Ecobuildings in the new Member States: Innovative Decision Support Web-based System for Building Refurbishment

A. Kaklauskas, S. Raslanas, A. Mickaityte, VGTU, Lithuania

The Main Building of Vilnius Gediminas Technical University (VGTU)

Building owner: Vilnius Gediminas Technical University

Location/address: Sauletekio av. 11, Vilnius

Building type and size:

The main building was built in 1971. The total floor area 8484,20 sq.m. It includes several departments and lecture halls seating from 50 to 100 students. Number of storeys – 7.

The Main Building of Vilnius Gediminas Technical University (VGTU)

New technologies are rarely applied because of a lack of knowledge at the decision makers. Yet those of them, having reliable information on innovative technologies tend to realize these technologies more often. Therefore it is important to provide them with profound knowledge including advantages and disadvantages, priority, utility degree and market value of analyzed retrofit technologies.

Main Tasks

- Development and Implementation of Innovative Decision Support Web-based System for Building Refurbishment (DSS-BR) which makes it easy to compare various retrofitting measures and scenarios according to different systems of criteria.
- Assist designers and evaluation teams to calculate the integral efficiency of the whole building.
- Improve the life cycle cost and quality of building.
- Develop DSS-BR that is immediately replicable at large scale in many locations.

The DSS-BR tasks aims to optimize the building retrofit process by analyzing the sectional and overall performance of a building considering all the major subsystems and in particular:

- The outdoor environment defining the microclimate
- The building envelope
- The indoor environment
- The HVAC system as well as the lighting
- The facilities management system

Refurbishment decisions influenced on many:

- **microlevel factors**: deterioration and obsolescence of building, indoor environmental quality, technological, technical, the lower fuel bills for householders, health benefits (reduced cold and damp related illness);
- **macrolevel factors**: environmental (a less polluted environment, the saving of limited nature resources), social (increasing social equity, improving human health) and economic (increasing employment, the creation of wealth) benefits.

Decision making models and methods

A thorough building refurbishment evaluation is quite difficult to undertake, because a building and its environment are complex system (technical, technological, ecological, social, comfort, esthetical, etc.), where all sub-systems influences to the total efficiency performance, and where the interdependence between sub-systems are playing a significance role.

Many decision making models and methods (cost-benefit analysis, multiple criteria analysis, the lattice method for optimisation, predicted building habitability index, an energy rating systems for existing houses, multiple criteria analysis, etc.) have been developed in the world for solving above and other problems.

MULTIPLE CRITERIA DECISION SUPPORT WEB-BASED SYSTEM FOR BUILDING REFURBISHMENT

Based on the analysis of the existing neural networks, information, expert and decision support systems and in order to determine most efficient versions of building refurbishment a MULTIPLE CRITERIA DECISION SUPPORT WEB-BASED SYSTEM FOR BUILDING REFURBISHMENT (DSS-BR) was developed. This System consisting of a database, database management system, model-base, model-base management system and user interface.

Database

The presentation of information needed for decision-making in the DSS-BR may be in a conceptual form (i.e. digital/numerical, textual, graphical, diagrams, graphs and drawing, etc), photographic, sound, video and quantitative forms.

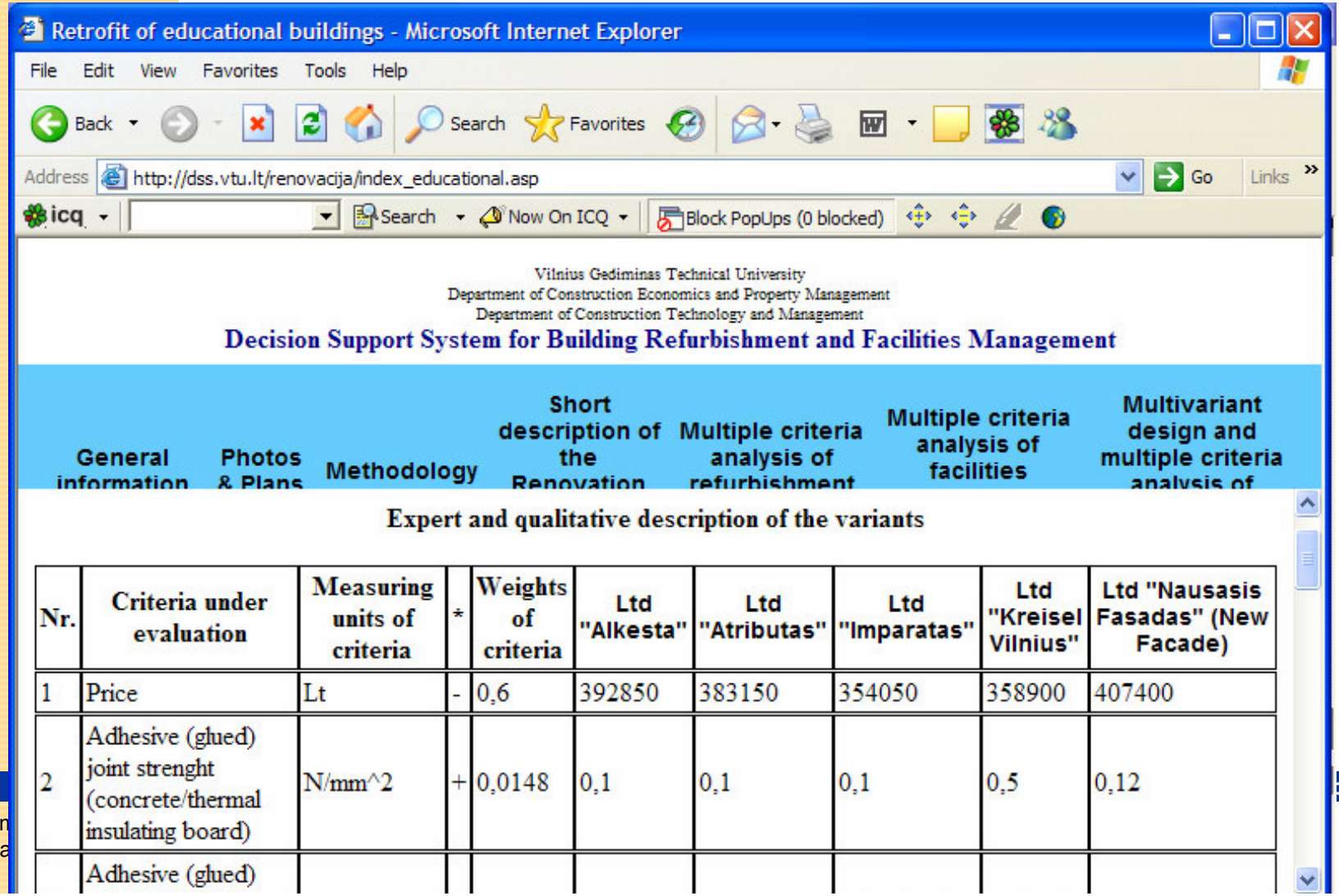
The following tables form the DSS-BR's database:

