction, materials in internal surfaces and HVAC services, and the use of water and wastewater) accounts for 45-75% of the total environmental impact (Seppo 2004). This underlines the importance of evaluating the sustainability level of existing buildings and suggesting a way to reduce their adverse impact on the pillars of sustainability.

As there are numerous sustainability assessment tools for building sustainability assessment, there are also some rating systems focusing specifically on the evaluation of existing buildings. Two important examples of these commercial tools are “LEED for Existing Buildings: Operations and Maintenance (LEED-EBOM)” (USGBC 2014) and “Green Star South Africa – Existing Building Performance (SA EBP)” (GBCSA 2014). The scope of LEED-EBOM involves the certification of sustainability levels of ongoing operations at existing institutional buildings, including offices, retail and service establishments, institutional buildings, hotels, and residential buildings of four or more habitable stories. It aims to provide the individual rating of a whole building, whether owner-occupied, multi-tenant, or multiple-building campus projects. Moreover, the rating system encourages the implementation of sustainable practices and reduction in the environmental impacts of existing buildings over their functional life cycles. It addresses exterior building site maintenance programs, water and energy use, environmentally preferred products and practices for cleaning and alterations, sustainable purchasing policies, waste stream management, and ongoing indoor environmental quality. There is a slight variation between weighting systems of LEED-EBOM and LEED for New Construction: e.g. the former accounts for solid waste management but the latter does not. This leads to differing environmental footprints addressed by each rating system (USGBC 2014).

Green Star SA EBP was developed based on the Green Star system proposed by the Green Building Council of Australia by tailoring its sustainability assessment criteria relevant to the South African context. It covers the same environmental categories addressed in the Green Star: new building tools which are management, indoor environment quality, energy, transport, water, materials, land use and ecology, emissions, and innovation. However, the focus is on the operations and management stage of the building's lifecycle to optimize its performance. The scope of the rating system spans from commercial buildings including office buildings, retail buildings, public assembly buildings, and low-risk industrial buildings to institutional and multi-unit residential buildings; addressing effectively relationships between buildings' landlords and tenants (GBCSA 2014).

Since the proposed LEED-EBOM and Green Star SA EBP both focus on the existing structures only, they share a relatively similar structure except for differences mainly due to the regional context (Table 1). Both sustainability assessment tools recognize the importance of the efficient use of energy and allocate a large weighting to this key category correspondingly. However, LEED-EBOM promotes the use of both on-site and off-site renewable energy sources which is completely overlooked by Green Star SA EBP. Another striking difference between the methods is that Green Star SA EBP treats transportation, emissions, and management as separate categories whereas LEED-EBOM distributes these parameters among other categories. There is a considerable similarity in how these tools evaluate IEQ category: they award almost equal amounts of credits to this category which assesses indoor air quality, lighting, acoustic and thermal comfort, daylight, and views. Both methods also promote building-scale metering and monitoring, sustainable land use, landfill diversion, efficient water use, control of refrigerants leaking, green cleaning practices, green procurement and purchasing, as well as innovations in sustainable solutions. They also give more credits to the existing building that has been certified with their ratings before and has accredited professionals consulting the owner or the building's management team. In summary, LEED-EBOM and Green Star SA EBP share more similarities than differences in evaluation of existing structures' sustainability performance.

1.3 Identified gaps of current sustainability rating tools

The sustainability assessment methods discussed above as well as other established rating systems share some common implementation issues. One of the major drawbacks of the tools is the complexity of their structure resulting from attempts to make the assessment framework as comprehensive as possible. The current state of many sustainability assessment methods requires a substantial amount of data and time, and any attempt to simplify procedures may result in the consideration of less indicators important for overall sustainability rating (Taisch et al. 2013, Alhumaidi 2016).

Another limitation of the existing methods is that most of them have a unique set of objectives or a certain niche they were designed for forcing their users to utilize a combination of different methods for a complete sustainability assessment of one project (Taisch et al. 2013). Moreover, the absence of a commonly agreed scientific way to develop a weighting system for criteria of varying significance leaves space for subjectivity and, therefore, possible misinterpretation of the actual sustainability level of the building (Alhumaidi 2016).

Due to global variations in geography, climate, economics, history, culture, and government regulations, tailored sustainability assessment tools have been generated for a number of countries (e.g. Asdrubali et al. 2015, Kridlova Burdova and Vilcekova 2015, Banani et al. 2016), since the assessment methods developed for one country/region may not be fully applicable to others (Cole 1999, Darus et al. 2009, Banani et al. 2013, Alhumaidi 2016). Contemporary sustainability assessment tools vary in aspects of their assessment models including indicators and weighting systems due to unique regional context involving climate and geographical features, level of development, priorities established by the governments, public awareness etc. (Banani et al. 2013). The origin of a specific tool determines the importance of different aspects of sustainability, and therefore, their inclusion in the assessment criteria (Todd and Geissler 1999). Moreover, the lack of consensus on how to calculate weights for each indicator and the subsequent emergence of different approaches to developing weighting systems also defined by the country of origin contributes to a globally inapplicability of these tools (Ding 2008). Mateus and Bragança (2011) state that the global tools require prior adaptation which needs time. These inconsistencies among the established sustainability tools lead to sophisticated and, thus, time-consuming and resource-intensive process of their adaptation to the regions outside of their origin.

In building sustainability assessment tools, occupants' involvement in assessments is either not considered at all or is optional accompanied by a minor weight in the overall assessment score. However, the opinions of residents can be used to provide a valuable basis that reflects the sustainability level of existing buildings. Residents living in a building are in a particularly good position to effectively evaluate different aspects of that building's performance as they spend the highest amount of time there and have a great interest in improving their experience and comfort levels. For example, Green Star SA EBP has an indicator called "occupant comfort survey" which facilitates the inclusion of householders in the sustainability assessment of the building they occupy and gives an insight of overall comfort levels. The survey is basically a 7-point scale questionnaire that assesses the respondent's satisfaction with acoustic comfort, thermal comfort, lighting, indoor air quality and ventilation, and building management (cleanliness, odors, etc.). However, conducting occupant surveys is not mandatory and is awarded only up to two points out of 110; based on population coverage, occupants' satisfaction level, improvement compared to previous survey (if applicable), and development of correction plan (GBCSA 2014).

A similar survey is a part of LEED-EBOM rating system, however; the tool only awards one point out of 110 if a survey is conducted covering at least 30% of the building's occupants; assessing the occupants' comfort including aspects such as thermal comfort, acoustics, indoor air quality, lighting levels, and building cleanliness. The tool requires, though, developing corrective actions plan based on the survey results (USGBC 2014). To conclude, LEED-EBOM and Green Star SA EBP seem to include the householders' opinions into the assessment of the building performance; however, this is optional and at an insignificant level.

