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Degree of Project Utility and Investment Value Assessments

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Abstract: This article recommends a new INVAR Method for a multiple criteria analysis (Degree of Project Utility and Investment Value Assessments along with Recommendation Provisions). Its use can be for a sustainable building assessment. The INVAR Method can additionally assist in determining the investment value of a project under deliberation and provide digital recommendations for improving projects. Furthermore, the INVAR Method can optimize the selected criterion seeking that the project under deliberation would be equally competitive in the market, as compared to the other projects under comparison. The INVAR Method is additionally able to calculate the value that the project under deliberation should be for this project to become the best among those under deliberation. The case studies presented in this research are for demonstrating this developed method.
Keywords: COPRAS, DUMA and INVAR Methods, Multiple criteria analysis, Investment value, Utility degree, Recommendations.

1 Introduction

The increased awareness about building energy consumption and sustainability has resulted in the development of various means for predicting performance and rating sustainability. The Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED) are the most commonly used Performance Rating Systems [1]. According to Lee [2], statistical analysis reveals a moderate degree of agreement amongst the five schemes (BREEAM, LEED, CASBEE, BEAM Plus and the Chinese ESGB) on weights and ranks of weights allocated to five key assessment aspects. Ferreira [3] compare the criteria weighting process of four sustainable construction assessment tools (LiderA, SB ToolPT, Code for Sustainable Homes and LEED for Homes 2012) and show that the four different weighting sets are robust and generally similar.

A discussion on BREEAM and multiple criteria decision making follows as an example.

The hierarchical structures of key criteria and features of BREEAM Offices are by levels of Issues, Categories and Criteria. The top level contains ten distinct issues (the maximum number of obtainable credits appears in parentheses): Management (22), Health & Well-being (14), Energy (30), Transport (9), Water (9), Materials (12), Waste (7), Land Use & Ecology (12), Pollution (13), Innovation (10). The second level includes 69 categories and the third level – 114 criteria. Expert opinion determines the total number of credits for each category [4]. The use of the BREEAM credits scoring system is for determining the overall assessment grade, which may be Pass ($\geq$ 30%), Good ($\geq$ 45%), Very Good ($\geq$ 55%), Excellent ($\geq$ 70%) and Outstanding ($\geq$ 85%). No weightings are applied to credits awarded under different categories, as the number of obtainable credits assigned to each category already reflects the weight assigned to a category of assessment relative to other categories (as per [2]). For example, BREEAM (Code for Sustainable Homes) divides into nine categories, which subdivide into 34 issues (criteria). The award for each issue according to its performance can be a maximum number of credits. Then, for each category, the percentage of the total credits awarded for all its issues is determined. That percentage is multiplied by its weight [5, 6]. In the end, the weighted values of all those nine categories are added up to obtain one of the six possible certification classes. Thus there is maintenance of the weighting structure with natural adjustments to market needs [3].

Multiple criteria decision making (MCDM) comprises a finite set of alternatives, which decision makers must select, evaluate or rank according to the weights of a finite set of criteria. The multiple criteria nature of the problem regarding energy performance assessment of buildings makes the MCDM Method ideal for coping with the complexity of the problem [7]. Berardi [8] emphasizes sustainability assessments in a built environment using multiple criteria rating systems. Other scientists [9–15] have also done multiple criteria and multi-aspect analysis of green buildings. COPRAS method [9, 10] was found to be an effective method for the green buildings assessment.

COPRAS (**Co**mplex **Pr**oportional **As**sessment Method) method was developed by E. Zavadskas and A. Kaklauskas [16]. The COPRAS method consists of five stages. Later, this method has been supplemented with a new "Method of **D**efining the **U**tility and **Ma**rket Value of a Property" (DUMA) developed by Kaklauskas [14], see [17]. The degrees of utility of the property considered as well as the market value of a property being valuated is determined in seven DUMA method stages.

The newly developed INVAR (Degree of Project Utility and Investment Value Assessments along with Recommendations) method by Kaklauskas integrates the philosophy of COPRAS and DUMA methods and offers the new opportunities. These new opportunities are as follows: defining the investment value of a project; providing digital tips for improving projects; optimizing a selected criterion; calculating the value of the project, which would permit it to be best among others under deliberation. Determining the priorities and utility degree of projects applying Stages 1-5 of the INVAR method are identical to COPRAS method. Other INVAR method 6-11 stages are different from the COPRAS and DUMA methods.

According to the International Valuation Standards [18], investment value is the value of an asset to the owner or a prospective owner for individual investment or operational objectives. As stated in Business Dictionary, investment value reflects the value of an asset to its owner, depending on his or her expectations and requirements. Schmidt [19] believes that investment value refers to the value to a specific investor, based on requirements of that investor, tax rate, and financing. The INVAR Method for an analysis of sustainable buildings (see case studies) use the same initial data as the BREEAM Method uses.

The INVAR Method was applied in research in various EU projects (INTELLITIES, IDES-EDU, Brita in Pubs); the author took part in the research. The results of these projects were discussed in a number of publications by the author in conjunction with colleagues [20–25].

The structure of this paper is as follows: after this introduction, Section 2 describes the INVAR Method. Section 3 follows with Case Studies. Finally the discussion and conclusions appear in Section 4.

2 INVAR Method

Assessing utility degree and the value of a project under investigation along with the establishment of priorities for this project's implementation is not especially difficulty. However, this first requires obtaining the numerical values and weights of criteria and applying multiple criteria decision making methods. The presentation of the analysis of projects under comparison is in the form of a grouped decision making matrix, where columns contain n alternative projects under consideration. Meanwhile the rows represent all the pertinent quantitative and conceptual information (see Table 1) [14].

Table 1: Grouped decision making matrix of the multiple criteria analysis of projects under comparison

Criteria describing the alternatives	*	Weights	Measurement units	Projects under comparison					
				a_1	a_2	...	a_j	...	a_n
X_1	z_1	q_1	m_1	x_{11}	x_{12}	...	x_{1j}	...	x_{1n}
X_2	z_2	q_2	m_2	x_{21}	x_{22}	...	x_{2j}	...	x_{2n}
X_3	z_3	q_3	m_3	x_{31}	x_{32}	...	x_{3j}	...	x_{3n}
...	...	...	...	...	...	...	...	...	...
X_i	z_i	q_i	m_i	x_{i1}	x_{i2}	...	x_{ij}	...	x_{in}
...	...	...	...	...	...	...	...	...	...
X_m	z_m	q_m	m_m	x_{m1}	x_{m2}	...	x_{mj}	...	x_{mn}
Conceptual information pertinent to projects (i.e., texts, drawings, graphics, video tapes and virtual and augmented realities)									

* – The sign $z_i(+(-))$ indicates that a greater (lesser) criterion value corresponds to greater (lesser) significance for stakeholders.