- Initial data tables. These contain general facts about the building considered and the information of its deterioration and obsolescence. The reasons for refurbishing and their significance as well as the money to be spent on it are also included.
- Tables assessing refurbishment solutions (data base of best practice). These contain quantitative and conceptual information about alternative building refurbishment solutions relating to a building's enclosures, utilities and space planning, etc.
- Tables of multi-variant design. These provide quantitative and conceptual information on the interconnection of the elements to be renovated, their compatibility and the possible combinations as well as data on the complex multi-variant design of a building refurbishment.

Database of Best Practice

- Walls,
- Windows,
- Roof,
- Thermal Units,
- Etc.

Walls - Database of Best Practice



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Department of Construction Economics and Property Management
Department of Construction Technology and Management

Decision Support System for Building Refurbishment and Facilities Management

General information | Photos & Plans | Methodology | Short description of the Renovation | Multiple criteria analysis of refurbishment | Multiple criteria analysis of facilities | Multivariant design and multiple criteria analysis of

Expert and qualitative description of the variants

Nr.	Criteria under evaluation	Measuring units of criteria	*	Weights of criteria	Ltd "Alkesta"	Ltd "Atributas"	Ltd "Imparatas"	Ltd "Kreisel Vilnius"	Ltd "Nausasis Fasadas" (New Facade)
1	Price	Lt	-	0,6	392850	383150	354050	358900	407400
2	Adhesive (glued) joint strenght (concrete/thermal insulating board)	N/mm^2	+	0,0148	0,1	0,1	0,1	0,5	0,12
	Adhesive (glued)								

