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SITE SELECTION AND PROJECT PLANNING RESULTING IN SUSTAINABLE BUILDINGS

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Abstract. By maximizing sustainability opportunities in the site selection and site planning process site issues are integrated into the pre-design process. Some opportunities continue through the design, development and to a more limited extent, through facility and landscape construction. By integrating the building with the site in a manner that minimizes the impact on natural resources, we can maximize human comfort and social connections. Decisions made during site selection and planning impact the surrounding natural habitat, architectural design integration, building energy consumption, occupant comfort and occupant productivity. These issues are involved in evaluation of sustainable building performance. The purposes of building assessment from environmental aspects are the determination of real buildings state from viewpoint of safety and reliability, the possibility of buildings comparison, the find of environmental buildings potential and the proposal of measures resulting in sustainable buildings. The environmental assessment systems deal with site selection criteria, the efficient use of energy and water resources during building operations, waste management during construction and operations, indoor environmental quality, demands for transportation services, and the selection of environmentally preferable materials. The Slovak building environmental assessment system was processed on the base of available experiences database analysis from environmental performance of buildings. The aim of this paper is introduced the building environmental assessment system developed in Slovakia and verification of this paper in field of site selection. The building site and project planning as the significant field and determination of weighting indicators in this filed by Saaty method will be introduced in the paper.

Keywords: building environmental assessment, assessment system, site selection, Analytic hierarchy process.

1. Introduction

Environmental rating of buildings and building products has been introduced in many countries. This new attention to building performance calls for a more holistic approach to designing and maintaining buildings. However, this in turn demands efficient ways to communicate complex information about building performance to clients, tenants and others (Malmqvist 2009). The assessment of building environmental performance covers a wide range of issues and may involve not only a number of environmental, but also economical and social factors. These integrated assessments of buildings require a multidisciplinary and multi-criteria approach which demands cooperation among civil engineers, architects, environmentalists and other experts from different areas of building environmental assessment (Vilčeková *et al.* 2010a).

The paper is organized as follows. The purpose of this paper is introduced the building environmental assessment system developed in Slovakia. The core of the paper started at next section with building site and project planning as the significant field in building environmental assessment system. The weighting significance of indicators was determined by Saaty's method. The last section is oriented on system verification.

2. Building environmental assessment in Slovakia

In the recent years the evaluation of building performance in terms of environmental, economical and social impacts and aspects is also a discussed topic in Slovak republic. BEAS (*Building Environmental Assessment System*) has been developed at the Institute of Building and Environmental Engineering, Technical University of Kosice. The systems and tools used in many countries were based on the new system development for applications under Slovak conditions. The main fields and relevant indicators of building environmental assessment were proposed on the basis of available information analysis from particular fields of the building performance and also according to our experimental experiences. The foundation of system development was mainly based on the SBTool. BEAS is a multi-criteria system which included environmental, social and cultural aspects. The proposed fields and indicators respected and adhered to Slovak standards, rules, studies and experiments. The developed assessment system for Slovakia contains 6 main fields. The proposed quantitative and qualitative indicators respect national standards and rules.

In the Figure 1 is shown a hierarchy structure of proposed building environmental assessment system. Main fields are: A – Site Selection and Project Planning (14.71%), B – Building Construction (20.59%), C – Indoor Environment (23.56), D – Energy Performance (26.47), E – Water Management (8.88%), F – Waste Management (5.88%). Some of main fields have subfields. Fields and subfields have determining indicators. The total number of the assessment indicators is 52 (Vilčeková *et al.* 2010b). Hierarchy structure allowed using methods of AHP (Saaty 2008).