The INVAR method [14] assumes direct and proportional dependence of significance and a priority of investigated versions in a system of criteria that adequately describe the alternatives and on the values and weights of those criteria. Significance, priority, utility degree and investment value of alternatives, presentation of quantitative recommendations and optimization of different criteria are determined in 11 stages.

INVAR method stages 1-5 are identical as COPRAS method [9, 10, 14].

Stage 1. First, form a weighted, normalized decision making matrix D. The purpose of this stage is to receive dimensionless, weighted values from the comparative indices. Upon establishing the dimensionless values of the indices, all criteria, originally having different dimensions, become comparable. The following formula for this purpose is:

$$d_{ij} = \frac{x_{ij} \cdot q_i}{\sum\limits_{j=1}^{n} x_{ij}}, \quad i = \overline{1,\text{ m}}; \quad j = \overline{1,\text{ n}}, \tag{1}$$

where x_{ij} is the value of the i-th criterion in the j-th alternative of a solution, m – the number of criteria, n – the number of the alternatives compared and q_i – the weight of the i-th criterion.

The sum of dimensionless, weighted index values d_{ij} of each criterion x_i is always equal to the weight q_i of this criterion:

$$q_i = \sum_{j=1}^{n} d_{ij}, \quad i = \overline{1,\text{ m}}; \quad j = \overline{1,\text{ n}}. \tag{2}$$

In other words, the value of the weight q_i of the investigated criterion proportionally distributes over all the alternative versions a_j according to their values x_{ij}.

Stage 2. The sums of weighted, normalized indices describing the j-th version are calculated. The minimizing of index S_{-j} and maximizing of index S_{+j} describe the versions. The lower value of minimizing indices is better (investment). The greater value of maximizing indices is better (management, health & wellbeing, energy, transport, water, materials, waste, land use & ecology, pollution, innovation). The formula for calculating the sums is:

$$S_{+j} = \sum_{i=1}^{m} d_{+ij}; \quad S_{-j} = \sum_{i=1}^{m} d_{-ij}, \quad i = \overline{1,\text{ m}}; \quad j = \overline{1,\text{n}}. \tag{3}$$

In this case, the values S_{+j} (the greater the project "pluses" of this value, the greater the satisfaction of interested parties) and S_{-j} (the lower the project "minuses" of this value, the better the goal attainments by interested parties) express the degree of goals attained by interested parties pertinent to each alternative project. In any case, the sum of the "pluses" S_{+j} and the "minuses" S_{-j} of all alternative projects is always respectively equal to all the sums of the weights of the maximizing and minimizing criteria:

$$\begin{aligned} S_{+} &= \sum_{j=1}^{n} S_{+j} = \sum_{i=1}^{m}\sum_{j=1}^{n} d_{+ij}, \\ S_{-} &= \sum_{j=1}^{n} S_{-j} = \sum_{i=1}^{m}\sum_{j=1}^{n} d_{-ij}, \quad i = \overline{1,\text{ m}}, \quad j = \overline{1,\text{ n}}. \end{aligned} \tag{4}$$

This way the calculations performed may be additionally checked.

Stage 3. The basis pertinent to determining the significance (efficiency) of the versions under comparison constitutes the descriptions of the features pertinent to positive project "pluses" and to negative project "minuses". The formula for finding the relative significance Q_j of each project a_j is:

$$Q_j = S_{+j} + \frac{S_{-min} \cdot \sum_{j=1}^{n} S_{-j}}{S_{-j} \cdot \sum_{j=1}^{n} \frac{S_{-min}}{S_{-j}}}, \quad j = \overline{1,\text{ n}}, \tag{5}$$

where S_{-min} is the least value of the S_{-j}.

Stage 4. Determining the priorities of projects pertains to the axiom that the greater the Q_j the higher the efficiency (priority) of the project. The analysis of the method presented allows stating that it may be easily applied for evaluating projects and selecting the most efficient of them, while fully aware of the physical meaning of the process. Moreover, it allows formulating a reduced criterion Q_j directly proportional to the relative effect of the compared criteria values d_{ij} and weights q_i on the end result (see Table 2). Determining the utility degrees of the project under consideration as well as the investment value of a project under valuation occurs in seven stages.

Stage 5. The formula used for the calculation pertinent to project a_j utility degree N_j is:

$$N_j = (Q_j \div Q_{max}) \cdot 100\% \tag{6}$$

Here Q_j and Q_{max} are the significances of the project obtained from Equation 5.

The utility degree N_j of project a_j indicates the satisfaction level of the interested parties. The more goals achieved and the more important they are, the higher is the degree of project utility.

Stage 6. Calculating the investment value $x_{1j\,cycle\,e}$ of the project under deliberation a_j can be by means of e approximation. The problem may be stated as follows: What investment value $x_{1j\,cycle\,e}$ of the assessed project a_j will make it equally competitive on the market with the projects under comparison $(a_1 - a_n)$ (see Table 3)? The measurement of the value $x_{1j\,cycle\,e}$ is by price (Euro, British pounds, U.S. dollar or others) per square meter.

Table 2: Alternative results of a multiple criteria analysis

Criteria describing the alternatives	*	Weights	Measurement units	Projects under comparison					
				a_1	a_2	...	a_j	...	a_n
X_1	z_1	q_1	m_1	d_{11}	d_{12}	...	d_{1j}	...	d_{1n}
X_2	z_2	q_2	m_2	d_{21}	d_{22}	...	d_{2j}	...	d_{2n}
X_3	z_3	q_3	m_3	d_{31}	d_{32}	...	d_{3j}	...	d_{3n}
...	...	...	...	...	...	...	...	...	...
X_i	z_i	q_i	m_i	d_{i1}	d_{i2}	...	d_{ij}	...	d_{in}
...	...	...	...	...	...	...	...	...	...
X_m	z_m	q_m	m_m	d_{m1}	d_{m2}	...	d_{mj}	...	d_{mn}
Sums of weighted, normalized, maximizing indices (project "pluses") of the project				S_{+1}	S_{+2}	...	S_{+j}	...	S_{+n}
Sums of weighted, normalized, minimizing indices (project "minuses") of the project				S_{-1}	S_{-2}	...	S_{-j}	...	S_{-n}
Significance of the project				Q_1	Q_2	...	Q_j	...	Q_n
Priority of the project				P_1	P_2	...	P_j	...	P_n
Utility degree of the project (%)				N_1	N_2	...	N_j	...	N_n

* – The sign $z_i(+(-))$ indicates that a greater (lesser) criterion value corresponds to greater (lesser) significance for stakeholders.