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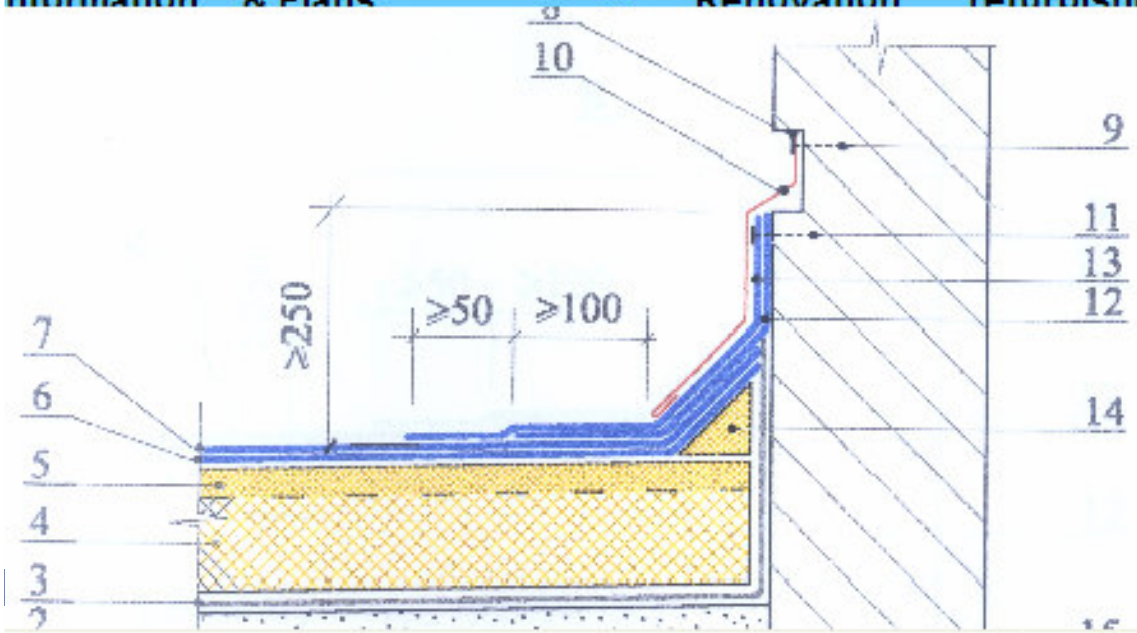
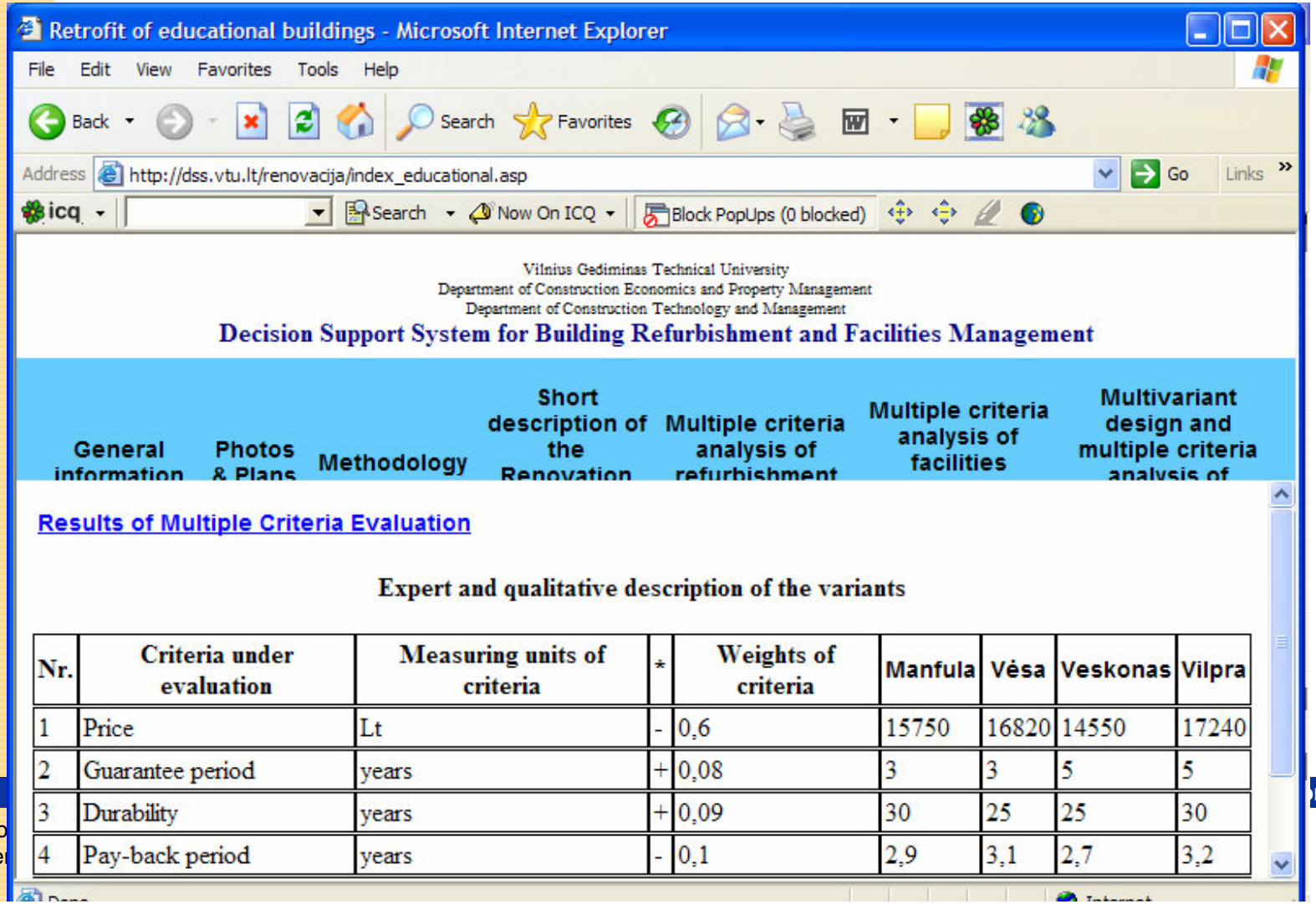


slabs
2. Inclination layer
3. Vapour insulation
4. Heat insulation
5. Base of roll covering
6. Bottom layer of hydroisolation
7. Top layer of hydroisolation
8. Sealing with sealant
9. Masonry nail for tin fixing
10. Bottom layer of additional hydroisolation covering
11. Top layer of additional hydroisolation covering

7 items remaining) Downloading picture http://dss.vtu.lt/renovacija/roof_1.jpg... Internet