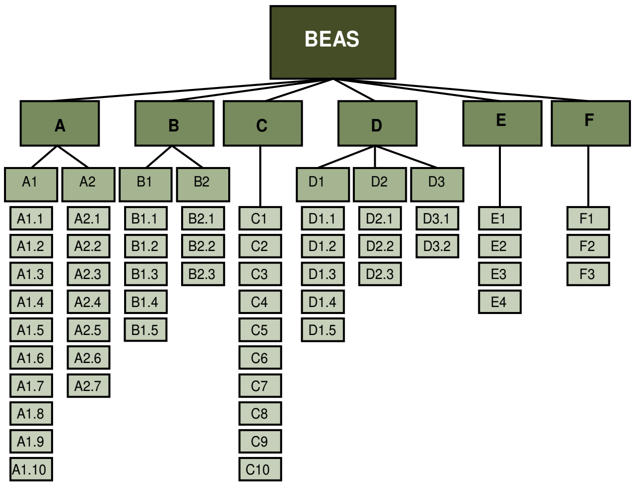

Fig 1. Hierarchy structure of proposed building environmental assessment system

Hierarchy structure allowed using Multi-criteria analysis (MCA) for weight significance determination. MCA is a tool for effectiveness evaluation and decision support. One of the Multi-criteria analysis methods is Analytic hierarchy process (AHP). AHP is a theory of measurement through pair-wise comparisons and relies on the judgments of experts to derive priority scales. It is these scales that measure intangibles in relative terms. The comparisons are made using a scale of absolute judgments that represents how much more; one element dominates another with respect to a given attribute (Saaty 2008). The multi-criteria framework incorporates the consideration of environmental issues in a development and it will take an important role in the evaluation approach.

3. Saaty's method

The Saaty's method enables us to model a complicated decision problem with the help of a hierarchical structure that is composed of the goal, criteria, sub criteria and alternatives. The advantage of this method is the possibility to handle both qualitative, as well as quantitative objects. The output of this method is a mathematically correct quantitative evaluation of alternatives being assessed (Laidre 2011). The Saaty's method dealt with consistency of the pair-wise comparison matrix. A consistent matrix mean e.g. if the decision maker says a criterion *i* is as important as another criterion j (so the comparison matrix will contain value of a_{ij} = 1= a_{ji}), and the criterion *j* is absolutely more important as the criterion *i* (a_{ji} = 9; a_{ij} = 1/9); then the criterion *i* should also be absolutely more important than the criterion *j* (a_{ij} = 9; a_{ji} = 1/9). The idea is based on the fact that it is easier for a person to come up with relational evaluations rather than with absolute evaluations. In addition, comparing items in pairs renders the most accurate evaluation of an assessed characteristic; the Saaty scale is used for that. In the Table 1 is scale of relative importance for pairwise comparison. This scale consists from intensity of importance and descriptor. A nine point scale is provided to quantify pairwise importance or preference and intermediate values are used to interpolate between adjacent scale values. After conducting such comparisons, what follow is the derivation of different alternatives' weights, as well as that of the criteria. This means composing absolute scales by using mathematical methods described by Saaty. It is an important fact that in conducting measurements, no standard scale has to be used - experience, intuition or knowledge is usually sufficient (Saaty 2003, 2008; Yang *et al.* 2010).

Table 1. Scale of relative importance for pairwise comparison

Intensity of Importance	Descriptor	
	Verbal Scale	Explanation
1	Equal importance of both elements	Two elements contribute equally
3	Moderate importance of one element over another	Experience and judgment favor one element over another
5	Strong importance of one element over another	An element is strongly favored
7	Very strong importance of one element over another	An element is very strongly dominant
9	Extreme importance of one element over another	An element is favored by at least an order of magnitude
Intensity of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements than are very close in importance.		

The weightings of criteria for methods of multi-criteria analysis have to be standardized and the condition (1) holds:

$$v = (v_1, v_2, ..., v_n)$$

$$\sum_{i=1}^{n} v_i = 1 \qquad (1)$$

$$v_i \geq 1$$

v_i – weight of i criterion,
n – number of criterion.

4. Site Selection and Project Planning

The Saaty's method enables us to model a complicated decision problem with the help of a hierarchical structure of building environmental assessment system. Site selection issues include transportation and travel distances for building occupants, impacts on wildlife corridors and hydrology, energy supply and distribution limitations. Decisions made during site selection and planning impact the surrounding natural habitat, architectural design integration, building energy consumption, occupant comfort and occupant productivity. In the Table 2 is shown main field A – Site Selection and Project Planning.