Assuming $N_{je} > \sum_{j=1}^{n} N_j \div n$, then continue increasing the value $x_{1j\ cycle\ e}$ of this project a_j (see Table 3) by 1 unit costs per square meter (e.g., 1 Euro/m^2) and performing calculations as per Stages 1-6 with the gained decision making matrix until arriving at Inequality $N_{je} < \sum_{j=1}^{n} N_j \div n$ during e approximations. Then the final value $x_{1j\ cycle\ e}$ (while $N_{je} > \sum_{j=1}^{n} N_j \div n$) equals the investment value:

$$x_{1j\ iv} = x_{1j\ cycle\ e} \tag{7}$$

Assuming $N_{je} < \sum_{j=1}^{n} N_j \div n$, then continue reducing the value $x_{1j\ cycle\ e}$ of this project a_j (see Table 3) by 1 unit costs per square meter (e.g., 1 Euro/m^2) and performing calculations as per Stages 1-6 with the gained decision making matrix until arriving at Inequality $N_{je} > \sum_{j=1}^{n} N_j \div n$ during e approximations. Then the final value $x_{1j\ cycle\ e}$ (while $N_{je} < \sum_{j=1}^{n} N_j \div n$) equals the investment value (see Formula 7).

Stage 7. Performing the optimization of value x_{ij} is possible for any criterion during e approximations. It is necessary to determine, what the optimized value $x_{ij\ cycle\ e}$ should be for alternative a_j to be equally competitive in the market with the other alternatives under comparison ($a_1 - a_n$) (see Table 3).

The optimization of value x_{ij} for any criterion pertinent to the project under deliberation a_j may be determined by performing complex analyses of the benefits and drawbacks of these projects. Development of a grouped, decision making matrix for the multiple criteria analysis of a project transpires by calculating the optimization of value x_{ij} during e approximations of a

Table 3: Grouped decision making matrix for the investment value assessment of project a_j (optimization of value x_{ij} for any criterion)

Criteria describing the alternatives	*	Weights	Measurement units	Project under valuation and projects under comparison					
				a_1	a_2	...	a_j	...	a_n
X_1	z_1	q_1	m_1	x_{11}	x_{12}	...	$\boldsymbol{x_{1j\,cycle\,e}}$	...	x_{1n}
X_2	z_2	q_2	m_2	x_{21}	x_{22}	...	x_{2j}	...	x_{2n}
X_3	z_3	q_3	m_3	x_{31}	x_{32}	...	x_{3j}	...	x_{3n}
...	...	...	...	...	...	...	...	...	...
X_i	z_i	q_i	m_i	x_{i1}	x_{i2}	...	$\boldsymbol{x_{ij\,cycle\,e}}$	...	x_{in}
...	...	...	...	...	...	...	...	...	...
X_m	z_m	q_m	m_m	x_{m1}	x_{m2}	...	x_{mj}	...	x_{mn}
N_{je}				N_{1e}	N_{2e}	...	$\boldsymbol{N_{je}}$	...	N_{ne}
Conceptual information pertinent to projects (i.e., texts, drawings, graphics, video tapes and virtual and augmented realities)									

* – The sign $z_i(+(-))$ indicates that a greater (lesser) criterion value corresponds to greater (lesser) significance for stakeholders.

project under valuation by the block-diagram, as presented in Figure 1. Use of Stages 1-5 and 7 accomplishes a set assessment of all the positive and negative features of a project (criteria, its values and weights). Perform calculations by using a grouped decision making matrix (see Table 3) and Stages 1-5 and 7.

The calculation for the corrected optimization of value $x_{ij\,cycle\,e}$ for any criterion a_j is by formula:

$$Assuming\, N_{je} > \sum_{j=1}^{n} N_j \div n\, and\, X_i\, is\, X_{i-},\, then\, x_{ij\,cycle\,e} = x_{ij\,cycle\,0} \times (1 + e \times r), \quad e = \overline{1,\, \mathrm{r}}$$

$$Assuming\, N_{je} > \sum_{j=1}^{n} N_j \div n\, and\, X_i\, is, X_{i+},\, then\, x_{ij\,cycle\,e} = x_{ij\,cycle\,0} \times (1 - e \times r), \quad e = \overline{1,\, \mathrm{r}} \tag{8a}$$

$$Assuming\, N_{je} < \sum_{j=1}^{n} N_j \div n\, and\, X_i\, is\, X_{i-},\, then\, x_{ij\,cycle\,e} = x_{ij\,cycle\,0} \times (1 - e \times r), \quad e = \overline{1,\, \mathrm{r}}$$

$$Assuming\, N_{je} < \sum_{j=1}^{n} N_j \div n\, and\, X_i\, is\, X_{i+},\, then\, x_{ij\,cycle\,e} = x_{ij\,cycle\,0} \times (1 + e \times r), \quad e = \overline{1,\, \mathrm{r}} \tag{8b}$$

where e is the number of cycles during which optimization value $x_{ij\,cycle\,e}$ can be determined by means of e approximation of the project under deliberation a_j. Meanwhile r is the amount by which the optimization value $x_{ij\,cycle\,e}$ of the project under deliberation a_j increases (decreeses) by means of cycling, to satisfy Inequality 9. $X_{i+}(X_{i-})$ – indicates that a greater (lesser) criterion value corresponds to a greater (lesser) significance for stakeholders.