Windows - Database of Best Practice



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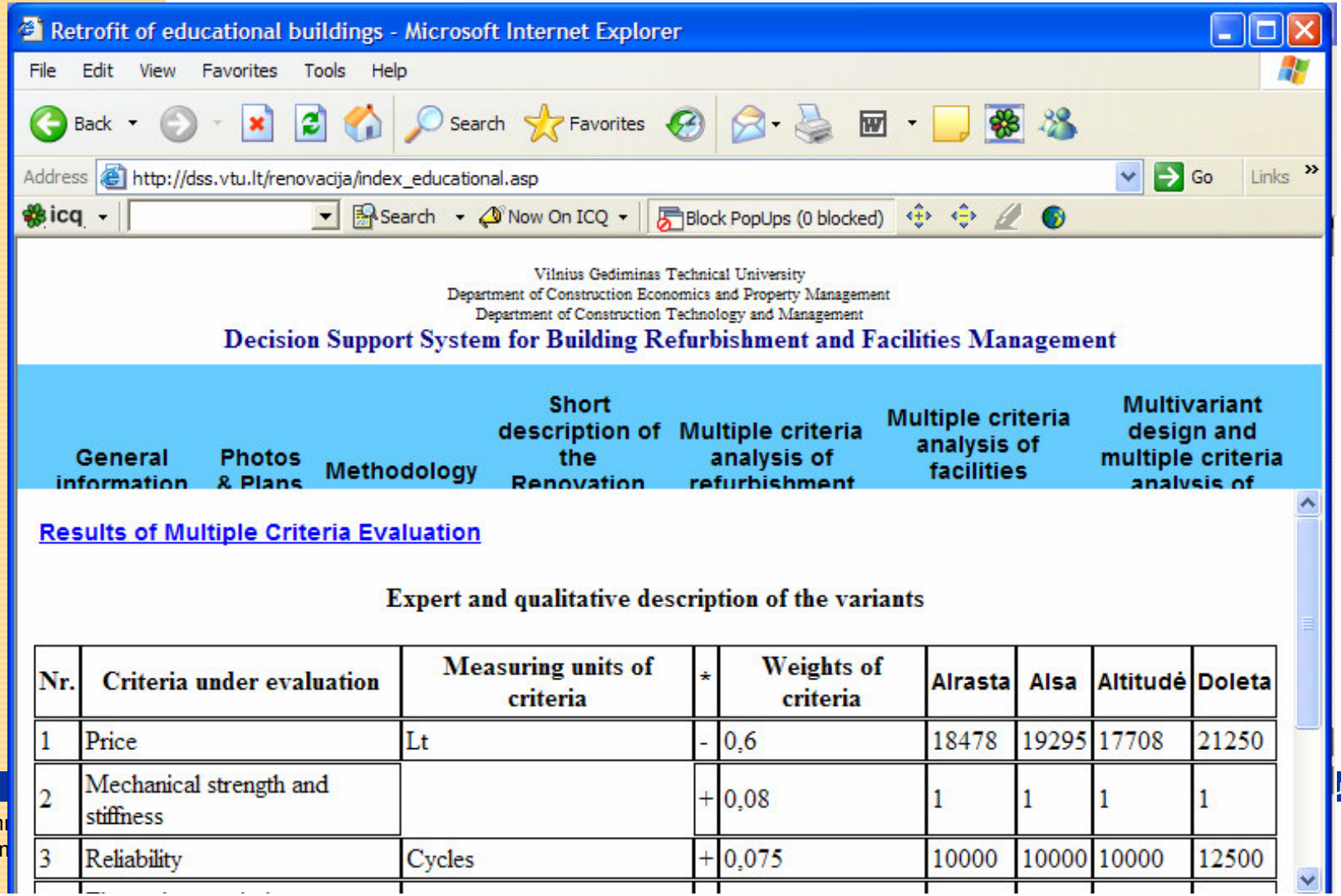
Results of Multiple Criteria Evaluation

Expert and qualitative description of the variants

Nr.	Criteria under evaluation	Measuring units of criteria	*	Weights of criteria	Manfula	Vėsa	Veskonas	Vilpra
1	Price	Lt	-	0,6	15750	16820	14550	17240
2	Guarantee period	years	+	0,08	3	3	5	5
3	Durability	years	+	0,09	30	25	25	30
4	Pay-back period	years	-	0,1	2,9	3,1	2,7	3,2

Thermal unit - Database of Best Practice



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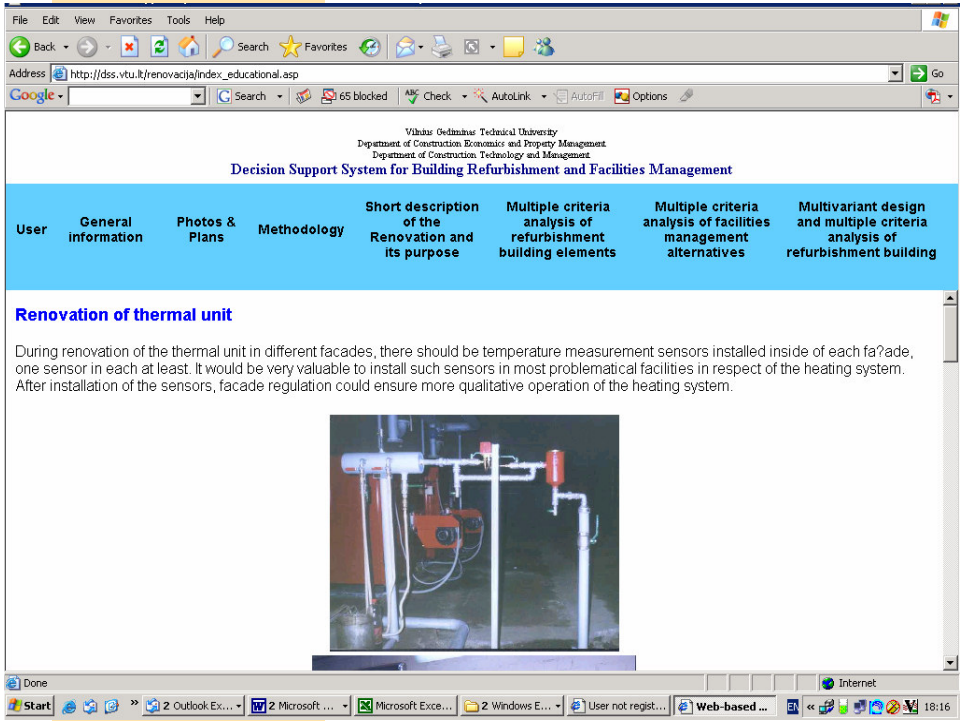
Expert and qualitative description of the variants

