DEVELOPING MULTI-CRITERIA MODEL FOR THE PROTECTION OF CULTURAL BUILT HERITAGE IN SERBIA FROM THE ASPECT OF ENERGY RECOVERY OF THE BUILDINGS

ANA STANOJEVIĆ
DUŠAN MILOŠEVIĆ
LJILJANA JEVREMOVIĆ
MIMICA MILOŠEVIĆ
BRANKO TURNŠEK

ANA STANOJEVIĆ
PhD student, Scholarship holder of Ministry of Education, Science and Tech. Advances, Faculty of Civil Engineering and Architecture, University of Nis, Serbia, stanojevicana1991@gmail.com

MIMICA MILOŠEVIĆ
PhD, Associate Professor, Faculty of Business Economics and Entrepreneurship, University of Belgrade, Serbia, mimica.milosevic@gmail.com

DUŠAN MILOŠEVIĆ
PhD, Full Professor, Faculty of Electronic Engineering, University, of Nis, Serbia, dusan.milosevic@elfak.ni.ac.rs

BRANKO AJ TURNŠEK
PhD, Associate Professor, Faculty of Civil Engineering and Architecture, University of Nis, Serbia, ajbranko@yahoo.com

LJILJANA JEVREMOVIĆ
PhD candidate, Teaching Assistant, Faculty of Civil Engineering and Architecture, University of Nis, Serbia, jevremovicljiljana@gmail.com

Introduction

- Sustainability represents an unavoidable segment of contemporary research paradigms, and recognized backbone of social development;
- Sustainable model of urban development - formation of an efficient urban entity that rationally uses all available resources without compromising the people' quality of life, the integrity of the environment while promoting the prosperity of society;
- Urban areas are directly responsible for as much as 80% of carbon dioxide emissions into the atmosphere and 75% of total energy consumption;
- Therefore, energy management in urban areas is extremely important;
- The greatest savings of energy resources, as well as financial expenditures, are achieved through energy recovery of an existing building stock;

Introduction

- The preservation of the built heritage is carried out through the application of the principles of revitalization, which sometimes also involves the re-use of these buildings;
- In the process of protection of cultural heritage, it is necessary to carry out energy revitalization of the buildings;
- Some buildings are recognized as significant bearers of cultural and historical heritage and are put under the protection regime;
- In the process of deciding the measures to be implemented to improve their energy performances, it is necessary to consider the requirements that the different degrees of building protection set;

Introduction

- The paper deals with the problem of multi-criteria decision making in the process of energy recovery of built heritage under protection in Serbia;
- Taking into account the criteria for improving energy efficiency, the paper aims to, using the AHP method, point out the most significant measures that need to be applied in the process of energy recovery of buildings;
- The methodological framework:

· review of requirements according to a different degree of protection;

· adopting the indicators for improving the energy efficiency;

· identification of priority indicators concerning each of the categories of cultural monuments.

1. Categorization of cultural heritage in Serbia

- Cultural heritage consists of cultural properties, which are defined as immovable and movable;
- Immovable cultural properties include cultural monuments (including architectural buildings of particular cultural and historical importance), spacious cultural and historical entities, archeological sites and landmarks;
- Depending on the significance, the immovable cultural properties fall into the category of cultural monuments, cultural monuments of great importance and cultural monuments of exceptional importance;
- The categorization of cultural properties implies the appropriate requirements that each of them set, which must be respected in the process of rehabilitation, reconstruction, and revitalization;

1. Categorization of cultural heritage in Serbia

I Cultural monuments of exceptional importance	II Cultural monuments of great importance	III Cultural monuments
alteration of the original form, nor any intervention such as upgrading is not allowed	alteration of the original form, nor any intervention such as upgrading is not allowed	limited interventions such as upgrades that do not greatly impair the original form are allowed
alteration of facades, facade articulation, and materialization is not allowed	alteration of facades, facade articulation, and materialisation is not allowed	alteration of facades and facade articulation is not allowed
alteration of the form, appearance and materialization of the roof is not allowed	alteration of materialization and partial appearance of the roof is permitted	alteration of façade and roof materialization is allowed while maintaining the original appearance of the façades
internal reorganization of the premises is not allowed	internal reorganization of the premises is not allowed	partial internal reorganization of the premises is permitted
modification of the openings is only allowed in the context of changing the glass and restoring the joinery	modification of the openings is only allowed in the context of changing the glass and restoring the joinery	modification of the openings is only allowed in the context of changing the glass and restoring the joinery
interventions on the interior structures are limited to enhancing stability and thermal characteristics if they do not impair the original appearance and the interior façade covering	all internal interventions on structures are allowed, both in terms of stability improvement and material change and thermal performance improvement	all internal interventions on structures are allowed, both in terms of stability improvement and material change and thermal performance improvement