The present research aims to develop a new sustainability rating system, RSAM, using stakeholders' perceptions and opinions for evaluating buildings. The rating tool uses the opinions of residents identified through questionnaires tailored to their level of knowledge of the building and expertise in sustainability providing rapid, low-cost, and dependable data to assess the building's sustainability performance. Although such a method might lack some of the comprehensiveness of existing and yet time-consuming and resource-intensive methods, it prioritizes the occupants' perspectives on the sustainability performance of the building with which they are quite familiar. It then specifically aims to obtain a snapshot of the current level of sustainability of existing residential buildings in Nur-Sultan, Kazakhstan by the application of RSAM to selected buildings. RSAM can also be directly used for assessment of buildings erected in the second half of the 20th century in other contexts (e.g. in cities of post-Soviet and Eastern Bloc countries with very similar building characteristics and construction practices) as well as indirectly following minor modifications (e.g. in cities of other developing countries).

2 Methodology

The RSAM method covers three pillars of sustainability (environmental, economic, social and functional) employing several assessment parameters hierarchically subcategorized into factors, then to indicators, and finally to sub-indicators. It measures stakeholder opinions on the existing applications of the building's structural elements and provided service systems. Specific weights have been assigned to calculate scores with a bottom-up approach based on the judgments of stakeholders. The model along with the indicator weights can be easily modified as a basis for evaluating buildings in other contexts. A graphical summary of the proposed method is given in Figure 2 and a detailed method (MethodsX) file is provided.

The three factors covered by RSAM are represented by the abbreviations: ENV - Environmental factor, S&F - Social and Functional factor, and ECO - Economic factor. Subsequently, indicators and sub-indicators of any factor are presented as level numbers following the corresponding factor abbreviation, e.g. ENV4.3, ECO2.1, or S&F3.2 (Table 3).

2.1 Identification of factors and indicators

The indicator selection stage has been completed via activities falling into two domains: people and knowledge resources (Figure 2). Information from stakeholders (people) and research (literature review) were utilized. Stakeholders (n = 68) between 19 and 57 years old from the following groups (Table 2) have been interviewed: "Public" (with a relevant engineering background, graduate degree (PG) and undergraduate degree or with high-school degree (PU)), "Academy" (sustainability expert academicians (AC)), and "Construction industry" (office workers (CO) and field workers (CF)). As a result, a total 12 indicators and 39 sub-indicators have been identified (Table 3).

2.2 Quantification of priorities and weights

Weights were collected from stakeholders via interviews and surveys. Likert rating scale (1-5) (i.e. “not important at all” (1), “not important” (2), “neutral” (3), “important” (4), and “very important” (5)) was used. The average values of all responses were calculated and used in the model as score multipliers (weights) (Table 3). After collecting the weights, a three-step statistical approach was conducted for further evaluation via SPSS 25.0 software. Firstly, the reliability of the considered data was tested using Cronbach’s Alpha test. It is a common measure of the internal consistency of a set of items in a survey to gauge its reliability (Cronbach 1951, George and Mallery 2003). If Cronbach’s alpha is as low as 0.50-0.60, then the data set is appropriate only for exploratory research, while 0.70 is generally perceived as well acceptable (Nunnally 1967, Hair et al. 2010). The result confirmed that the survey outputs are reliable.

Shapiro-Wilk normality test was used to identify the nature of the collected data ($p <.05$ for all stakeholder opinions on 51 indicators (Table 4)). It showed that the collected data can be analyzed using non-parametric statistical techniques. Kruskal-Wallis test is a non-parametric test, and its dependency on fewer assumptions leads to more reliable results (Reimann et al. 2008). It was used for identifying the differences in opinions between various stakeholder groups. Some other similar studies used the Analysis of Variance (ANOVA) for analysis of multiple sample means (e.g. Toor and Ogunlana 2009, Mascarenhas et al. 2014, Heravi et al. 2015). However, since the sample size of the collected surveys was not very large and the normality of the data was under question, the Kruskal-Wallis test was more appropriate to use for the present study.

Finally, ranking using Mean Score Analysis (MS) was used to indicate the overall respondents' perception of the indicators. It is commonly used (e.g. Makuei and Oladapo 2014, Aigbavboa et al. 2017) to assess respondents' understanding of sustainable construction practices and prioritization of all the indicators measured with Likert scales (Ojoko et al. 2018). MS can be calculated as follows:

$$MS = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{(n_5 + n_4 + n_3 + n_2 + n_1)} \qquad (1)$$

Where, n_1 *to* n_5 are the number of respondents who choose the options: 1 ("not important at all"), 2 ("not important"), 3 ("neutral"), 4 ("important"), 5 ("very important"); respectively.

2.3 Ten points scaling (TPS) system and RSAM score

RSAM performs a quantitative assessment based on a TPS assessment. The main aim of assigning points in this method was to reveal exact implementations that were better or superior to the average or common applications in the context of the selected city. The measurement for each sub-indicator should support the rapid assessment based on householder opinion i.e. it should not be complicated or highly technical. After reviewing the existing literature along with the feedback from the stakeholders, householder opinion/information-based measurement methods were suggested for all sub-indicators (further details presented in the methods (MethodsX) file).

The weighted RSAM scores for objective sets: indicators, factors, and overall, are calculated as:

$$I_j = \frac{\sum_{i=1}^{n} W_i \times SI_i}{\sum_{i=1}^{n} W_i}, F_k = \frac{\sum_{j=1}^{m} W_j \times I_j}{\sum_{i=1}^{m} W_i}, S = \frac{\sum_{k=1}^{3} W_k \times F_k}{\sum_{k=1}^{3} W_k},$$

Where *n, m,* and *k* are the number of sub-indicators, indicators, and factors belonging to those objective sets, respectively; $W_{i,j,k}$ is the related weights; and I_j, F_k, and *S* are the RSAM scores of the indicators, factors, and overall, which are the weighted averages of all objective sets, respectively. All ratings are between 0 and 10.

3 Results and Discussion

3.1 Stakeholder opinions on sustainability indicators

The descriptive statistics of all stakeholder groups' perception of the indicators denotes a mean value of 4.22, variance of 0.11, and a standard deviation of 0.33. The analyses showed that the coefficient of variation is not high (<8%). The reliability test of the various stakeholder groups' opinions about the presented indicators reveals that the Cronbach's alpha score is 0.84, which is >0.70 – the threshold value for considering whether data have a good internal consistency (Nunnally 1967; Hair et al. 2010). A further investigation using the Kruskal-Wallis test was performed to find significant differences between stakeholder groups on the indicators. It showed that various groups (PG, PU, AC, CO, and CF) have a significant difference in opinion on sustainability indicators ($p < 0.05$) (Table 5), all stakeholder groups' opinions on the considered indicators showed significant differences.