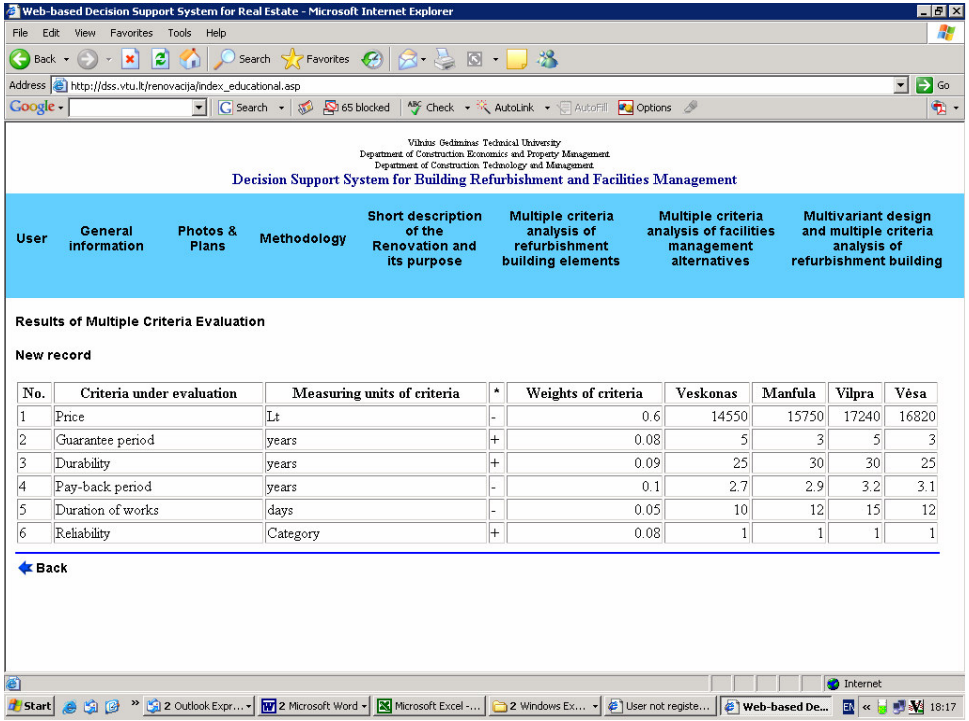
Nr.	Criteria under evaluation	Measuring units of criteria	*	Weights of criteria	Alrasta	Alsa	Altitudė	Doleta
1	Price	Lt	-	0,6	18478	19295	17708	21250
2	Mechanical strength and stiffness		+	0,08	1	1	1	1
3	Reliability	Cycles	+	0,075	10000	10000	10000	12500

The following models form the DSS-BR's model base:

- Search for alternatives (walls, windows, heating systems, roof, FM, etc.).
- Finding out or developing alternatives and making initial negotiation table.
- Multiple criteria analysis of alternatives.
- Development of suggestions as to what interested parties to use and for what reasons further negotiation should be carried out.
- Negotiations based on real calculations.
- Determination of the most rational variant (walls, windows, FM, roof, etc.).
- Provision of recommendations for future actions to interested parties.
- Computer-aided formation of versions of whole building refurbishment.
- Multiple criteria analysis of alternatives.
- Negotiations based on real calculations.
- Selection of the most efficient alternatives of the whole building refurbishment.

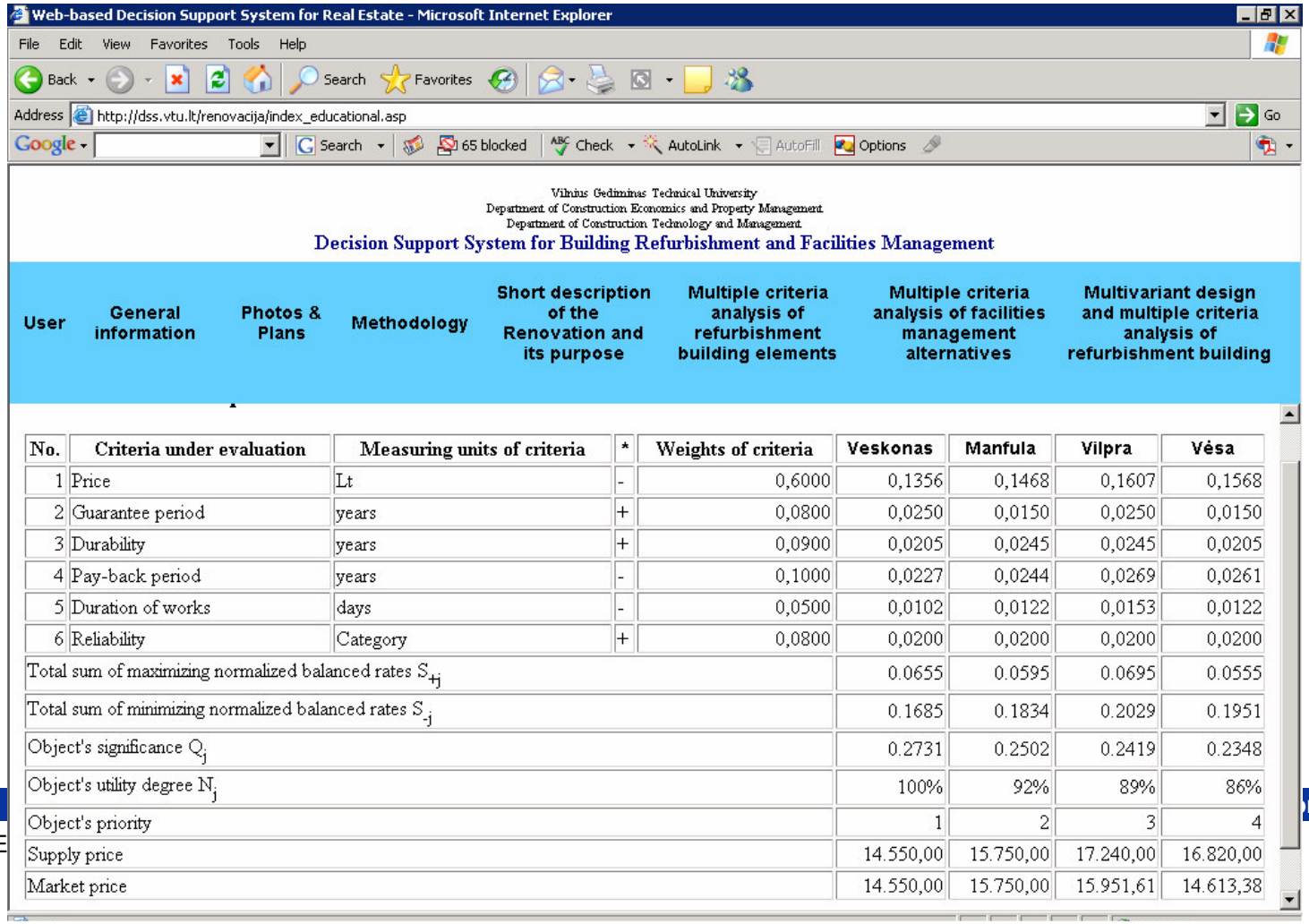
Search results for specific heating system can be submitted in textual, photo/video, graphical, etc. information