Assuming the utility degree N_{je} of the project under deliberation a_j is greater than the average utility degree (Formula 8a) of the projects under comparison, it means project a_j is more beneficial on average than the projects under comparison are. For the project under deliberation

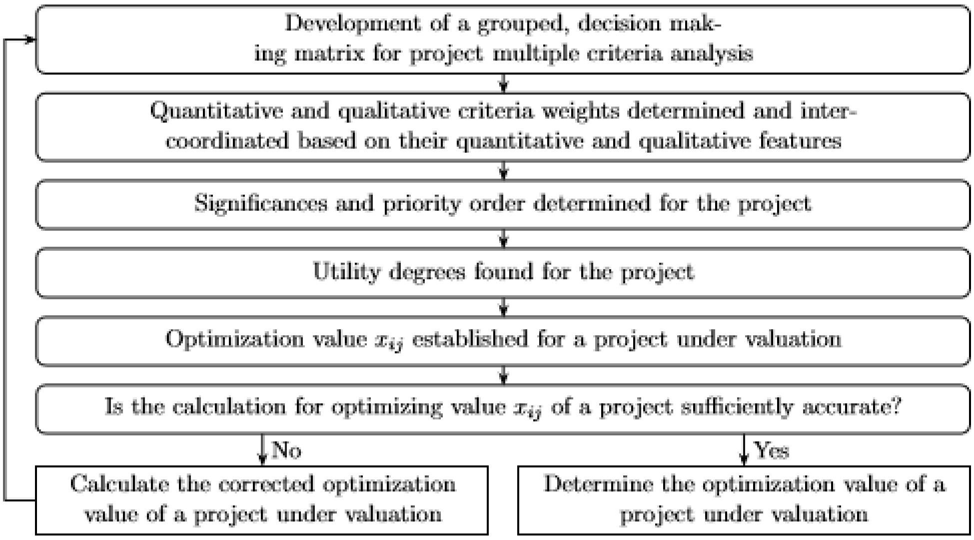

Figure 1: Block-diagram for a project's optimization value assessment

to be equally competitive on the market with the projects under comparison ($a_2 - a_n$), reduce (increase) the value $x_{ij\,cycle\,e}$ of its criterion (see formula 8a) under deliberation by an r amount over e cycles, until satisfying the next inequality:

$$|\, N_{je} - \sum_{j=1}^{n} N_{je} \div n| < s \tag{9}$$

where s is the accuracy, by percentage, to be achieved by calculating the value $x_{ij\,cycle\,e}$ of the criterion under deliberation of project a_j. For example, given that $s = 0.5\%$, the number of calculation approximations will be lower than it is at $s = 0.1\%$.

The decision maker selects the r and s amounts depending on the accuracy needed for the calculations.

Assuming the utility degree N_{je} of the project under deliberation a_x is lower than the utility degree (Formula 8b) is on average of the projects under comparison, it means project a_j is less beneficial on average than the projects under comparison are. For the project under deliberation to be equally competitive on the market with comparison projects ($a_1 - a_n$), increase (reduce) the value $x_{ij\,cycle\,e}$ of its criterion (see formula 8b) under deliberation by an r amount over e cycles, until satisfying Inequality 9.

Assuming Inequality 9 is not satisfied, it means the calculation of the value $x_{ij\,cycle\,e}$ of the criterion under deliberation of the project under valuation a_j is not sufficiently accurate, and it is necessary to repeat the approximation cycle. Thereby the corrected revision of value $x_{ij\,cycle\,e}$ of the project under valuation substitutes into a grouped decision making matrix of a project's multiple criteria analysis. Recalculate Formulae 1-8 until satisfying Inequality 9.

There is a determination of the optimization value $x_{ij\,cycle\,e}$ for any criterion of the project under valuation a_j. Upon satisfaction of Inequality 9, the application of the next, Formula 10 is to determine the optimization value $x_{ij\,cycle\,e}$ for any criterion of project a_j:

$$x_{ij\,opt\,value} = x_{ij\,cycle\,e} \tag{10}$$

Stage 9. Presenting indicator x_{ij} of the quantitative recommendation i_{ij} showing the percentage of a possible improvement in the value of indicator x_{ij} for it to become equal to the best value

$x_{i\,max}$ of criterion X_i is by the formula (see Tables 4 and 8):

$$i_{ij} = |x_{ij} - x_{i\,max}| \div x_{ij} \times 100\% \tag{11}$$

where i_{ij} is the quantitative recommendation i_{ij} of indicator x_{ij} showing the percentage of a possible improvement in the value of indicator x_{ij} for it to become equal to the best value $x_{i\,max}$ of criterion X_i. Meanwhile $x_{i\,max}$ is the value of the indicator of the best criterion X_i of the variants under comparison.

Stage 10. Indicator x_{ij} of quantitative recommendation r_{ij} showing the percentage of possible improvement of utility degree N_j of alternative a_j upon presentation of $x_{ij} = x_{i\,max}$. In other words, r_{ij} shows the percentage of possible improvement in the utility degree N_j of alternative a_j, assuming the value of indicator x_{ij} can be improved up to the best value $x_{i\,max}$ of the indicator of criterion X_i. The calculation is by formula:

$$r_{ij} = (q_i \times x_{i\,max}) \div (S_{-j} + S_{+j}) \times 100\% \tag{12}$$

where r_{ij} is the indicator x_{ij} of the quantitative recommendation r_{ij} showing the percentage of possible improvement in the utility degree N_j of alternative a_j, when $x_{ij} = x_{i\,max}$.

The submission of the quantitative recommendations i_{ij} and r_{ij} of value x_{ij} is in a matrix form (see Table 4).

Stage 11. This stage involves calculation by approximation e cycle to determine, what the value $x_{1j\,cycle\,e}$ should be for the project under deliberation a_j to become the best among those under deliberation. The problem may be stated as follows: What investment value $x_{1j\,cycle\,e}$ of the project under valuation a_j will make it the best on the market, as per the projects under comparison $(a_1 - a_n)$ (see Table 3)? The measurement of value $x_{1j\,cycl\,e}$ is by price (Euro, British pounds, U.S. dollar or others) per square meter. The reduction in the price of this project per 1 square meter unit (e.g., 1 Euro/m^2) continues until utility degree $N_{j\,e}$ of the project under deliberation a_j equals 100%.

3 Case Studies: Describing the sustainability of buildings assessed by the INVAR Method

3.1 Case Study 1: Calculations of the IKEA shopping center utility degree

A specific example appears next to demonstrate the INVAR method more clearly. Five buildings for retail operations a_1 – a_5 are under analysis for this case study. All the data come from the BREEAM pre-assessment reports and other sources pertinent to IKEA shopping center a_1 [26, 27], Orchard Park District Centre a_2 [28], Friargate Court & Retail Units a_3 [29], Dorking Store a_4 [30] and Retail Foodstore a_5 [31]. Table 5 shows this data. Table 5 consists of criteria (BREEAM Sections and investment), their values (BREEAM Section scores and prices per square meter) and weights. The sum of the weights of all the BREEAM criteria (BREEAM Sections) is equal to one, because the calculation of the section score section has assessed the weighting. The weight of the Investment criterion is compared to the sum of the weights from all the other criteria (BREEAM Sections). This associates with the requirement that the price of these projects must equal the achieved results.

The basis for performing an assessment of the sustainability of retail buildings consists of the 11 INVAR method stages. These calculations appear in brief below.

