Weight Determination of Building Environmental Assessment Indicators

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***Abstract* – Building environmental assessment systems were developed in the past decade and used in different countries for evaluating the building environmental performance. Building environmental assessment and certification is a specific complex of proceedings oriented to systematic and objective evaluation of buildings and their environment. In Slovakia the building environmental assessment system is in process of development. The base of system available in Slovakia is systems used in many countries. The proposal of system and weight determination of building environmental system indicators via Saaty's method is presented in this paper. Saaty´s method was used for determination percentage weight of main assessment fields.**

Key words – Building Environmental Assessment, Saaty´s Method, System, Weight

I. Introduction

The field of building environmental assessment has matured remarkably quickly since the introduction of BREEAM, and the past thirteen years have witnessed a rapid increase in the number of building environmental assessment methods in use world-wide [1]. The most significant building environmental assessment systems used over the world are BREEAM, Green Globes, LEED, SBTool, CASBEE, HK-BEAM, NABERS, LEnSE, etc. (Table 1). These eight models used world wide in relation to environmental assessment of buildings, were compared on the basis of their covered [2, 3].

II. The proposal of building environmental assessment systems applicable in SR

The building environmental assessment system applicable in Slovakia is in process of development on the bases of available information analysis from evaluating of building performance and also on the base of own experiences. The base of building environmental assessment system proposal was mainly system SBTool [2, 3, 4, 5]. Percentage weight of each proposed indicator will be determined on the base of their significance, according to mathematical method. Mathematical mechanism for evaluation processes in field of environmental engineering is extensive. There are many methods for the determination of criteria significance, parameters significance, control of dependency, tests of sensitivity etc. For example: Saaty's method, Metfessel allocation, Point method, EDIP method etc.. Objective methods was analyzed and evaluated in context of building environmental assessment requirements in benefit with respect to qualitative and quantitative characteristic of ranking the significance of the particular indicators. Following analyze of criteria weights estimation methods were determined by Saaty's method. This method was used for determination percentage weight of main fields of assessment.

TABLE 1

THE MOST SIGNIFICANT BUILDING ENVIRONMENTAL ASSESSMENT SYSTEMS USED OVER THE WORLD

System	Country	Main fields
BREEAM	UK	Management, Healthy and well being, Energy use, Pollution transport, Materials, Land and ecology, Waste Water
Green Globes	Canada	Energy, Water, Resources, Indoor environment, Emissions, Environmental management
SBTool	28 countries	Site selection, Project planning and development; Energy and resource consumption; Environmental loadings; Indoor environmental quality; Functionality and controllability of building systems; Long-term performance; Social and economic aspects
LEED	USA	Sustainable site, Water efficiency, Energy & Atmosphere, Materials & Resources, Indoor environmental quality, Innovation & Design process
CASBEE	Japan	Quality Q – Building environmental quality and performance (Indoor environment, Quality of service, Outdoor environmental on site) and loadings L – Reduction of building environmental loadings (Energy, Resources and materials, Off-site environment)
HK-BEAM	Hong Kong	Site aspects, Materials aspect, Water use, Energy use, Indoor environmental quality, Innovations and performance enhancements
NABERS	Australia	Land, Materials, Energy, Water, Interior, Resources, Transport, Waste
LEnSE	**	Environmental, Social and Economical aspects

**Belgium, France, Great Britain, Germany, Netherlands, Greece, Switzerland a Czech Republic

A.Main fields

Table 2 summarizes the proposed fields and their sub-fields and conkrete indicators of building environmental assessment system with their weights determined by Saaty's method.