No.	Criteria under evaluation	Measuring units of criteria	*	Weights of criteria	Veskonas	Manfula	Vilpra	Vėsa
1	Price	Lt	-	0.6	14550	15750	17240	16820
2	Guarantee period	years	+	0.08	5	3	5	3
3	Durability	years	+	0.09	25	30	30	25
4	Pay-back period	years	-	0.1	2.7	2.9	3.2	3.1
5	Duration of works	days	-	0.05	10	12	15	12
6	Reliability	Category	+	0.08	1	1	1	1

Results of multiple criteria evaluation of the heating system's alternatives



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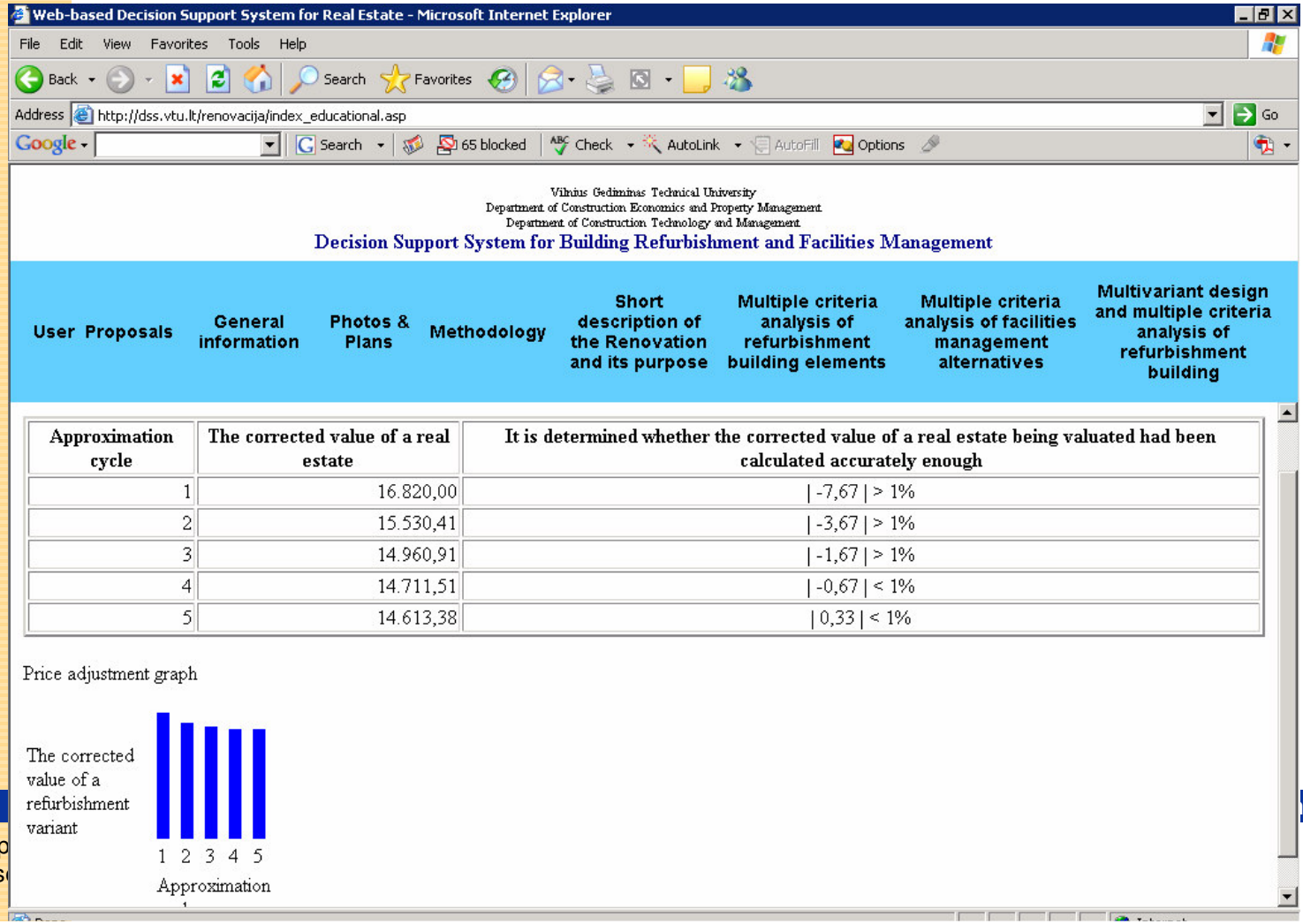
Decision Support System for Building Refurbishment and Facilities Management