Table 2. Site Selection and Project Planning

Field, subfields, indicators	
A	Site Selection and Project Planning
A1	Site selection
A1.1	Selection of ecologically valuable or sensitive land
A1.2	Selection of land vulnerable to flooding
A1.3	Selection of land near by water object
A1.4	Selection of Brownfield lands
A1.5	Distance to road-traffic infrastructure
A1.6	Distance to commercial and cultural facilities
A1.7	Distance to public green space
A1.8	Distance to engineering networks
A1.9	Possibilities of renewable energy sources utilization
A1.10	Applicable orientation to maximize passive solar potential
A2	Site development
A2.1	Development of density
A2.2	Possibility of change building purpose
A2.3	Relationship of design with existing streetscapes
A2.4	Policies governing use of private vehicles
A2.5	Ensure of sufficient public green space
A2.6	Use of trees for solar shading and sequestration of CO_2
A2.7	Maintenance or development of wildlife corridors

5. Results

The weighting significance of indicators was determined by Saaty's method. The criteria weight was assigned using Saaty's matrix. In the Table 3 is shown determination of weighting significance of sub-field of main field – A – Site selection and project planning. This main field of assessment has two sub-fields of assessment: A1 – Site selection (56,3%) and A2 – Site development (43,8%).

Table 3. Determination by Saaty's matrix (Main field A)

Saaty matrix			Computing of Saaty matrix		
a(i,j)	Criteria		Π	R(i) =	Weights
Criteria	A1	A2	a(i,j)	[Π a(i,j)] $^{1/2}$	v(i)
A1	1	1.286	1.286	1.134	0.563
A2	0.778	1	0.778	0.882	0.438
Total:				2.016	1

In the Table 4 (Saaty matrix) and Table 5 (computing of Saaty matrix) is shown determination of weighting significance of indicators of first sub-field of assessment. This sub-field of assessment has ten indicators of assessment (Table 2).

Table 4. Saaty's matrix (Sub-field A1)

a(i,j)	A1.1	A1.2	A1.3	A1.4	A1.5	A1.6	A1.7	A1.8	A1.9	A1.10
A1.1	1	1	1.1	2	2.6	1.6	2	1.3	1	1.1
A1.2	1	1	1.1	2	2.6	1.6	2	1.3	1	1.1
A1.3	0.8	0.8	1	1.7	2.3	1.4	1.7	1.1	0.8	1.0
A1.4	0.5	0.5	0.5	1	1.3	0.8	1	0.6	0.5	0.5
A1.5	0.3	0.3	0.4	0.7	1	0.6	0.7	0.5	0.3	0.4
A1.6	0.6	0.6	0.7	1.2	1.6	1	1.2	0.8	0.6	0.7
A1.7	0.5	0.5	0.5	1	1.3	0.8	1	0.6	0.5	0.5
A1.8	0.7	0.7	0.8	1.5	2.0	1.2	1.5	1	0.7	0.8
A1.9	1	1	1.1	2	2.6	1.6	2	1.3	1	1.1
A1.10	0.8	0.8	1.0	1.7	2.3	1.4	1.7	1.1	0.8	1

Table 5. Computing of Saaty's matrix (Sub-field A1)

a(i,j) Criteria	Π a(i,j)	R(i) = [Π a(i,j)] $^{1/10}$	Weights v(i)	%
A1.1	29.722	1.404	0.133	13.33
A1.2	29.722	1.404	0.133	13.33
A1.3	7.819	1.228	0.117	11.67
A1.4	0.029	0.702	0.067	6.67
A1.5	0.002	0.526	0.050	5.00
A1.6	0.270	0.877	0.083	8.33
A1.7	0.029	0.702	0.067	6.67
A1.8	1.674	1.053	0.100	10.00
A1.9	29.722	1.404	0.133	13.33
A1.10	7.819	1.228	0.117	11.67
Total:		10.529	1.000	100

In the Table 6 (Saaty matrix) and Table 7 (computing of Saaty matrix) is shown determination of weighting significance of indicators of second sub-field of assessment. This sub-field of assessment has seven indicators of assessment (Table 2).