Stage 1: The weighted normalized decision making matrix D is formed (see Formula 1, Table 5 and 9). The first formula for this purpose is:

Table 4: Quantitative recommendations submitted in a matrix form

Criteria describing the alternatives	*	Weights	Measurement units	Compared projects					
				a_1	a_2	...	a_j	...	a_n
X_1	z_1	q_1	m_1	x_{11}	x_{12}	...	x_{1j}	...	x_{1n}
Possible improvement of the value of indicator x_{1j} for it to become equal to the best value $x_{1\,max}$ of criterion X_1			%	i_{11}	i_{12}	...	i_{1j}	...	i_{1n}
Possible improvement of the utility degree N_j of alternative a_j upon presentation of $x_{1j} = x_{1\,max}$			%	r_{11}	r_{12}	...	r_{1j}	...	r_{1n}
X_2	z_2	q_2	m_2	x_{21}	x_{22}	...	x_{2j}	...	x_{2n}
Possible improvement in the value of indicator x_{2j} for it to become equal to the best value $x_{2\,max}$ of criterion X_2			%	i_{21}	i_{22}	...	i_{2j}	...	i_{2n}
Possible improvement of utility degree N_j of alternative a_j upon presentation of $x_{2j} = x_{2\,max}$			%	r_{21}	r_{22}	...	r_{2j}	...	r_{2n}
...	...	...	...	...	...	...	...	...	...
X_i	z_i	q_i	m_i	x_{i1}	x_{i2}	...	x_{ij}	...	x_{in}
Possible improvement in the value of indicator x_{ij} for it to be equal to the best value $x_{i\,max}$ of criterion X_i			%	i_{i1}	i_{i2}	...	i_{ij}	...	i_{in}
Possible improvement in utility degree N_j of alternative a_j upon presentation of $x_{ij} = x_{i\,max}$			%	r_{i1}	r_{i2}	...	r_{ij}	...	r_{in}
...	...	...	...	...	...	...	...	...	...
X_m	z_m	q_m	m_m	x_{m1}	x_{m2}	...	x_{mj}	...	x_{mn}
Possible improvement in the value of indicator x_{mj} for it to be equal to the best value $x_{m\,max}$ of criterion X_m			%	i_{m1}	i_{m2}	...	i_{mj}	...	i_{mn}
Possible improvement of utility degree N_j of alternative a_j upon presentation of $x_{mj} = x_{m\,max}$			%	r_{m1}	r_{m2}	...	r_{mj}	...	r_{mn}

$d_{11} = 10 \times 1774 \div (1774 + 1953.8 + 2370 + 1890 + 2045) = 1.7682$

$d_{12} = 1.1 \times 1953.8 \div (1774 + 1953.8 + 2370 + 1890 + 2045) = 1.9474$

$d_{13} = 1.1 \times 2370 \div (1774 + 1953.8 + 2370 + 1890 + 2045) = 2.3623$

The value of weight q_i of the investigated criterion distributes proportionally among retail buildings under analysis a_j according to their values x_{ij} (see Table 6). For example:

$q_2 = 0.1068 + 0.2403 + 0.1942 + 0.2403 + 0.2185 = 1.0$

$q_4 = 0.2709 + 0.1996 + 0.0925 + 0.1913 + 0.2457 = 1.0$

Stage 2: The sums of weighted normalized indices describing the j-th version are calculated. Formula 3 calculates the sums:

$S_{+1} = 0.1068 + 0.2293 + 0.2709 + 0.2056 + 0.0957 + 0.1186 + 0.13 + 0.1944 + 0.2557 + 0.0 = 1.607$

$S_{-1} = 1.7682\ etc.$

In any case, the sums of the "pluses" S_{+j} and "minuses" S_{-j} of all alternative projects are always, respectively, equal to all sums of the weights of maximizing and minimizing criteria (see Formula 4):

$S_+ = 1.607 + 1.7515 + 2.2967 + 1.6557 + 2.689 = 10.0$

$S_- = 1.7682 + 1.9474 + 2.3623 + 1.8838 + 2.0383 = 10.0$

Table 5: Initial data for INVAR method calculations (see [32])

Quantitative and qualitative information pertinent to retail buildings								
Criteria describing the retail buidlings	*	Measurement units	Weight	Compared retail buidlings				
				a_1	a_2	a_3	a_4	a_5
Investment	-	Euro/m^2	10	**1774**	1953.8	2370	1890	2045
Management	+	Points	1	4.8	10.8	8.73	10.8	9.82
Health & Wellbeing	+	Points	1	10.65	10	7.5	8.3	10
Energy	+	Points	1	14.44	10.64	**4.93**	10.2	13.1
Transport	+	Points	1	5.6	4.92	7.11	2.5	7.11
Water	+	Points	1	1.98	5.33	4	4.7	4.67
Materials	+	Points	1	4.12	5.77	9.62	4.8	10.42
Waste	+	Points	1	3.22	4.69	3.75	5.6	7.5
Land Use & Ecology	+	Points	1	7	6	7	7	9
Pollution	+	Points	1	5.8	3.08	6.15	3.8	3.85
Innovation	+	Points	1	0	0	2	0	2

* – The sign "+/-" indicates that a greater (lesser) criterion value corresponds to greater (lesser) significance for a user (stakeholder).

Stage 3: Formula 5 finds the relative significance Q_j of each project a_j (see Table 6):

$$Q_1 = 1.607 + \frac{1.7682 \times (1.7682 + 1.9474 + 2.3623 + 1.8838 + 2.0383)}{1.7682 \times (1.7682 \div 1.7682 + 1.7682 \div 1.9474 + 1.7682 \div 2.3623 + 1.7682 \div 1.8838 + 1.7682 \div 2.0383)} = 3.8478$$

$$Q_2 = 1.7515 + \frac{1.7682 \times (1.7682 + 1.9474 + 2.3623 + 1.8838 + 2.0383)}{1.9474 \times (1.7682 \div 1.7682 + 1.7682 \div 1.9474 + 1.7682 \div 2.3623 + 1.7682 \div 1.8838 + 1.7682 \div 2.0383)} = 3.7861$$

Stage 4: The greater the Q_j, the higher is the efficiency (priority) of the retail buildings: $Q_5 > Q_3 > Q_1 > Q_2 > Q_4$ (see Table 6: $4.6329 > 3.974 > 3.8478 > 3.7861 > 3.759$).