2. Indicators for improvement of energy efficiency

A - thermal and energy properties of technical systems

- A_1 - Improvement of technical systems;
- A_2 - Implementation of RES;

B - thermal properties of the envelope and internal structure of the building

- B_1 - thermal zoning;
- B_2 - improvement of thermal envelope;
- B_3 - improvement of thermal properties of interior;

2. Indicators for improvement of energy efficiency

A_1 - improvement of technical systems

- A_{11} - Installation of valves for thermoregulation;
- A_{12} - Use of a chimney for the ventilation;
- A_{13}- Automatization of all technical systems;
- A_{14}- Regulation of water consumption;
- A_{15}- Changing the type of energy source ;
- A_{16}- Use of energy-efficient lighting and home appliance;

2. Indicators for improvement of energy efficiency

A_2 – implementation of RES

- A_{21} - Use of solar energy roof panels;
- A_{22} - Use of geothermal energy for heating and cooling;
- A_{23}- Use of biomass for heating;
- A_{24}- Use of wind energy;

B_1 - thermal zoning

- B_{11} - Linear and vertical thermal zoning;
- B_{12} - Concentrated zoning;

2. Indicators for improvement of energy efficiency

B_2 - improvement of thermal envelope

- B_{21} - thermal insulation of facade walls;
- B_{22} - thermal insulation of the roof;
- B_{23}- Changing the glass of facade openings;
- B_{24}- The sealability of joinery;
- B_{25}- Introduction of double facades and green-houses;
- B_{26}- Use of modern energy-efficient facade mate-rials ;
- B_{27}- Introduction of a sun protection system;
- B_{28}- Introducing greenery on the roof and facade;

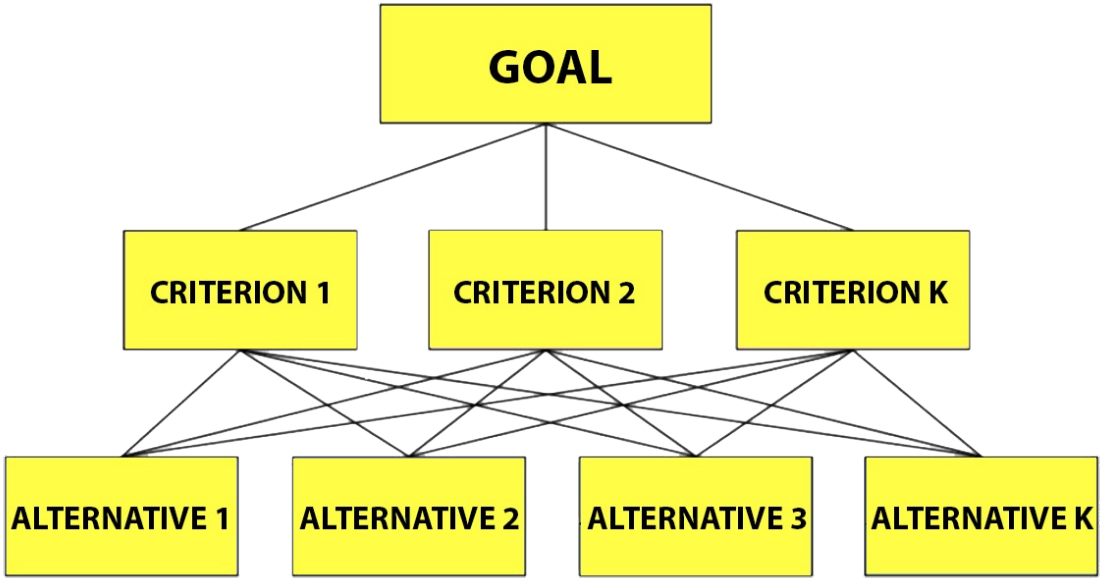
2. Indicators for improvement of energy efficiency