TABLE 2

BUILDING ENVIRONMENTAL ASSESSMENT SYSTEM PROPOSAL

	Fields and sub-fields	Weights [%]
A	Site Selection, Project Planning	14
A1	Site selection	
Selection of ecologically valuable or sensitive land, land vulnerable to flooding, land close to water endangered contamination, Brownfield lands; Distance to commercial and cultural facilities, to public green space, to engineering networks, to road-traffic infrastructure		
A2	Project Planning	
Assessment of renewable feasibility, Preparation of impact assessment report, Applicable orientation to maximize passive solar potential		
A3	Urban Design and Site Development	
Development density; Possibility change building purpose; Relationship of design with existing streetscapes; Policies governing use of private vehicles; Use of trees for solar shading and sequestration of CO_2; Development of wildlife corridors		
B	Building Construction	12
B1	Materials	
Certified building products; Use of cement substitutes in concrete, materials that are locally produced, recycled materials; Non-renewable primary energy embodied in construction materials; Radioactivity building materials; Creation hazardous substances during production building materials; Selection low - emission building materials; Constructions limiting migration pollutions between occupations rooms, Eco-labeling		
B2	LCA	
Dismountable, reuse and recycling; LCA impact on cost; LCA; Renewable		
C	Indoor Environment	19
Thermal comfort in heating season, in cooling season; Ventilation; Air quality; Noise attenuation through the exterior envelope; Noise isolation between primary occupancy areas; Daylighting; Shading and blind; Artificial lighting; Interior materials; Particular matters; Pollutant migration between occupancies		
D	Energy	28
D1	Operation Energy	
Energy for heating, domestic hot water, mechanic ventilation and cooling, lighting and energy for appliances		
D2	Active systems on using renewable energy sources	
Solar system; Heat pump for heating and domestic hot water and cooling; Photovoltaic technology; Heat recuperation		
D3	Maintains Energy	
Energy management; Operation and maintains		
E	Water	12
Reduction and regulation water flow; Surface water run-off; Drinking water supply; Using filtration “grey water”		
F	Waste	14
F1	Solid waste	
Solid waste; Measures to minimize solid waste resulting from building construction and operations; Composting		
F2	Liquid waste	
Measures to minimize gas waste from building construction, operation		

B.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. The Saaty's method dealt with consistency of the pairwise 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 aij = 1= aji), and the criterion j is absolutely more important as the criterion i (aji = 9; aij = 1/9); then the criterion i should also be absolutely more important than the criterion j (aij = 9; aji = 1/9). The idea of the Saaty method 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 (Table 3) 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 [5, 6, 7, 8].

TABLE 3

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

In the table below (Table 4) is presented example of main field's weighting by Saaty's method. The main fields are marked: A – Site Selection, Project Planning and Development; B – Building Construction; C – Indoor Environment; D – Energy; E – Water, and F – Waste.

The criteria weight was assigned using Saaty's matrix implementation in excel program.

TABLE 4

EXAMPLE OF ANALYTIC HIERARCHY PROCESS (SAATY) METHOD

a(i,j) Criteria	A	B	C	D	E	F	Weights v(i)
A	1,00	1,00	0,67	0,50	1,50	1,00	0,141
B	1,00	1,00	0,67	0,50	0,67	1,00	0,124
C	1,50	1,50	1,00	0,67	1,50	1,50	0,194
D	2,00	2,00	1,50	1,00	2,50	2,00	0,280
E	0,67	1,50	0,67	0,40	1,00	0,67	0,119
F	1,00	1,00	0,67	0,50	1,50	1,00	0,141
Total							1,000

A. *The way of evaluation*

The way of each indicators evaluation is in principle the same. All performance criteria are scored (from -1 (negative) to +5 (best practice)), then summed using weightings. The result of assessment is histogram. All performance criteria are assessment according to standards and laws valid in Slovak Republic.

1.Site Selection, Project Planning

Indicator from sub-field "Site selection" is related to selection of land vulnerable to flooding. This indicator introduced in the table 5 is assessed according to height above 100-year flood plain as defined in official documentation.

TABLE 5

SELECTION OF LAND VULNERABLE TO FLOODING

A1.2	Selection of land vulnerable to flooding		
Purpose	To discourage the selection of land for building where there is a substantial risk that the site may be flooded.		
Indicator	Height above 100-year flood plain as defined in official documentation or assessment by component authorities.		score
Negative	The height of the minimum elevation of the site above the elevation of the 100-year flood plain is:	1,0 m	-1
Acceptable		1,3 m	0
Good		2,0 m	3
Best		2,5 m	5

2.Building construction

In table 6, there is presented indicator "Eco-labeling" from sub-field "Materials". The evaluation of this indicator is according to the percentage, by weight, of building environmentally friendly product which are inbuild in rating building. The pursose of this indicator id to encourge production and consumtion of product with less adverse effects on the environment.