Stage 5: Formula 6 is used for calculating utility degree N_j:

$N_1 = (3.8478 \div 4.6329) \times 100\% = 83.05\%$
$N_2 = (3.7861 \div 4.6329) \times 100\% = 81.72\%$
$N_3 = (3.974 \div 4.6329) \times 100\% = 85.78\%$
$N_4 = (3.759 \div 4.6329) \times 100\% = 81.14\%$
$N_5 = (4.6329 \div 4.6329) \times 100\% = 100\%$

The results of a multiple criteria evaluation of the sustainable retail buildings under analysis appear in Table 6. Table 6 shows that the fiftht version a_5 is the best by utility degree equaling $N_5 = 100\%$. The third version a_3 was second according to priority, and its utility degree was equal to $N_3 = 85.78\%$.

3.2 Case Study 2: Calculations of the IKEA shopping center investment value

The calculations of the investment value of the IKEA shopping center under valuation are according to data from Table 5 and Stages 1-6. Construction of the IKEA shopping center for furniture and home furnishings was in several stages. First, there was selection of a lot and then, the detailed planning for merging two lots. Upon approval of the detailed plan, there were

Table 6: INVAR method calculation results

Quantitative and qualitative information pertinent to retail buildings								
Criteria describing retail buidlings	*	Measurement units	Weight	Retail buidings under comparison				
				a_1	a_2	a_3	a_4	a_5
Investment	-	Euro/m^2	10	1.7682	1.9474	2.3623	1.8838	2.0383
Management	+	Points	1	0.1068	0.2403	0.1942	0.2403	0.2185
Health & Wellbeing	+	Points	1	0.2293	0.2153	0.1615	031787	0.2153
Energy	+	Points	1	0.2709	0.1996	0.0925	0.1913	0.2457
Transport	+	Points	1	0.2056	0.1806	0.261	0.0918	0.261
Water	+	Points	1	0.0957	0.2577	0.1934	0.2273	0.2258
Materials	+	Points	1	0.1186	0.1661	0.277	0.1382	0.3
Waste	+	Points	1	0.13	0.1894	0.1515	0.2262	0.3029
Land Use & Ecology	+	Points	1	0.1944	0.1667	0.1944	0.1944	0.25
Pollution	+	Points	1	0.2557	0.1358	0.2712	0.1675	0.1698
Innovation	+	Points	1	0	0	0.5	0	0.5
Sums of weighted, normalized maximizing indices (project "pluses") of the retail buildings				1.607	1.7515	2.2967	1.6557	2.689
Sums of weighted, normalized minimizing (projects "minuses") indices of the retail buildings				1.7682	1.9474	2.3623	1.8838	2.0383
Significance of the retail buildings				3.8478	3.7861	3.974	3.759	4.6329
Priority of the retail buildings				3	4	2	5	1
Utility degree of the retail buildings (%)				83.05%	81.72%	85.78%	81.14%	100%

* – The sign "+/-" indicates that a greater (lesser) criterion value corresponds to greater (lesser) significance for a user (stakeholder).

ecological tests conducted on the lot, followed by the design and then the arrangement of the lot. Some 2,400 units of garages and their foundations were demolished. The partial use of processed construction materials was for new construction, and the remaining materials, for transferring to other waste handlers. The amount of contaminated soil removed was 1,000 tons (see Figure 2). The retail buildings designed a parking lot for 953 automobiles of which 37 are for the disabled and 36 for families with children. The unused areas of the lot have planted greenery. The water supply of the city provides the water for the building. Centralized sewage networks of the city handle the captured wastewater from the facilities and rainwater that then flow into appropriate piping. The facility contains an installed, autonomous water heating system using solar energy. Air conditioning installations consist of efficient heat pumps and the ventilation – of productive recovery systems. The centralized heating network supplies heat. The design and construction of the building were according to customer specifications and were in consideration of permissible noise level maintenance. The project blueprint stipulates an external enclosure that insulates noise to no less than 32 dB. The main indicators of the project are total building area – 25,359 m^2, main area – 21,533 m^2, building height – 15.84 m, drinking water supply pipeline – 3,300 m, wastewater pipeline – 1,900 m and rainwater pipeline – 2,358 m. Air conditioning and ventilation systems are installed in the retail buildings for assuring hygienic stipulations for the facilities and the required, stable air temperature and moisture stipulations for the administrative facilities of the work environment. The lighting for the building divides into zones that are all independently controlled. Only certified materials having the least impact on the environment over the life of the building were used for the building's internal and external systems. The insulation materials used were those having the least impact on the environment but containing the best thermal insulation properties. The investment of the IKEA shopping center was 47.2 mln. Euro.

The aim was to establish, what the investment value $x_{11\,cycle\,e}$ (see the bold-faced numbers a b

Figure 2: IKEA shopping center for furniture and home furnishings: a) IKEA lot under arrangement and b) operating IKEA shopping center

in Tables 5 and 7) of the investment should be for a_1 to be equally competitive in the market against the other retail buildings under comparison (a_2 – a_5). Applications of INVAR Stages 1-6 serve to accomplish a set assessment of the positive and negative features of all these retail buildings.

As Table 7 shows, the most beneficial retail building during the 124^{th} cycle of approximation ($e = 124$), according to its designation for use, is a_5 ($N_{5\,124} = 100\%$). The second under comparison that is most beneficial is a_1 ($N_{1\,124} = 86.43\%$) and the third under comparison – a_3 ($N_{3\,124} = 85.77\%$). The calculated utility degrees of the sustainable retail buildings under comparison make it apparent that the cost $x_{11\,124} = 1650$ (Euro/m^2) for IKEA shopping center under valuation a_1 is still too high. Therefore this retail buildings a_1 is not equally competitive in the market, as compared to the sustainable retail buildings under comparison, once the assessment of their sets of specific positive and negative features is complete. Stage 6 also affirms the same fact: the calculation of the investment value for retail building a_1 during the 124^{th} cycle of approximation was not sufficiently accurate (see column 9 in Table 7). Table 7 shows that Inequality (see column 9 in Table 7) was unsatisfactory for the first 144 cycles. The determination of the investment value of a_1 under valuation with respect to the other retail buildings under comparison appears in the final, 145^{th} approximation cycle – $N_{1\,145cycle} = 87.04\%$ ($N_{2\,145cycle} = 81.53\%$, $N_{3\,145cycle} = 85.77\%$, $N_{4\,145cycle} = 80.91\%$ and $N_{5\,145cycle} = 100\%$). In the 144^{th} approximation cycle, the utility degree of project under comparison a_1 calculates at $N_1 = 87.02\%$. The degrees of utility for the retail buildings under analysis show that a_1 under valuation in the 145^{th} approximation cycle is more beneficial than is the second retail building under comparison a_2 by 5.51% and more beneficial than retail building under comparison a_4 by 6.13%. There was a revision of the investment value x_{11} in every cycle (from $x_{11\,cycle\,0} = 1774$ Euro/m^2), each by 1 Euro/m^2 by size until Inequality (see column 9 in Table 7) was satisfied ($x_{11\,cycle\,145} = 1629$ Euro/m^2). Thus investment value $x_{11\,cycle\,e}$ (respectively, 1774, ..., 1629) is checked for accuracy pertinent to retail building a_1 by placing them into the bold cell of the decision making matrix (see Table 5). All calculations were repeated according to Stages 1-6 until Inequality (see column 9 in Table 7) was satisfied in the 145^{th} cycle. Table 7 shows that the calculations of investment value $x_{11\,cycle\,e}$ become more and more accurate with each, next e approximation cycle for retail building a_1 under analysis.