In order to elaborate and further discuss the main differences in the stakeholders' opinions, the average weights of the groups for Level 1 parameters ("environmental", "economic", and "social and functional") are illustrated in Figure 3. The economic factor was rated as the second important factor at around 4.5 in all groups except for "field workers", who assigned equal weights (4.6) to all three factors. Meanwhile, the most and the least important factors vary significantly between the remaining groups. Both “graduate degree holders” and “office workers” gave priority to “social and functional factor”, whereas “academy” and “university or high school diploma holders” rated it as the least important factor. A substantial difference in the weights was observed in the opinions of the graduate degree holders against the other groups since they are the only group to rate the environment factor as the least important one (at 4.3). Despite some disagreement among the stakeholder groups on the order of priorities given to Level 1 parameters, the range of the weights of these parameters are slim i.e. spanning only from 4.2 to 4.7 out of 5, and the stakeholder groups assign them similar significance in the overall assessment.

The results of Mean Score Analysis (Table 6) showed that in “environmental” category (ENV), respondents rated both “water” and “energy” indicators as the most important and relevant ones, whereas “soil use and biodiversity” was perceived as the least important. More specifically, “heat loss/insulation” and “water consumption” are considered as the most important sub-indicators by not only the study stakeholder groups but also the residents of Nur-Sultan. This can be explained by harsh winters and relative water scarcity due to extreme continental climate of the region (characterized by long winters and relatively dry summers). Typically, occupants were not satisfied with the drops in room temperature when windows are opened for ventilation purposes. Energy provider companies in Nur-Sultan also highlight decreasing heat losses throughout the city as their operational priority, though Nur-Sultan has significantly lower heat losses (13.6%) compared to Almaty (20%), the second major city in Kazakhstan (ESMAP 2018). The local population finds the hardness of the city’s tap water too high to drink without any further treatment; therefore, the majority prefers filtered (obtained by installing a filtering device in the apartment) or bottled water (ordered from local suppliers or bought in stores) for drinking purposes (Lee

2016). Filtering tap water is appreciated significantly by “AC” stakeholder group (comprised mostly of citizens of other countries), who uses mainly bottled water for drinking and finds its delivery timing issues problematic.

During the evaluation of “economic” category (ECO), which encourages an integrated design process optimizing building performance, the stakeholders of all groups voted for “operational costs” of the building. The main costs which influence “operational costs” and represent sustainability of the building are “energy” and “water consumption” costs. This result (rank 9, Table 6) clearly indicates that the residents are more concerned with the costs on energy and water consumption in Nur-Sultan mainly due to their income levels. Kazakhstan has a developing economy with a GDP recently moved up into the level of middle-income country. Generally, average-income households are able to pay for energy and water, yet low-income population has issues with paying these bills. For this reason, heat tariffs are highly subsidized and thus kept artificially low (at about one-fifth of the actual cost), but the energy and water costs cannot be lowered further without substantial financial support from the state (ESMAP 2018). Although Kazakhstan has initiated water and energy efficiency programs (“Energy Efficiency 2020”, “Integrated Water Resources Management and Water Efficiency up to 2025”), the population is still concerned about the costs on consumption of water and energy.

Among the stakeholders' ratings, “social and functional” category (S&F) parameters, “indoor air quality” indicator was considered as the most critical issue for Nur-Sultan’s residents since all survey respondents identified this indicator as the highest priority (rank 1, Table 6). As respondents are aware that poor indoor air quality causes numerous health issues, the need for better indoor air quality monitoring to combat health risks and enhance occupants’ comfort becomes more apparent. Moreover, it is important to use the right combination of strategies of passive design and active measures (e.g. cooling, heating, solar energy, electric ventilation). The survey showed that the population rated “mobility plan” and “passive systems” as the least important indicators, whilst “ventilation” and “temperature” were given 2nd and 4th priority levels after “indoor air quality”.

3.2 Classification and assessments of residential buildings (case studies)

Nur-Sultan, as the new capital of Kazakhstan since 1998, is a rapidly developing city with the greatest construction output in the country. With a nearly three-fold population growth over the last two decades since the city was appointed as the new capital, Nur-Sultan has previously struggled to provide sufficient housing stock to meet the growing demand. The government has been continuously providing substantial financial support to tackle this issue, which has led to a notable construction boom and has made the construction sector one of the leading industries (Cole 1999, Kridlova Burdova and Vilcekova 2015). At present, the city has a diverse residential building stock ranging from Soviet-era buildings to the ones built after the establishment of the newly independent government in 1991 until 1998, and finally, the new generation buildings built after the Kazakh government appointed Nur-Sultan as the capital city in 1998.

The previous research by the authors has investigated the sustainability level of residential buildings in Kazakhstan and has pointed out that the level of sustainability has a correlation with the building’s age and comfort levels (Tokbolat et al. 2018). The study classified residential buildings as (a) “old”: panel and brick multistory buildings depending on materials and components used for construction, and houses typical single-standing dwellings; and, (b) “new”: buildings built using mainly concrete, different filling materials, and bricks, subcategorized as ‘economy, comfort, business, and premium’ class buildings based on their comfort level. The latter category covers nearly two-thirds of the housing needs of the city's population (Tokbolat et al. 2018).

The present study uses RSAM to assess the sustainability of residential buildings and complexes in Nur-Sultan using a slightly different classification than Tokbolat et al. (2018). The building-related information about the case studies was gathered mainly from the buildings' residents whereas a small amount of additional data acquired from other stakeholder groups such as building management and construction companies. For example, "old" buildings were classified in two categories: (1) buildings constructed in the period between industrialization in 1950-60s and the dissolution of the Soviet Union in 1991, (2) buildings constructed in the period from the independence of Kazakhstan in 1991 to the appointment of Nur-Sultan as the capital city in 1998. At the same time, "new" buildings were not further categorized based on their comfort levels but were rather considered as one group, since dividing buildings by their comfort level is a predominantly commercial initiative developed by the construction companies for marketing purposes, which may be biased. Therefore, the present study used a third generalized category - (3) "new buildings". Categories (1) and (2) had one sample building per category and category (3) included ten buildings selected from various districts of Nur-Sultan. The greater prevalence of new buildings in the samples pool is due to (a) the interest in new buildings as they will be in service longer than the older buildings, (b) their ever increasing share in the city's building portfolio, and (3) a larger availability of data which supports sustainability assessment. Householders' data were collected from a minimum five randomly selected samples per building, and results were reported and discussed based on the average values.