TABLE 6

SELECTION OF LAND VULNERABLE TO FLOODING

B1.1	Eco-labeling		
Purpose	To encourage production and consumption of products with less adverse effects on the environment, to inform consumers about the environmental characteristics of products.		
Indicator	Use of environmentally friendly building products		score
Negative	The percentage, by weight, of building environmentally friendly product is:	3 %	-1
Acceptable		15 %	0
Good		51 %	3
Best		75 %	5

3.Indoor Environment

The example of way of assigning score is according to the rule that is show in the table (Table 7). The indicator from field "Indoor environment" related to thermal comfort is assessing according to requirements of European standard (EN 15251:2007). Scale of assessment is making on the base of operative temperatur whicht is in 95 % of building volume.

TABLE 7

THERMAL COMFORT IN HEATING SEASON

C1	Thermal comfort in heating season		
Purpose	To ensure thermal comfort in heating season.		
Indicator	Designed value of operative temperature is in accordance with requirements of relevant standards (EN 15251:2007).		score
Negative	In 95 % of building volume the operative temperature is:	$\theta o<19°C$	-1
Acceptable		$19\leq\theta o<20°C$	0
Good		$20\leq\theta o<21°C$	3
Best		$\theta o \geq 21°C$	5

4.Energy

In table 8 is presented indicator "Energy needs for heating" from field about energy. The assessing of energy needs for heating is according to standards about energy efficiency of buildings (Law No. 555/2005).

TABLE 8

ENERGY NEEDS FOR HEATING

D1.1	Energy needs for heating	
Purpose	To determine energy needs for heating.	
Indicator	Class of energy for heating according standards related to energy performance of buildings (Law No. 555/2005).	score
Negative	Energy for heating is in lower class as C.	-1
Acceptable	Energy for heating is in class C.	0
Good	Energy for heating is in class B.	3
Best	Energy for heating is in class A.	5

5.Water management

In table 9, there is presented indicator Surface water run-off “”. The evaluation of this indicator is according to quality of a surface water management plan.

TABLE 9

SURFACE WATER RUN-OFF

E2	Surface water run-off	
Purpose	To ensure that surface water is managed within site boundaries and is re-injected into the aquifer.	
Indicator	The quality of a surface water management plan.	score
Negative	A credible general plan has not been developed for the management of surface water.	-1
Acceptable	A general plan has been developed for the man agreement of surface water and its percolation into the ground within site boundaries, including at least 80 % of natural surface water courses, paved and landscaped areas.	0
Good	A detailed plan has been developed for the management of surface water and its percolation into the ground within site boundaries, including at least 90 % of natural surface water courses, paved and landscaped areas.	3
Best	A detailed plan has been developed for the management of surface water and its percolation into the ground within site boundaries, including 100 % of natural surface water courses, paved and landscaped areas.	5

6.Waste management

In table 10, there is presented indicator “Measures to minimize solid waste resulting from building operations”. The evaluation of this indicator is according to development of a credible construction waste management plan.

TABLE 10

MEASURES TO MINIMIZE SOLID WASTE RESULTING FROM BUILDING OPERATIONS

F 1.2	Measures to minimize solid waste resulting from building operations		
Purpose	To minimize the amount of waste off the site by encouraging the development and implementation of a construction waste management program, with sorting, re-using and recycling measures.		
Indicator	The development of a credible construction waste management plan.		score
Negative	The percentage, by weight, of construction waste to be re-used or re-cycled, as predicted in the construction was management plant, is:	3 %	-1
Acceptable		15 %	0
Good		51 %	3
Best		75 %	5

Conclusion

The approaches of the assessment methods used in many countries are principally not different. Several differences are in terminological expression, in some of them the different indicators are assessed under the same areas; as well as the ways of impact rate classification are different and mostly respect national particularity. In this paper is introduced the proposal of building environmental assessment system applicable in Slovak conditions. The base of assessments development is systems and methods used in many countries. The main building environmental assessment fields are site selection, project planning and development; building construction; indoor environment; energy; water and waste. There are presented the way of evaluation with respects of standards and laws valid in Slovakia.

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