User | General information | Photos & Plans | Methodology | Short description of the Renovation and its purpose | Multiple criteria analysis of refurbishment building elements | Multiple criteria analysis of facilities management alternatives | Multivariant design and multiple criteria analysis of refurbishment building

No.	Criteria under evaluation	Measuring units of criteria	*	Weights of criteria	Veskonas	Manfula	Vilpra	Vėsa
1	Price	Lt	-	0,6000	0,1356	0,1468	0,1607	0,1568
2	Guarantee period	years	+	0,0800	0,0250	0,0150	0,0250	0,0150
3	Durability	years	+	0,0900	0,0205	0,0245	0,0245	0,0205
4	Pay-back period	years	-	0,1000	0,0227	0,0244	0,0269	0,0261
5	Duration of works	days	-	0,0500	0,0102	0,0122	0,0153	0,0122
6	Reliability	Category	+	0,0800	0,0200	0,0200	0,0200	0,0200
Total sum of maximizing normalized balanced rates S_{+j}					0.0655	0.0595	0.0695	0.0555
Total sum of minimizing normalized balanced rates S_{-j}					0.1685	0.1834	0.2029	0.1951
Object's significance Q_j					0.2731	0.2502	0.2419	0.2348
Object's utility degree N_j					100%	92%	89%	86%
Object's priority					1	2	3	4
Supply price					14.550,00	15.750,00	17.240,00	16.820,00
Market price					14.550,00	15.750,00	15.951,61	14.613,38

Calculation of the market value in numerical and graphic form



Example - The initial data for multiple criteria analysis of thermal renovation of walls

	The criteria considered	*	Measu-ring units	Signifi-cance	Numerical values of criteria of the compared 1 sqm wall versions					
					1	2	3	...	10	11
1	Cost	-1	Lt/sqm	0.3550	160	175	360	...	158	101
2	Annual fuel economy	1	Lt/sqm	0.1630	5.75	5.97	5.97	...	5.54	5.87
3	Tentative pay-back time	-1	Years	0.2069	10.2	10.3	17.4	...	10.3	6.9
4	Harmfulness to health	1	Points	0.0245	6.0	8.0	9.0	...	9.0	8.0
5	Aesthetics	1	Points	0.0350	5.0	6.0	8.0	...	9.0	6.0
6	Maintenance properties	1	Points	0.0342	6.4	7.4	8.2	...	5.8	6.6
7	Functionality	1	Points	0.0220	1.0	1.0	1.0	...	1.0	1.0
8	Comfortability	1	Points	0.0948	7.0	7.0	10.0	...	7.0	5.0
9	Sound insulation	1	Points	0.0215	7.0	8.0	10.0	...	7.0	7.0
10	Longevity	1	Years	0.0875	20.0	25.0	25.0	...	25.0	20.0

Example - The multiple criteria analysis of wall versions

STV

THE KNOWLEDGE BASE OF THERMAL RENOVATION OF WALLS

THE KNOWLEDGE BASE OF THERMAL RENOVATION OF ROOF

THE KNOWLEDGE BASE OF THERMAL RENOVATION OF BASEMENT

THE KNOWLEDGE BASE OF THERMAL RENOVATION OF WINDOWS

THE MULTIPLE CRITERIA ANALYSIS OF WALL VERSIONS

Number of versions	WEIGHT OF VERSIONS	Priority of versions	Utility degree of versions, %	*	Negotiated cost of versions, Lt/sqm
1	0.078690	8	75.589	5.758	169.21
2	0.080445	6	77.275	9.183	191.07
3	0.068570	11	65.868	-2.096	352.46
4	0.079965	7	76.814	-1.150	187.82
5	0.090381	3	86.819	8.855	131.72
6	0.070195	10	67.429	-10.535	286.29
7	0.070448	9	67.672	-10.292	260.15
8	0.104103	1	100.00	22.037	134.24
9	0.086524	4	83.114	5.151	129.34
10	0.082299	5	79.056	1.092	159.73
11	0.098557	2	94.672	16.709	117.88

Example - Three best versions of solutions under consideration

THE KNOWLEDGE BASE OF THERMAL RENOVATION OF WALLS
THE KNOWLEDGE BASE OF THERMAL RENOVATION OF ROOF
THE KNOWLEDGE BASE OF THERMAL RENOVATION OF BASEMENT
THE KNOWLEDGE BASE OF THERMAL RENOVATION OF WINDOWS
THREE BEST VERSIONS OF SOLUTIONS UNDER CONSIDERATION

THREE BEST VERSIONS OF SOLUTIONS UNDER CONSIDERATION

The solutions considered		WEIGHT OF SOLUTIONS	The numeration of versions		
Thermal renovation of	roof	0.12350	6	4	5
	walls	0.23640	8	11	5
	basement	0.14560	1	2	5
	windows	0.10950	10	2	1
Planimetric and volumetric changes		0.00655	2	1	4
The improvement of architectural apearance		0.00332	3	5	2
The elimination of physical deterioration		0.02530	1	4	2
Priority of versions			1	2	3