The assessment scores of all case studies are summarized in Figure 4 where first two bars present the overall and weighted factor contributions of the "old buildings", while the following three bars illustrate the lowest, average, and best scores of the “new buildings”, respectively. In general, the assessment results have shown that the “Case 1” building (built before 1991) has the lowest sustainability performance score overall as well as in each factor individually. “Case 2” building (built between 1991-1998) presents a rather unexpected and competitive sustainability level compared to some of the more recent structures – “new residential buildings” (“Case 3” and “Case 4”), mainly due to its great performance in the economical aspect. Another significant finding of the assessment is that the environmental parameter scores are either low or not satisfactory across all building categories, and yet there seems to be a gradual improvement in the environmental aspect of buildings’ sustainability over time. Moreover, to validate the occupants’ assessment of the building in “Heat loss/Insulation” sub-category, the authors estimated R-value, the thermal resistance of the wall materials (the greater the R-value – the better the insulating properties of the building), of the case study buildings and compared them to the responses. The findings suggest that there is an as strong correlation between estimated R-values and the assessment of the building’s insulation done by occupants. The subsections below present the details of the selected case studies and their assessment results.

3.2.1 Case 1: residential building built before 1991

A typical residential building representative of the structures built before 1991 is selected from a suburban area in Nur-Sultan. The neighborhood where the building is located, including the building itself, was constructed at the end of 1980s (relatively new as a Soviet-era building, and thus comparable to other buildings) in accordance with the construction standards and regulations of the Soviet Union. The neighborhood was initially planned as a ‘residential district’ consisting of similar buildings, and now contains two schools, two kindergartens, one clinic, and several grocery and convenience stores. The area has many large trees which enhances the overall image of the neighborhood. Currently, the average price of the apartments of this kind of buildings is relatively low due to unfavorable conditions (e.g. old elevators or none, inconvenient floor plans, smell from basement, old pipes that break often, limited parking space) and the unwillingness of city residents to live in old buildings. The assessed building has four floors with 126 apartments in total. The average monthly energy consumption is 133 kWh per person, which is higher than the average energy consumption by the city's residents (101 kWh per person) (ESMAP 2017). This can be explained by the age of the building, associated losses through the building's envelope (R-value of the external wall components is calculated as 14.7 W/m^2K), and inefficient household equipment. Nevertheless, the building received a relatively high score of 5.3 in S&F factor improved by the location of the building in a vibrant and socially comfortable area. The fact that the building is surrounded by rich vegetation and trees native to the region has also contributed positively to the S&F score. However, results show that ENV score of the building is very low (2.3). The overall RSAM score for the building is 3.9, which corresponds to a low sustainability performance level and can be explained by the age of the building and the poor/non-existing sustainability agenda at the time of its design and construction.

3.2.2 Case 2: residential building built from 1991 to 1998

A residential building typical to this category was selected among the buildings constructed prior to Nur-Sultan becoming a capital in 1998. The area consists of several dozens of multistory residential buildings built starting from 1997 and located on the embankment of Ishim River. It also has a wide range of commercial amenities such as convenience stores, development centers, beauty salons, and flower shops among others, which are usually located in the buildings' basement or ground floor. The notable difference of this neighborhood from the one described in the previous case is a yard with various children's playgrounds and football and basketball courts. Currently, apartments in these buildings are privately owned or rented out. The location of the neighborhood on the river's bank as well as in the geographic center of the city makes this residential area attractive to city residents. The case study building has 16 floors and a total of 64 apartments. The average energy consumption is around 120 kW/h per person, which is higher than the average energy consumption in Nur-Sultan, but lower than that of "Case 1" building. The R-value for the building materials used for wall construction was calculated to be 17.2 W/m^{2}K. The best performing category is ECO with an exceptionally high score of 8.0 which is the maximum achieved score in this category among all assessed buildings. The overall RSAM score of this residential building is 5.5 which is an impressive result given the average performance score (5.3) of the supposedly more sustainable new-generation buildings evaluated in the present study.

3.2.3 Case 3: new residential building (lowest sustainability score)

A building built in 2004 was selected from a residential area of Nur-Sultan located in a wealthier part of the city. This area has been constructed in order to provide accommodation for the fast-growing population of Nur-Sultan after its appointment as the capital city. However, not all the new buildings were good quality construction. This, in the past, has been evident after strong wind events during which façade materials of buildings of poor-quality build got damaged easily. Such residential areas are quite common and at present, they usually provide accommodation for people working in nearby governmental agencies. The case study building consists of seven floors and a total of 114 apartments. The average monthly energy consumption was 98 kWh per person, which is slightly lower than the city-wide average. Overall, the building's sustainability performance was rated low in many sub-categories. The lowest score category-wise was obtained in ENV category (2.9), it is possible that sustainability in general, as well as environmental aspects, have not been considered in the building's design at that time. Despite the proximity to various amenities, the occupants expressed dissatisfaction with the accessibility of amenities, and social and functional dimensions of the residential area. More specifically, S&F5 indicator ("facilities") was estimated to be only 4.1. Another significantly lower score of 2.5 was scored in ECO2 ("local economy") indicator indicating the absence of affordable solutions for householders. However, the building scored high results in indicators such as, for example, S&F4 ("space flexibility and adaptability") and S&F1 ("user's health and comfort"). These results suggest that such buildings would tend to be more attractive for higher-income occupants. All in all, the overall RSAM score of the building is 4.4, which is lower than the score of "Case 2" building built much earlier.

3.2.4 Case 4: new residential building (highest sustainability score)

A representative complex from the newest generation buildings group which received high scores was selected from one of the favorable areas of the city near the entertainment center Khan-Shatyr. The selected residential complex is built close to an artificial lake and is positioned as a green neighborhood with the integration of renewable energy technologies such as solar panels, wind turbines, and piezoelectric energy harvesting devices mainly used to supply outdoor lighting devices. The apartments are privately owned by individuals or rented out. The location of the complex is convenient in terms of transport accessibility, presence of various outdoor amenities, and proximity to business and cultural areas of the city. The case study residential complex contains buildings with 8, 10, 12, and 15 floors with a total number of 620 apartments. The average monthly energy consumption is 110 kWh per person and the calculated R-value of the exterior wall for the assessed buildings is 8.7 W/m^2K. The complex showed outstanding results in S&F category by scoring 7.9 points. ECO factor is another area where the building performed well by scoring 7.2. In addition, the residential complex is one of the first buildings in the country that implemented a wide set of green building measures. For example, it is estimated that the complex saves up to 19% of energy due to various energy-efficient solutions and passive design. Moreover, the complex collects and reuses greywater achieving reduction up to 32% in water consumption compared to conventional buildings in Nur-Sultan. However, the residents rated ENV1 (“energy”) and ENV4 (“water”) poorly resulting in poor performance of the complex in ENV factor (3.7), which is still the best score among all assessed residential buildings. Overall, “Case 4” building complex achieved a higher level of sustainability in two out of three main areas of RSAM assessment, and its sustainability performance was assessed as 6.3.