Table 6. Saaty's matrix (Sub-field A2)

a(i,j)	A2.1	A2.2	A2.3	A2.4	A2.5	A2.6	A2.7
A2.1	1	1.6	2	1.6	1.14	1.33	1.33
A2.2	0.625	1	1.25	1	0.71	0.83	0.83
A2.3	0.5	0.8	1	0.8	0.57	0.66	0.66
A2.4	0.625	1	1.25	1	1.4	0.83	0.83
A2.5	0.875	1.4	1.75	0.714	1	1.16	1.16
A2.6	0.75	1.2	1.5	1.2	0.85	1	1
A2.7	0.75	1.2	1.5	1.2	0.85	1	1

Table 7. Computing of Saaty's matrix (Sub-field A2)

a(i,j) Criteria	Π a(i,j)	R(i) = $[\Pi\ a(i,j)]^{1/7}$	Weights v(i)	%
A2.1	10.403	1.397	0.196	19.6
A2.2	0.388	0.873	0.122	12.2
A2.3	0.081	0.699	0.098	9.8
A2.4	0.76	0.961	0.135	13.5
A2.5	2.084	1.111	0.156	15.6
A2.6	1.389	1.048	0.147	14.7
A2.7	1.389	1.048	0.147	14.7
Total:		7.137	1	100