3.3 Case Study 3: Provision of recommendations

The results of the provision of recommendations by applying Stages 1-5, 9 and 10 of the INVAR method for the retail buildings appear in Table 8. Initial data for the calculations are presented in Table 5. Meanwhile, the recommendations for bettering the criteria for these retail buildings under comparison appear in Table 8. Recommendations arrive in a matrix (see Table

Table 7: Revised changes in value and investment value determinations for IKEA shopping center under valuation a_1

Approximation cycle	*	Utility degree change in retail buildings under deliberation by rationalizing the corrected value $x_{11\,cycle\,e}$ of building a_1					**	***
		Utility degree N_{1e}	Utility degree N_{2e}	Utility degree N_{3e}	Utility degree N_{4e}	Utility degree N_{5e}		
1	2	3	4	5	6	7	8	9
0	**1774**	83.05%	81.72%	85.78%	81.14%	100%	86.34%	$\lvert -4.11\%\rvert < 0.02\%$
...	...	...	...	...	...	...	...	...
124	**1650**	86.43%	81.56%	85.77%	80.95%	100%	86.94%	$\lvert -0.64\%\rvert < 0.02\%$
...	...	...	...	...	...	...	...	...
134	**1640**	86.72%	81.55%	85.77%	80.93%	100%	87.00%	$\lvert -0.34\%\rvert < 0.02\%$
...	...	...	...	...	...	...	...	...
144	**1630**	87.02%	81.53%	85.77%	80.91%	100%	87.05%	$\lvert -0.03\%\rvert < 0.02\%$
145	$\boldsymbol{x_{1j\,iv}}$ = **1629**	87.04%	81.53%	85.77%	80.91%	100%	87.05%	$\lvert -0.01\%\rvert < 0.02\%$

* - revised changes in value and investment value $x_{11\,cycle\,e}$ (Euro/m^2) of IKEA shopping center under valuation a_1.

** $(N_{1e} + N_{2e} + N_{3e} + N_{4e} + N_{5e}) \div 5$

*** Inequality to determine, whether the calculation of revised value $x_{11\,cycle\,e}$ of IKEA shopping center under valuation a_1 is sufficiently accurate.

8) by using Formulae 10 and 11 during Stages 9 and 10. Every window in Table 8 describing Alternative a_j consists of three parts: x_{ij} – the value of the i-th criterion (X_i) in the j-th alternative; quantitative recommendation i_{ij} showing the percentage of a possible improvement in the value of indicator x_{ij} for it to become equal to the best value $x_{i\,max}$ of criterion X_i $(x_{ij} = x_{i\,max})$; and quantitative recommendation r_{ij} showing the percentage of possible improvement of utility degree N_j of alternative a_j upon presentation of $x_{ij} = x_{i\,max}$. If, for example, it would be possible to improve the assessment of the Health & Wellbeing criterion for building a_3 $(i_{33} = 42\%)$ from the $x_{33} = 7.5$ value achieved up to the best value for a_1 $(x_{34} = 10.65)$, then the utility degree N_3 for building a_3 would increase by $r_{33} = 2.1\%$. Analogically, if the assessment of the Energy criterion for building a_3 $(x_{43} = 5.1)$ could be improved up to the amount of the best assessment for building a_1 $(x_{41} = 14.44)$, then the effectiveness of the criterion Energy for building a_3 would increase by $i_{43} = 183.14\%$, and the utility degree N_3 would increase by $r_{43} = 9.1569\%$ (see Table 8).

3.4 Case Study 4: Optimization of the value

This example, based on Stages 1-5 and 7, will determine, what the value $x_{43\,cycle\,e}$ of the BREEAM Energy Section (see the number in bold in Table 5) must be for project a_3 to be equally competitive on the market, as compared to the other retail buildings under comparison (a_1, a_2, a_4, a_5) by a set assessment of all their positive and negative features. It is possible to optimize any one of the criteria or their composite parts by the new INVAR method, which deliberates the sustainability of retail buildings under analysis in an integrated manner by using Pre-assessment Reports. The optimization of the score of the Energy Section of BREEAM, which appears next, will serve as an example (see Table 5).

The determination of the optimized score $x_{43\,cycle\,e}$ for the project under valuation a_3 appears

Table 8: Quantitative recommendations submitted in a matrix form

Quantitative and qualitative information pertinent to alternatives								
Criteria describing the alternatives	*	Measurement units	Weight	Alternatives				
				a_1	a_2	a_3	a_4	a_5
Health & Wellbeing	+	Points	1	$\boldsymbol{x_{31}} = 10.65$ (0%) (0%)	10 (6.5%) (0.325%)	$\boldsymbol{x_{33}} = 7.5$ ($\boldsymbol{i_{33}} = 42\%$) ($\boldsymbol{r_{33}} = 2.1\%$)	8.3 (28.31%) (1.4157%)	10 (6.5%) (0.325%)
Energy	+	Points	1	$\boldsymbol{x_{41}} = 14.44$ (0%) (0%)	10.64 (35.71%) (1.7857%)	$\boldsymbol{x_{43}} = 5.1$ ($\boldsymbol{i_{43}} = 183.14\%$) ($\boldsymbol{r_{43}} = 9.1569\%$)	10.2 (41.57%) (2.0784%)	13.1 (10.23%) (0.5115%)

*- The sign "+/-" indicates that a greater (lesser) criterion value corresponds to a greater (lesser) significance for a user (stakeholder).

in Table 9. The formulation of this task is the following: determine, what the optimized score $x_{43\,cycle\,e}$ should be for building under valuation a_3 for it to be equally competitive in the market, as compared with the sustainable retail buildings (a_1, a_2, a_4, a_5) after a complex assessment of their positive and negative features. The decision making matrix (see Table 5), the amalgamated block diagram submitted in Figure 1 and the calculations performed by Stages 1-5 and 7 serve as the basis for these calculations. The results of the e approximation cycles of these calculations appear in Table 9. The aim was to establish, what the score $x_{43\,cycle\,e}$ should be (see the numbers