3.4 Comparison of RSAM structure with established methods for existing buildings

Two well-established sustainability rating systems dedicated to the assessment of existing buildings, LEED-EBOM (USGBC 2014) and Green Star SA EBP (GBCSA 2014), were compared to the resultant structure of the RSAM framework. All three methods recognize the importance of the efficient use of energy and allocate correspondingly great weighting to this category. However, neither LEED-EBOM nor Green Star SA have incorporated heat loss and insulation into their assessment framework, while RSAM emphasizes its essence due to the considerable negative impact of coal-powered combined heating and power systems widespread in Kazakhstan on the environment. Moreover, LEED-EBOM and RSAM promote the use of renewable energy sources which is overlooked by Green Star SA. Nonetheless, RSAM considers only green energy produced on-site, whereas LEED-EBOM takes into account the use of off-site renewable energy, too. All three methods encourage the building’s owner or management to support and protect the site’s ecology as well as favor previously built areas. Moreover, all sustainability assessment tools include solid waste management (i.e. waste separation and storage) and water use efficiency into the sustainability level evaluation process. Though they all require proper collection and management of stormwater (e.g. use it for irrigation purposes), only RSAM considers the recycling and reuse of greywater with its separation from black water.

One key difference between RSAM and the existing two methods is that the former accounts for the economic aspect of sustainability by measuring initial and operational costs of the building and promoting the use of local goods and services which helps to balance the evaluation outcome between the pillars. Another considerable difference between RSAM and the available methods is that the proposed rating system encourages the use of natural ventilation, but LEED-EBOM and Green Star SA do not differentiate between mechanical and natural ventilation systems as long as the desired level of indoor air quality is achieved. The toxicity levels of interior spaces seem to be a major concern for all of the methods, as well as the use of natural light and the thermal and visual comfort of occupants. However, only RSAM encourages the incorporation of passive systems and considering the layout and orientation of the building for minimizing the need for cooling, heating, and mechanical ventilation.

LEED-EBOM, Green Star SA EBP, and RSAM all emphasize the importance of the availability of alternative transport options, but RSAM performs a thorough assessment of sustainability performance of the building by including occupant safety, accessibility, availability of social areas for bringing people together, and space optimization and flexibility in the equation. What RSAM does not include, in comparison to LEED-EBOM and Green Star SA EBP, is the evaluation of parameters such as green cleaning, sustainable purchasing, innovative approach to sustainability, and refrigerants management – concepts which are still new to Kazakhstan, therefore, might compromise the survey speed and quality as they may require detailed explanations for householders and if not understood may lead to poor quality answers. All in all, there are numerous similarities along with some important differences between the established rating systems and the proposed method mainly due to three reasons: (1) the RSAM method aims to cover the pillars of sustainability evenly, (2) a few indicators are left out as they cannot be effectively evaluated via occupant surveys, and (3) the method's content is significantly affected by the regional context, in the present case, of Kazakhstan.

4 Conclusions and Implications

A fast and resource-efficient sustainability assessment method, Rapid Sustainability Assessment Method (RSAM), has been designed based on stakeholders' perceptions and opinions evenly covering the three pillars of sustainability (environmental, economic, social and functional). Then, it has been used to rate the sustainability performance of selected existing residential buildings representative of different eras in Nur-Sultan (formerly Astana), Kazakhstan. The assessments were based on the responses of the buildings' occupants to questionnaires. It has identified key differences in the sustainability performances of buildings of three different generations (built during the Soviet era i.e. prior to 1991, built between 1991 and 1998 following Kazakhstan's independence, and built after 1998 when Nur-Sultan city has become the country's capital). Out of three main sustainability categories, the environmental aspect of the residential building sector has the lowest performance rating, which nonetheless has gradually improved over the years. For further improvement, adopting the developed methodology will allow the construction sector and governmental agencies to understand the sustainability condition of individual residential buildings in the city or country for a relatively low cost. The method can also be modified to expand the assessment to non-residential buildings. These, in combination, would further enable the use of assessment results for decision-making at governmental level for the improvement of building sustainability performances for new constructions in the future.

There were certain limitations to the present research. First, the sustainability research in Kazakhstan in general and sustainability of buildings in particular is limited to only a few studies (Tokbolat and Calay 2015, Tokbolat et al. 2018, Akhanova et al. 2020). Furthermore, the domain of sustainability is new to the general public requiring some on-site education on the subject prior to the survey. This, along with the subjectivity of responses to certain sub-indicator questions (e.g. perceived average temperature) made the data collection and analysis a labor-intensive process. In the case of older buildings, the data were often less elaborate and required additional processing due to the absence of measuring devices (meters) or unavailability of records, preventing the residents from reporting accurate data such as energy or water consumption.

One of the most important features of RSAM framework is its flexibility allowing modifications on the structure (addition or omission of any indicator or sub-indicator) and the weighting system (assigning weights acquired for a specific region or context). This flexibility gives an opportunity to re-purpose the framework to either include wide range of buildings or focus on a particular type depending on the goals of such sustainability assessment.

Given the relatively young age of the capital city and very limited construction before the second half of 20th century, traditional and historic buildings in Nur-Sultan are rare. Moreover, the current state of construction sector in the city favors new construction which is much more profitable than renovating old buildings. However, if the framework is to be applied to an older city (e.g. Almaty, the cultural center of Kazakhstan with over a century-long history), it can be adjusted to account for cultural, social, and other benefits that renovating traditional and historical buildings brings. The existing structure of the framework already favors reusing old buildings with an inclusion of sub-indicators like “reuse of previously built or contaminated areas”, but it may omit other significant factors. Some of the suggested major aspects of adaptive reuse of old historic buildings include “heritage preservation” and “appropriateness of the new scope” of the building, which can be easily added as indicators or sub-indicators to social and functional factor (S&F). Other aspects such as “the contribution of the building to revitalization of the area” and “increased tourism” may also be important (Misirlisoy and Gunce 2016), but they might pose a challenge in finding rapid and easy ways to rate these aspects. On the contrary, some sub-indicators including the initial costs of construction might have to be changed or overlooked in order to assess renovation costs. These kinds of adjustments would require iterating the process of framework development starting from choosing appropriate indicators and sub-indicators as well as ways to measure them and ending with developing a new weighting system derived from stakeholders’ opinions adding a great prospect in RSAM improvement in the future.

RSAM has the potential to become a good alternative to elaborate and resource-intensive international sustainability certification tools. The recommended future work includes (1) the development of a user-friendly online tool with an easy-to-navigate structure (to make the adoption of RSAM easier for stakeholders), (2) building a city-wide sustainability map with the help of stakeholders and governmental agencies to access larger quantities of building information (to aid the decision-making process of the municipality in improving urban sustainability), and (3) to develop a causality model for RSAM parameters which can measure householders' loyalty and satisfaction levels for housing developers (to understand the correlation between various sustainability-related variables and the clients' satisfaction, to view subsequent changes in satisfaction levels after making adjustments to building-related variables during design and construction phases).