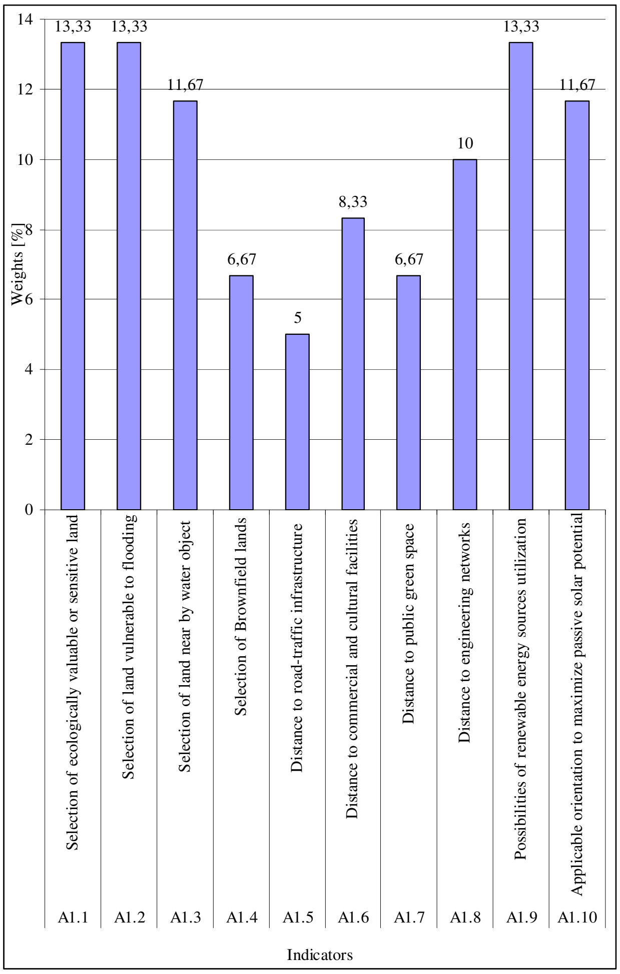

Fig 2. Weights of indicators of sub-field A1 – Site selection

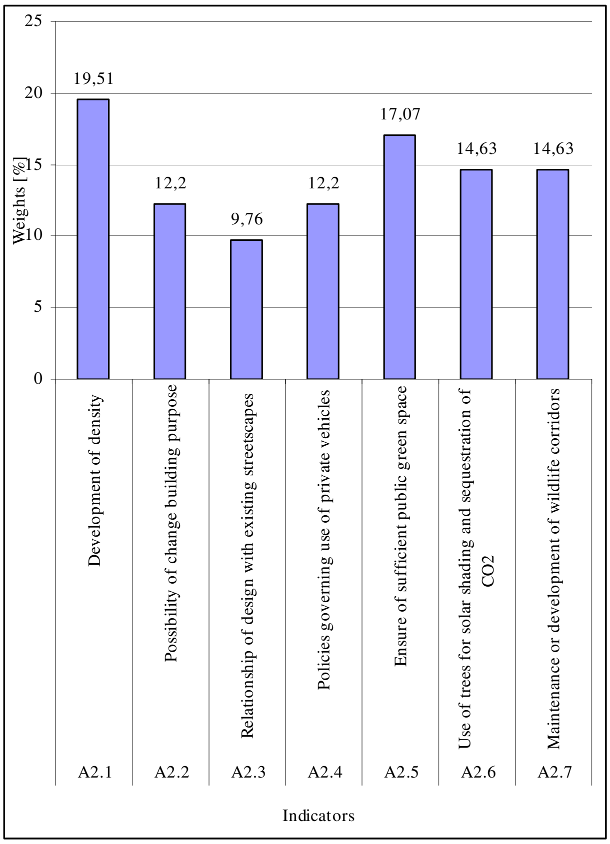

Fig 3. Weights of indicators of sub-field A2 – Site development

6. Verification of building environmental assessment system

The aim of this paper is also assessment of selected six office buildings located in the east of Slovakia for the purpose of system verification. The evaluated office buildings were assessed according to available documentations, mainly drawings. The assessment was performed using software tool for BEAS prepared in MS Excel. The software tool was developed on the base of international software tool in Microsoft Excel for building environmental assessment – SBTool. The software tool supported BEAS allows easy and comprehensive evaluation of buildings. All performance criteria are evaluated according to standards and laws valid in Slovak Republic. Each main field has several indicators of assessment which have the intent of assessment and the scale of assessment. This scale is from negative (-1 point), acceptable practice (0 point), good practice (3 point) and best practice (5 point).

Result of each indicator assessment is obtained so that the point from scale is multiplying with weight of indicator. This result is presented in last evaluative list in form of column graph and comprehensive tables (Vilčeková *et al.* 2010).

In the Figure 4 is shown result of first main fields assessment in column graph.

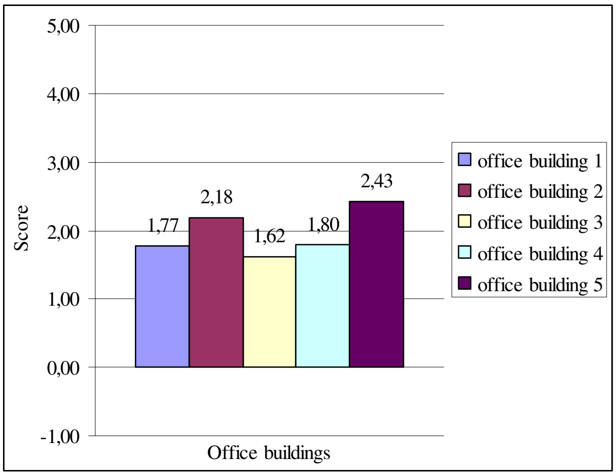

Fig 4. Results of office buildings assessment in first main field – A Site selection and project planning

The average score of assessed buildings is 1.91 which is classified as Environmentally acceptable building on the base of classification key shown in the Table 8. The results from the comprehensive environmental assessment of selected office it can assert, that it is necessary to propose measures to improve the environmental suitability and safety of the evaluated office buildings in all assessed fields.

Table 8. Classification key

Score	Category
-1	Environmentally unacceptable building
0	Environmentally acceptable building
3	Environmentally friendly building
5	Sustainable building

7. Discussion

By integrating the building with the site in a manner that minimizes the impact on natural resources, we can maximize human comfort and social connections. The development footprint should enhance the existing biodiversity and ecology of the site by strengthening the existing natural site patterns and making connections to the surrounding site (Sustainable guidelines, 2002).

According to study (Lee *et al*. 2002) weighting is the heart of all assessment schemes since it will dominate the overall performance score of the building being assessed. An appropriate assessment tool must provide the possibility for a designer to consider the sensitivities of these factors in single and multiple analysis together with the sensitivity of the weighting (Soebarto *et al*. 2001). Identifying assessment indicators requires rigorous method of solving multi-criteria decision making problems of choice and prioritization in policy making. This paper introduced a integrated method of identifying indicators for Site selection and project planning assessment in office buildings applying feasibility, completeness, effectiveness and multi-attribute decision making rules. According to a study (Andersen *et al*. 2005) this method of multi-criteria analysis was used to determine the weights of significance of E-audit used in Poland.

8. Conclusions

The aim of this paper was introduced the proposal of Building site and project planning field and system verification. The percentage weights of significance were determined for proposed sub-fields and relevant indicators. The selected office buildings were evaluated from this point of view. The average score of assessed buildings is 1.91 which is classified as Environmentally acceptable building. For the purpose of system verification, a statistically significant set of buildings is required to be evaluated. The outcome from the system verification will be result in the modification of indicators weighting.

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