B_3 - improvement of thermal properties of interior

- B_{31} - Internal thermal insulation of walls, ceilings, and floors;
- B_{32} - Use of interior walls with collector function-Tromb wall;
- B_{33}- Introduction of floor heat storage;

Metodology – AHP method

- Analytical Hierarchical Processes method is a multi-criteria technique based on the interpretation of a complex problem through a hierarchy, so that the goal is at the top, while the criteria, sub-criteria and alternatives are at lower levels:



Metodology – the AHP method

- The process of applying AHP method has five stages:

1. Structuring the problem
2. Collecting data and forming a pairwise comparison matrix
3. Determination of relative weights
4. Assessment of relative weights
5. Determining the solution to the problem

Metodology – AHP method

- Any comparison of the two elements of the hierarchy is made using the Satty's scale:

Importance	Definition	Explanation
1	Same meaning	The two elements are of identical importance concerning the goal
3	Weak dominance	Experimental or reasoning slightly favor one element over another
5	Strong dominance	Experimental or reasoning significantly favors one element over another
7	Demonstrated dominance	The dominance of one element confirmed in practice
9	Absolute dominance	Highest degree dominance
2,4,6,8	Intermediates	Needs compromise or further division

- Following this ranking method, the decision-maker will assign weights to each pair individually as a measure of how much one criterion is more important than the other

Metodology – AHP method

- Monitoring the consistency by using the indexes:

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad CR = \frac{CI}{RI}$$

- λ_{max} - the maximum eigenvalue of a matrix; RI - a random index; CR - ratio of the consistency; CI - index of consistency; n - the dimension of comparison matrix;

Results

Weight coefficients for the two main criterion groups A and B

	I (Wc)	II (Wc)	III (Wc)
Technical systems (A)	0.5000	0.3333	0.3333
Thermal performances (B)	0.5000	0.6667	0.6667

Weight coefficients for the sub-criterion group technical systems (A)

	I (Wsc)	II (Wsc)	III (Wsc)
Technical systems improvement (A_1)	0.8333	0.7500	0.6667
Implementation of RES (A_2)	0.1667	0.2500	0.3333

Weight coefficients for the sub-criterion group thermal properties (B)

	I (Wsc)	II (Wsc)	III (Wsc)
Thermal zoning (B_1)	0.0719	0.0973	0.1219
Improvement of thermal envelope (B_2)	0.2789	0.3331	0.5584
Thermal improvement of interior (B_3)	0.6491	0.5695	0.3196

Results

Weight coefficients for the sub-criterion group technical systems improvement (A1)

	I (Wssc)	II (Wssc)	III (Wssc)
Thermoregulation valves and isolation of hot water pipes (A_{11})	0.3462	0.3399	0.3274
Use of a chimney for ventilation (A_{12})	0.2099	0.2025	0.1883
Automatizaton of all technical systems (A_{13})	0.1273	0.2025	0.1883
Regulation of water consumption (A_{14})	0.2099	0.1173	0.0987
Changing the type of energy source (A_{15})	0.0533	0.0689	0.0987
Use of energy-efficient lighting and home aplicance (A_{16})	0.0533	0.0689	0.0987

Results

Weight coefficients for the sub-criterion implementation of RES (A2)

	I (Wssc)	II (Wssc)	III (Wssc)
Use of solar energy roof panels (A_{21})	0.1352	0.4948	0.4729
Use of geothermal energy for heating and cooling (A_{22})	0.1352	0.1336	0.1699
Use of biomass for heating (A_{23})	0.6729	0.3102	0.2844
Use of wind energy (A_{24})	0.0565	0.0614	0.0729

Weight coefficients for the sub-criterion thermal zoning (B1)

	I (Wssc)	II (Wssc)	III (Wssc)
Linear and vertical thermal zoning (B_{11})	0.1250	0.2500	0.3333
Concentrated zoning (B_{12})	0.8750	0.7500	0.6667