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Table 1. Comparison of sub-indicators of Rapid Sustainability Assessment Method (RSAM) with LEED - Existing Buildings: Operations & Maintenance (EBOM) and Green Star for Existing Building Performance (SA EB)

Sub-indicators of RSAM	LEED - EBOM	Green Star SA EB
ENV1.1: Primary energy consumption/area (or volume) (Energy efficiency rating)	X	X
ENV1.2: Heat loss/Insulation		
ENV1.3: Local energy production	X	
ENV2.1: Layout optimization		
ENV2.2: Soil sealing		
ENV2.3: Reuse of previously built or contaminated areas	X	X
ENV2.4: Ecological protection of the site	X	X
ENV2.5: Rehabilitation of the surrounding	X	
ENV2.6: Use of native plants		
ENV3.2: Reused products and recycled materials	X	X
ENV3.3: Waste separation and storage	X	X
ENV4.1: Water consumption	X	X
ENV4.2: Recycling and reuse of grey water		
ENV4.3: Rain and storm water collection and use	X	X
ENV4.4: Separation of black water		
ECO1.1: Initial costs (cost of the building)		
ECO1.2: Operational costs (e.g. energy and water consumption costs)		
ECO2.1: Hiring local goods and services		
S&F1.1: Natural ventilation		
S&F1.2: Toxicity of finishing materials	X	X
S&F1.3: Thermal comfort	X	X
S&F1.4: Visual comfort	X	X
S&F1.5: Acoustic comfort		X
S&F1.6: Indoor air quality	X	X
S&F1.7: Natural light	X	X
S&F2.1: Layout and orientation		
S&F2.2: Passive systems (e.g. no electric ventilation, cooling and heating, etc.)		
S&F3.1: Occupant safety		
S&F3.2: Accessibilities		
S&F4.1: Availability and accessibility to social areas		
S&F4.2: Space optimization, flexibility and adaptability		
S&F5.1: Accessibility to public transport	X	X
S&F5.2: Local amenities		
S&F5.3: Low impact mobility	X	X
S&F5.4: Building management and availability of services		X

Table 2. Data on participants belonging to one of the three stakeholder groups (n = 68)

	Stakeholder groups	**Description of participants**
Public	PG: People with graduate degree (n = 15)	Specialists, managers, graduate students, engineers (civil, environmental, mechanical, electrical), research assistants, teaching assistants
	PU: People with undergraduate degree and/or with high school degree (n = 20)	Accountants, auditors, students, high school graduates, businessmen, teachers, doctors
Academy	AC: University professors (n = 15)	Professors at various levels
Construction industry	CO: Office workers (n = 9)	Architects, computing engineers, project managers, structural engineers, pumping engineers, electrical engineers
	CF: Field workers (n = 9)	Foremen, chief managers, project managers, technical document specialists, project group specialists, chief engineers, site engineers

885 Table 3. Hierarchical structure of RSAM framework with weight summaries

Level 1 (Factors)	**Weights [1-5]**	**Level 2 (Indicators)**	**Weights [1-5]**	**Level 3 (Sub-indicators)**	**Weights [1-5]**
ENV: Environmental	4.57	**ENV1**: Energy	4.65	**ENV1.1**: Primary energy consumption/area (or volume) (Energy Efficiency rating)	4.47
				ENV1.2: Heat loss/insulation	4.56
				ENV1.3: Local energy production	4.08
		ENV2: Soil use and biodiversity	3.99	**ENV2.1**: Layout optimization	4.03
				ENV2.2: Soil sealing	4.05
				ENV2.3: Reuse of previously built or contaminated areas	3.51
				ENV2.4: Ecological protection of the site	4.20
				ENV2.5: Rehabilitation of the surrounding	3.95
				ENV2.6: Use of native plants	3.71
		ENV3: Materials and Solid Waste	4.15	**ENV3.1**: Reused products and recycled materials	4.07
				ENV3.2: Waste separation and storage	4.31
		ENV4: Water	4.58	**ENV4.1**: Water consumption	4.53
				ENV4.2: Recycling and reuse of grey water	3.87
				ENV4.3: Rain and storm water collection and use	3.53
				ENV4.4: Separation of black water	3.79
ECO: Economic	4.41	**ECO1**: Cost of building	4.47	**ECO1.1**: Initial costs (cost of the building)	4.33
				ECO1.2: Operational costs (e.g. energy and water consumption costs)	4.63
		ECO2: Local Economy	4.13	**ECO2.1**: Hiring local goods and services	4.13
	4.51		4.53	**S&F 1.1**: Natural ventilation	4.61

Level 1 (Factors)	Weights [1-5]	Level 2 (Indicators)	Weights [1-5]	Level 3 (Sub-indicators)	Weights [1-5]
S&F: Social and functional		**S&F1**: User's health and comfort		**S&F 1.2**: Toxicity of finishing materials	4.61
				S&F1.3: Thermal comfort	4.61
				S&F1.4: Visual comfort	4.31
				S&F1.5: Acoustic comfort	4.53
				S&F1.6: Indoor air quality	4.69
				S&F1.7: Natural light	4.43
		S&F2: Passive design	3.86	**S&F2.1**: Layout and orientation	3.92
				S&F2.2: Passive systems (e.g. no electric ventilation, cooling and heating, etc.)	3.73
		S&F3: Mobility plan	3.86	**S&F3.1**: Occupant safety	4.64
				S&F3.2: Accessibilities	4.28
		S&F4: Space flexibility and adaptability	3.88	**S&F4.1**: Availability and accessibility to social areas	4.16
				S&F4.2: Space optimization, flexibility and adaptability	4.09
		S&F5: Facilities	4.09	**S&F5.1**: Accessibility to public transport	4.23
				S&F5.2: Local amenities	3.93
				S&F5.3: Low impact mobility	3.71
				S&F5.4: Building management and availability of services	4.12

Table 4. Shapiro-Wilk normality test performed on the collected data from the participants

Stakeholder group	**Shapiro-Wilk test parameters**		
	Statistic	**df**	**Sig.**
AC	0.934	51	0.006
CF	0.934	51	0.007
CO	0.915	51	0.001
PG	0.943	51	0.015
PU	0.945	51	0.019

Table 5. Kruskal-Wallis test on overall score of stakeholder groups' opinion on all indicators

Levels	**df**	**H value**	**Critical value**	**P value**	**Conclusion**
Level 3 - Sub-indicators	4	3644237.8	0.7	<0.000	Not all group medians are equal. Differences between some of the medians are statistically significant. Rejection of null hypothesis.
Level 2 - Indicators	4	138402.8	0.7	<0.000	
Level 1 - Factors	4	106709.7	0.7	<0.000	