Table 9: What score $x_{43\,cycle\,e}$ should be for building a_3 to be equally competitive in the market with other retail buildings under comparison (a_1, a_2, a_4, a_5)

Approximation cycle	Score $x_{43\,cycle\,e}$	Utility degree N_{1e}	Utility degree N_{2e}	Utility degree N_{3e}	Utility degree N_{4e}	Utility degree N_{5e}	*	**
0	**4.93**	83.05%	81.72%	85.78%	81.14%	100%	86.34%	$\lvert -0.7\%\rvert > 0.1\%$
...	**...**	...	...	...	...			...
7	**5**	83.05%	81.72%	85.81%	81.14%	100%	86.34%	$\lvert -0.67\%\rvert > 0.1\%$
...	**...**	...	...	...	...			...
57	**5.5**	83.04%	81.72%	86.03%	81.14%	100%	86.39%	$\lvert -0.45\%\rvert > 0.1\%$
...	**...**	...	...	...	...			...
107	**6**	83.02%	81.72%	86.25%	81.14%	100%	86.43%	$\lvert -0.19\%\rvert > 0.1\%$
...	**...**	...	...	...	...			...
157	**6.5**	83.01%	81.72%	86.47%	81.14%	100%	86.47%	$\lvert 0\%\rvert < 0.1\%$

* $(N_{1e} + N_{2e} + N_{3e} + N_{4e} + N_{5e}) \div 5$

** Inequality 9 to determine, whether the calculation of revised value $x_{43\,cycle\,e}$ of under valuation a_3 is sufficiently accurate.

in bold in Tables 5 and 9) for building a_3 to be equally competitive in the market with other retail buildings under comparison (a_1, a_2, a_4, a_5). Applications of INVAR Stages 1-5 and 7 serve to accomplish a set assessment of the positive and negative features of all these retail buildings. Table 9 shows that Inequality 9 was unsatisfactory for the first 156 cycles. The score x_{43} was increased in every cycle (from $x_{43\,cycle\,0} = 4.93$) by an amount of 0.01 until Inequality 9 was satisfied ($x_{43\,cycle\,157} = 6.5$). Then scores $x_{43\,cycle\,e}$ (respectively, 4.94, ... and 6.5) are checked for accuracy pertinent to building a_3 by placing these results into the bold cell of the decision making matrix (see Tables 5 and 9). All the calculations were repeated according to Formulae Stages 1-5 and 7 until Inequality 9 was satisfied in the 157^{th} cycle. Table 9 shows the

Table 10: What should the value $x_{11\ cycle\ e}$ of IKEA shopping center be for this project to become the best among those under deliberation?

Approximation cycle	Investment value $x_{11\ cycle\ e}$ (Euro/m^2)	Utility degree				
		N_{1e}	N_{2e}	N_{3e}	N_{4e}	N_{5e}
0	1774	83.05%	81.72%	85.78%	81.14%	100%
124	1650	86.43%	81.56%	85.77%	80.95%	100%
134	1640	86.72%	81.55%	85.77%	80.93%	100%
174	1600	87.92%	81.49%	85.77%	80.86%	100%
274	1500	91.14%	81.34%	85.77%	80.68%	100%
424	1350	96.73%	81.07%	85.76%	80.37%	100%
474	1300	98.84%	80.97%	85.76%	80.25%	100%
484	1290	99.27%	80.95%	85.76%	80.23%	100%
494	1280	99.72%	80.93%	85.76%	80.20%	100%
499	1275	99.94%	80.92%	85.76%	80.19%	100%
504	1270	100%	80.78%	85.62%	80.04%	99.84%

calculations of score $x_{43\ cycle\ e}$ becoming more and more accurate with each, next approximation cycle for building under analysis a_3.

3.5 Case Study 5: What should the value of the IKEA shopping center be for this project to be the best among those under deliberation?

The calculations in this example are by approximation e cycle to determine, what the value $x_{11\ cycle\ e}$ of IKEA shopping center a_1 should be for this project to become best among those under deliberation a_1-a_5. The price of this project continues being reduced by 1 Euro/m^2 until N_{1e} becomes equal to 100% (Stages 1-5 and 11).

Table 10 shows that $N_{1e} = 100\%$ had not been satisfied over 503 cycles. That is the reason the investment value $x_{11\ cycle\ e}$ of the project under valuation a_1, which had been revised 504 times, was entered into the decision making matrix (Table 5) for the multiple criteria analysis of retail building. Table 10 shows that, in each following approximation cycle, the calculation of the revised investment value $x_{11\ cycle\ e}$ of building under valuation a_1 became more and more accurate.

All the calculations by Stages 1-5 and 11 were repeated, until $N_{1e} = 100\%$ was satisfied in the 504^{th} cycle. It can be stated that this project can become the most effective among the projects under comparison, once the value $x_{11\ cycle\ e}$ of the IKEA shopping center = 1270 Euro/m^2.

4 Conclusion

This article recommends a new multiple criteria analysis, the INVAR method (Degree of project Utility and investment value Assessments along with recommendation provisions). INVAR method stages 1-5 are identical as COPRAS method [9, 10, 14]. It generates conditions to assess management, health & wellbeing, energy, transport, water, materials, waste, land use

& ecology, pollution, innovation, comfort, quality of life and aesthetics as well as its technical, economic, legal/regulatory, educational, social, cultural, ethical, psychological, emotional, religious and ethnic aspects in conformity with requirements and opportunities for clients, designers, contractors, users and other stakeholders. The systems and the values and weights of the quantitative and qualitative criteria express these requirements. The INVAR method allows determining the strongest and weakest aspects of each project pertinent to a sustainable building and its constituent parts. Performance of the analyses is to learn by what degree one alternative is better than is another. Furthermore, this discloses the details, why this is so. The practical case studies presented in this research validate this developed method. An analysis of the results reached by the INVAR method permits making the following claims:

- The INVAR method can determine the utility degree and investment values of the projects under deliberation.
- The INVAR method can provide digital tips for improving projects.
- The INVAR method can define, what the value of a selected criterion needs to be for the project under deliberation to be equally competitive in the market, as compared with others under comparison after a set assessment of all their positive and negative features.
- The INVAR method can calculate, what the value of the project under deliberation should be for this project to become the best among others under deliberation.

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