Computer-aided formation of versions of building refurbishment

STV

THE KNOWLEDGE BASE OF THERMAL RENOVATION OF WALLS

THE KNOWLEDGE BASE OF THERMAL RENOVATION OF ROOF

THE KNOWLEDGE BASE OF THERMAL RENOVATION OF BASEMENT

THE KNOWLEDGE BASE OF THERMAL RENOVATION OF WINDOWS

THREE BEST VERSIONS OF SOLUTIONS UNDER CONSIDERATION

The formation of versions of building refurbishment

		The solutions considered	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Thermal	roof	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
2	renovation	walls	8	8	8	8	8	8	8	8	8	8	8	8	8	8	5	5
3	of	basement	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4		windows	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
5	Planimetric and volumetric changes		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	The improvement of architectural appearance		6	6	6	6	3	3	3	3	5	5	5	5	2	2	2	2
7	The elimination of physical deterioration		5	1	4	2	5	1	4	2	5	1	4	2	5	1	4	2

Fragment of formation of complex building refurbishment versions

		The criteria considered	*	Measu-ring units	Signifi-cance	Numerical values of criteria of the compared building refurbishment versions								
						1	…	65	…	129	…	193	…	
1	Cost		-1	Lt/sqm	0.3900	369	...	214	...	230	...	352	. . .	
2	Annual fuel economy		1	1000 Lt	0.0650	13.2	...	13.5	...	13.8	...	13.1	. . .	
3	Tentative pay-back time		-1	Years	0.0662	17.2	...	15.5	...	15.6	...	16.5	. . .	
4	Harmfulness to health		1	Points	0.0145	6.25	...	6.5	...	6.5	...	7	. . .	
5	Aesthetics		1	Points	0.0680	7.5	...	6.3	...	6.3	...	7	. . .	
6	Maintenance properties		1	Points	0.0442	8.65	...	7.9	...	7.9	...	8.15	. . .	
7	Longevity		1	Points	0.0875	20	...	20	...	20	...	15	. . .	
8	Sound insulation		1	Points	0.0536	8	...	7	...	7	...	8	. . .	
9	Comfortability		1	Points	0.0948	9	...	7	...	8	...	8.5	. . .	
10	Plannability and volumetric changes		1	Points	0.0510	1	...	1	...	1	...	1	. . .	
11	The elimination of physical deterioration		1	Points	0.0522	4	...	4	...	4	...	4	. . .	

Example - Selection of the most efficient alternatives of the building refurbishment

STV

- THE KNOWLEDGE BASE OF THERMAL RENOVATION OF WALLS
- THE KNOWLEDGE BASE OF THERMAL RENOVATION OF ROOF
- THE KNOWLEDGE BASE OF THERMAL RENOVATION OF BASEMENT
- THE KNOWLEDGE BASE OF THERMAL RENOVATION OF WINDOWS
- THREE BEST VERSIONS OF SOLUTIONS UNDER CONSIDERATION

Selection of the most efficient alternatives of the building refurbishment

Priority	Numeration	Total weight	Total utility degree
1	1	61.50	100.00
2	1729	61.42	99.87
3	3457	61.27	99.63
4	193	61.13	99.40
5	1921	61.05	99.27
6	3713	60.90	99.02
7	577	60.48	98.36
8	2305	60.41	98.23
9	65	60.33	98.10
10	4033	60.26	97.98
11	1793	60.25	97.97

Negotiation - Business Benefits

- Development and evaluation of unlimited number solutions.
- Common data and knowledge bases of best practices.
- Negotiators can use intelligent sub-systems for resolve disputes, agree upon courses of action, bargain for individual or collective advantage, and attempt to craft outcomes which serve their mutual interests.
- Negotiations can be performed in different places and time.
- Reduction in meeting time as compared with equivalent conventional meetings.
- More open and fuller alternatives analysis based on the use of anonymous input where appropriate.
- e-Support for different optimization criteria.

The presented System for Building Refurbishment enables to form up to 100,000 of alternative versions. This system allows to determine weak and strong points of each building refurbishment project and its constituent parts and provide negotiation facilities. Calculations are made to find out by what degree one version is better than the other and reasons are disclosed why it is so. Landmarks are set for efficiency increase of project versions. All this is done argumentatively, basing oneself on indexes under investigation, as well as on their values and weights.

Practical application of System to the VGTU main university building


At the moment the windows in VGTU are replaced. Total cost of windows replacement is 106 501 €.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Alternative windows of 5 companies according to 16 indicators were analyzed:

- Price
- Mechanical strength and stiffness
- Reliability
- Thermal transmittance Up of profile
- Thermal transmittance Uw of double glazing unit
- Emission ability of low emissive glass coating ε
- Parameter *Rw* of air sound isolation
- Air leakage, when pressure difference *Dp* = 50 Pa
- Waterproof-ness
- Guarantee period
- Longevity
- Light transmission of double glazing unit
- Pay-back period
- Duration of works
- Quantity of windows with two opening positions (horizontal and vertical) (in percent of the area of all windows)
- Quantity of windows with closing infiltration air vent or the third opening position (in percent of the area of all windows

At the moment the side doors of VGTU main building are changed

Currently the glass partitions off are changed in the corridors

At the moment the convector heaters are also changed in lobbies

Energy saving measure/investment	Area [m²]	Total costs [€]	Current situation
Insulation of facades	2425	105.350	The project is under preparation. The works are planned to be done from 2005 06 01 to 2005 09 01
Windows	1000	144.800	Changed for 106501 €
Roof	1306	17.020	The works are planned to be made from 2005 08 01 to 2005 09 01
Change of side entrance door	25	6.150	Changed
Renovation of the thermal unit		3.650	The renovation is foreseen to take place from 2005 01 01 to 2005 02 01
Heating system		185.030	Convector heaters in lobbies are being changed, the project under preparation. The works will be done from 2005 06 01 to 2005 10 01.
Total €		462.000	