894 Table 6. Indicator priorities by all stakeholder groups

Parameters	**Number of responses and priority ranking**						
Indicators	**1**	**2**	**3**	**4**	**5**	**MS**	**Rank**
A. LEVEL 3 PARAMETERS							
Indoor air quality	0	2	6	17	49	335	1
Natural ventilation	0	1	6	25	40	320	2
Heat loss/Insulation	0	2	2	26	40	314	3
Thermal comfort	0	0	2	33	35	313	4
Acoustic comfort	0	2	5	22	41	312	5
Toxicity of finishing materials	0	1	3	20	44	311	6
Water consumption	0	2	8	13	46	310	7
Natural light	0	4	8	23	37	309	8
Occupant safety	0	2	3	19	44	309	8
Primary energy consumption	0	2	5	23	38	301	9
Operational costs	0	0	2	20	43	301	9
Visual comfort	0	3	10	27	31	299	10
Accessibilities	0	5	6	34	27	299	10
Waste separation and storage	0	2	7	27	32	293	11
Availability and accessibility to social areas	0	5	8	38	21	291	12
Accessibility to public transport	0	4	9	30	26	285	13
Initial costs (cost of the building)	1	3	5	22	35	284	14
Ecological protection of the site	0	3	10	24	30	282	15
Space optimization, flexibility and adaptability	0	4	14	30	22	280	16
Reused products and recycled materials	0	5	8	32	23	277	17
Building management and availability of services	0	2	11	32	21	270	18
Local Energy production	1	4	11	23	27	268	19
Construction waste	1	6	11	27	22	263	20
Use of native plants	3	9	19	30	13	260	21
Recycling and reuse of grey water	2	4	13	29	19	258	22
Local amenities	0	4	12	33	16	256	23
Soil sealing	0	2	16	19	24	248	24
Separation of black water	3	6	16	27	16	248	25
Layout and Orientation	0	3	11	37	12	247	26
Rehabilitation of the surrounding	2	5	11	28	17	240	27
Reuse of previously built or contaminated areas	6	7	21	22	14	235	28
Passive Systems	3	5	15	24	15	226	29
Rain and storm water collection and use	3	6	20	26	9	221	30
Heat island effect	3	7	15	19	14	205	31

Low impact mobility	1	5	19	16	9	176	32
B. LEVEL 2 PARAMETERS							
User's health and comfort	0	2	6	20	43	317	1
Water	0	1	6	22	41	313	2
Cost of Building	0	2	4	28	36	308	3
Energy	0	1	5	15	46	307	4
Materials and Solid Waste	2	1	15	27	26	285	5
Local Economy	0	2	12	29	25	281	6
Facilities	0	2	6	41	16	266	7
Space flexibility and adaptability	0	3	17	38	11	264	8
Passive design	0	4	14	32	13	243	9
Mobility plan	0	4	19	30	10	235	10
Soil use and biodiversity	0	1	14	32	12	232	11
C. LEVEL 1 PARAMETERS							
Environmental	0	4	7	18	45	326	1
Economic	0	1	4	31	36	318	2
Social and functional	0	1	6	28	34	302	3

* 1 – Not at all important, 2 - Not important, 3 - Neutral, 4 – Important, 5 - Very important

897 Figure 1. Comparative (sensitivity) analysis for LEED, BREEAM, Green Star, and CASBEE in

898 terms of major key categories

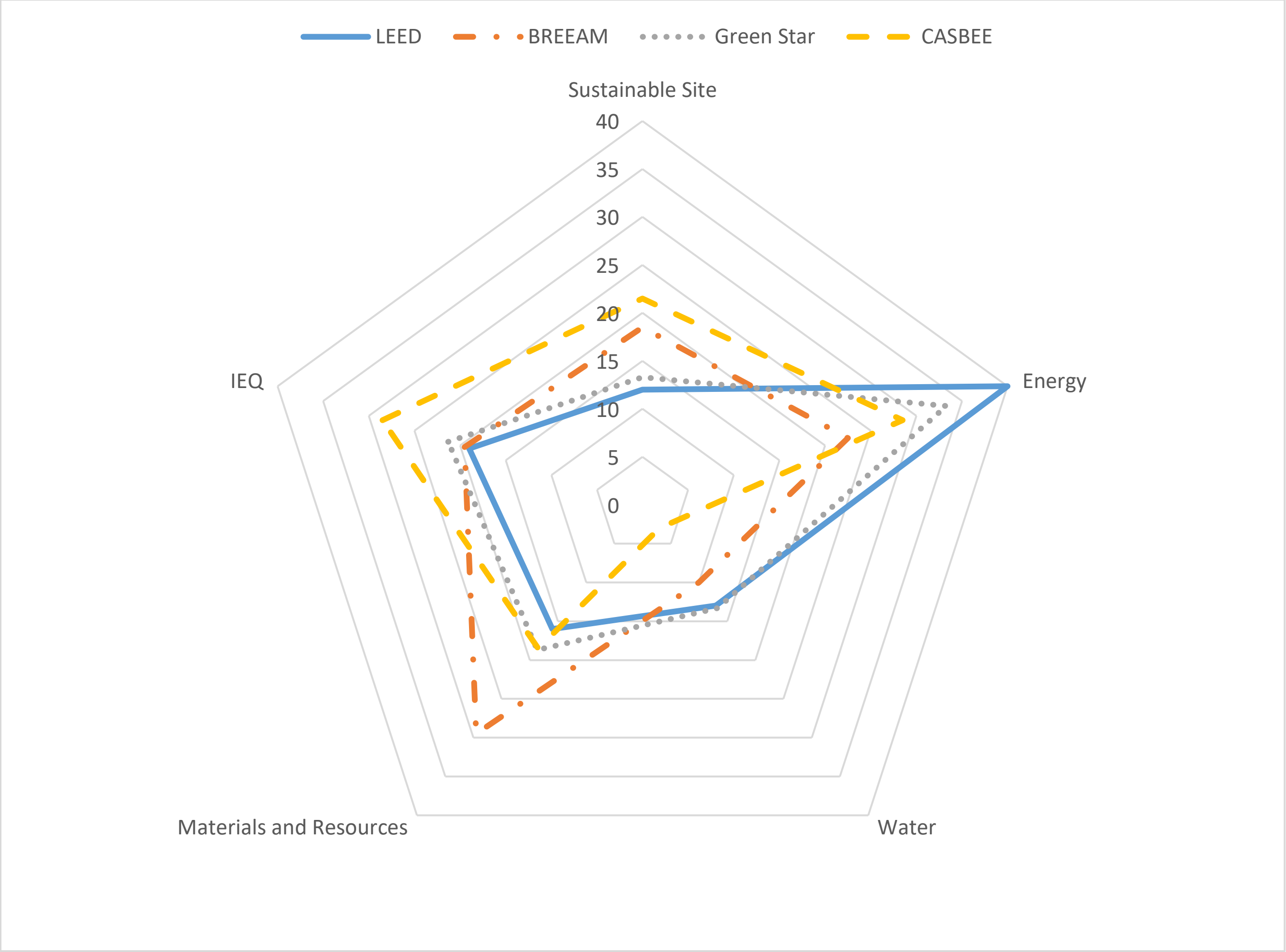

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Figure 2. Development methodology for Rapid Sustainability Assessment Method (RSAM)