Results

Weight coefficients for the sub-criterion improvement of thermal envelope (B2)

	I (Wssc)	II (Wssc)	III (Wssc)
Thermal insulation of facade walls (B_{21})	0.1324	0.1995	0.1913
Thermal insulation of the roof (B_{22})	0.3562	0.3029	0.2957
Changing the glass of facade openings (B_{23})	0.2571	0.1995	0.1913
Sealability of joinery (B_{24})	0.0242	0.0432	0.0339
Introduction of double facades and greenhouses (B_{25})	0.0242	0.0289	0.0339
Use of modern energy-efficent facade materials (B_{26})	0.1324	0.1327	0.1224
Introduction of a sun protection system (B_{27})	0.0367	0.0289	0.0518
Introducing greenery on the roof and façade (B_{28})	0.0367	0.0645	0.0796

Results

Weight coefficients for the sub-criterion thermal improvement of the interior (B3)

	I (Wssc)	II (Wssc)	III (Wssc)
Internal thermal insulation of walls, ceilings, and floors (B_{31})	0.5584	0.5396	0.5396
Use of interior walls with collector function-Tromb wall (B_{32})	0.3196	0.2970	0.2970
Introduction of floor heat storage (B_{33})	0.1219	0.1634	0.1634

Conclusion

- In the process of energy recovery of cultural monuments as part of built heritage, the limitations imposed by the regime of protection should be taken into consideration;
- These limitations in the energy recovery process are a prerequisite for selecting appropriate measures to improve the energy efficiency of the buildings;
- Research indicates that the proposed method can be successfully applied in the decision-making process related to energy recovery and reconstruction of the existing architectural buildings of cultural and historical value that are under the regime of protection.

Conclusion

Rank	Indicator name	I (W)	II (W)	III (W)
1.	Internal thermal insulation of walls, ceilings, and floors (B_{31})	0.18124	0.20489	0.11498
2.	Thermoregulation valves and isolation of hot water pipes (A_{11})	0.14427	0.08497	0.07275
3.	Use of interior walls with collector function-Tromb wall (B_{32})	0.10373	0.11275	0.06328
4.	Use of a chimney for ventilation (A_{12})	0.08748	0.05062	0.04184
5.	Regulation of water consumption (A_{14})	0.08748	0.02933	0.02193
6.	Use of biomass for heating (A_{23})	0.05608	0.02585	0.03160
7.	Automatizaton of all technical systems (A_{13})	0.05304	0.05062	0.04184
8.	Thermal insulation of the roof (B_{22})	0.04968	0.06726	0.11010
9.	Introduction of floor heat storage (B_{33})	0.03958	0.06205	0.03482
10.	Changing the glass of facade openings (B_{23})	0.03586	0.04429	0.07122
11.	Concentrated zoning (B_{12})	0.03147	0.04870	0.05420
12.	Changing the type of energy source (A_{15})	0.02220	0.01723	0.02193
13.	Use of energy-efficient lighting and home aplicance (A_{16})	0.02220	0.01723	0.02193

Conclusion

Rank	Indicator name	I (W)	II (W)	III (W)
14.	Thermal insulation of facade walls (B_{21})	0.01847	0.04429	0.07122
15.	Use of modern energy-efficent facade materials (B_{26})	0.01847	0.02946	0.04556
16.	Use of solar energy roof panels (A_{21})	0.01127	0.04123	0.05254
17.	Use of geothermal energy for heating and cooling (A_{22})	0.01127	0.01113	0.01888
18.	Introduction of a sun protection system (B_{27})	0.00512	0.00642	0.01930
19.	Introducing greenery on the roof and façade (B_{28})	0.00512	0.01431	0.02964
20.	Use of wind energy (A_{24})	0.00471	0.00512	0.00810
21.	Linear and vertical thermal zoning (B_{11})	0.00450	0.01623	0.02710
22.	Sealability of joinery (B_{24})	0.00338	0.00959	0.01263
23.	Introduction of double facades and greenhouses (B_{25})	0.00338	0.00642	0.01263

Thank you for your attetion!