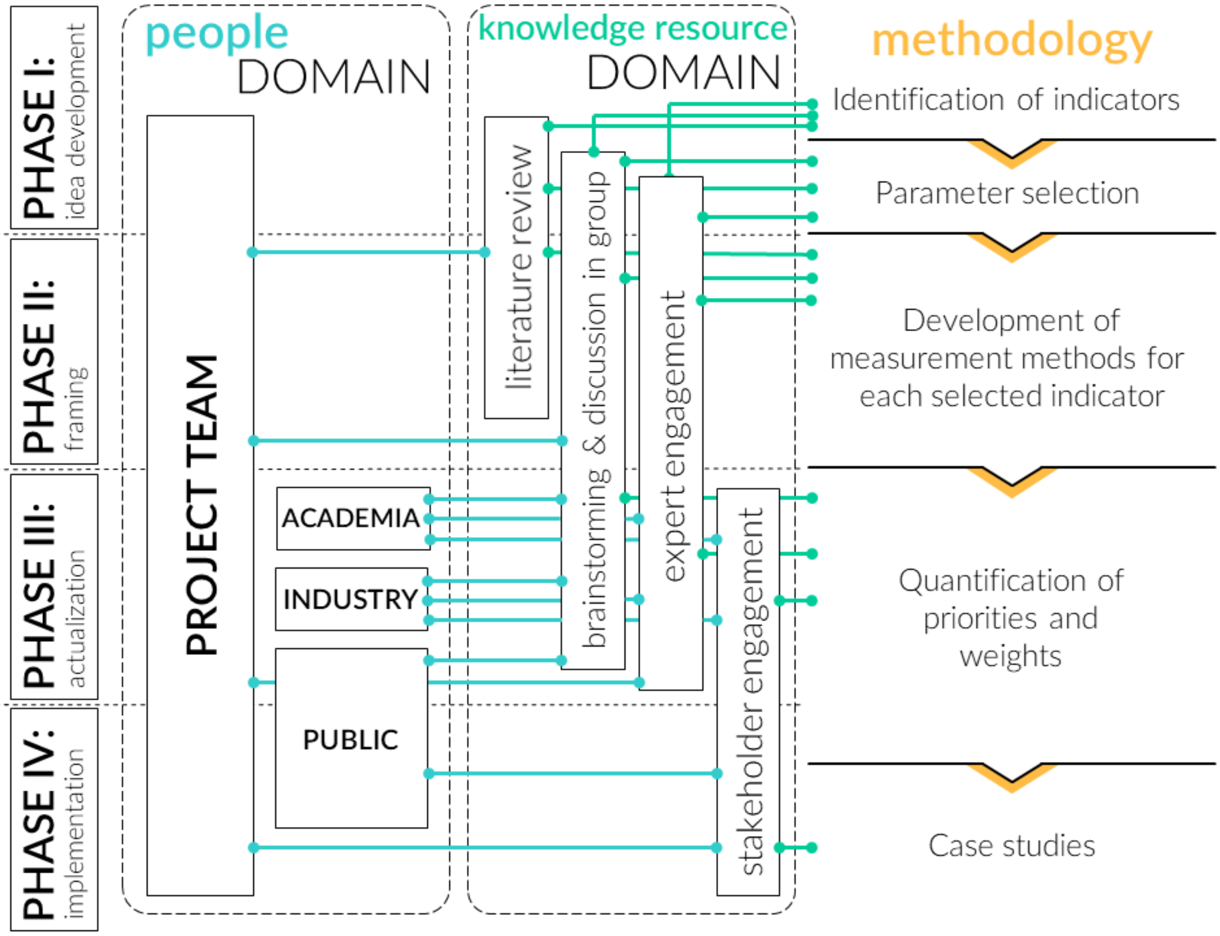

Figure 3. Stakeholder groups' weights for Level 1 parameters

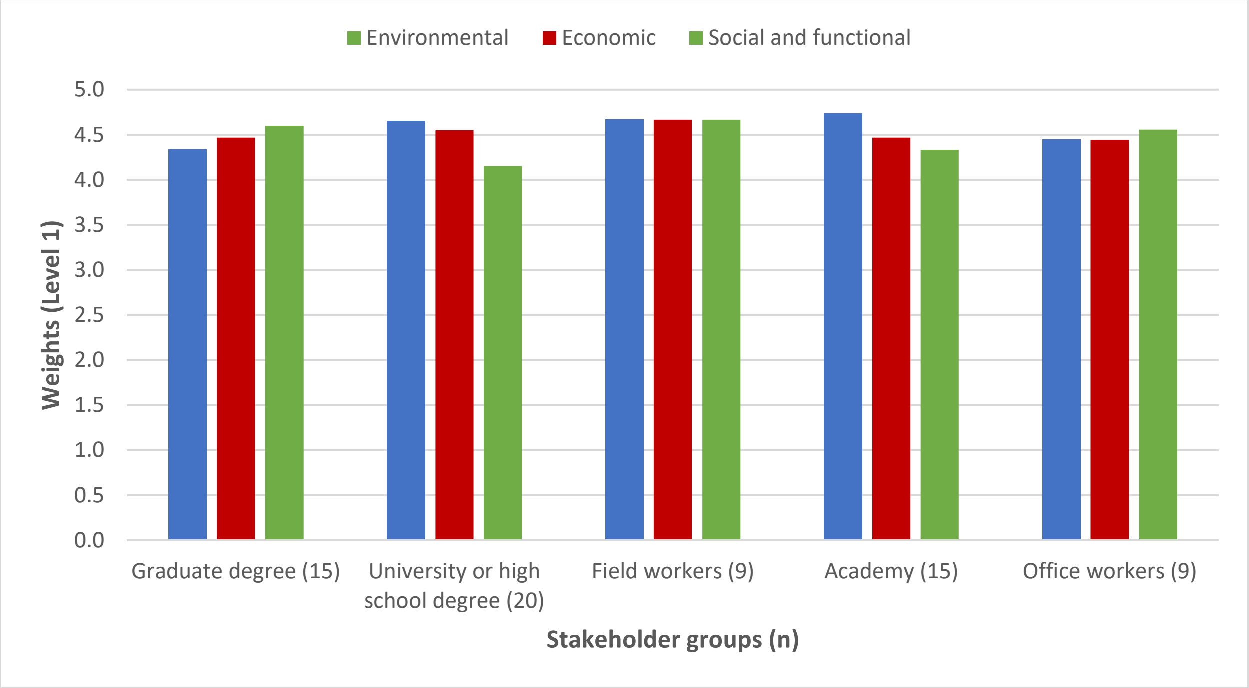

Figure 4. Overall RSAM scores of all case studies