BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 65 (69), Numărul 2, 2019
Secția
CONSTRUCȚII. ARHITECTURĂ

THE PERFORMANCE OF RESIDENTIAL BUILDINGS

BY

BOGDAN CHIRILĂ* and ION ŞERBĂNOIU

Technical University “Gh. Asachi” of Iasi,
Faculty of Civil Engineering and Building Services

Received: April 10, 2019
Accepted for publication: May 20, 2019

Abstract. The evaluation act in the process of performance measurement and comparison with predefined performance criterion leads to conclusions on how efficient a construction is. The performance of residential buildings is the result of performance criterion that quantifies users' demands. The characterization of buildings only seismically and energetically is incomplete, so that for defining the performance of buildings it is necessary to quantify all the criteria that define its performance and the grading of buildings in performance classes. Classification of residential buildings is required in all phases defining the rehabilitation process.

Keywords: requirements; users; criteria; post utilisation; rehabilitation.

1. Introduction

The evaluation act in the process of performance measurement and comparison with predefined performance criteria leads to conclusions about how efficient a construction is Wolfgang Preiser *et al*., (1995). The recommendations, corroborated with the related assessments, are used as a

*Corresponding author: *e-mail:* chirila_bogdan2006@yahoo.com

response and directions for further development in the performance of similar buildings (Fig. 1) (Hoblea, 2015).

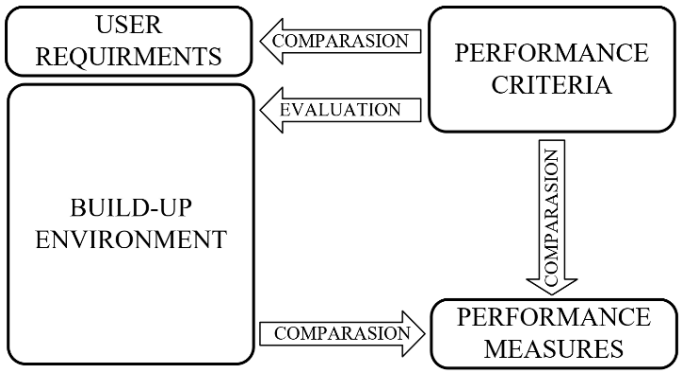

Fig. 1 − The primary scheme of the concept of performance in construction.

2. Performance Evaluation of Residential Buildings

The purpose of performance is to set performance requirements to meet user requirements during the lifetime of buildings.

Performance features are:

• Identifying the exigent requirements of building users;

• Transforming requirements into performance;

• Establishing quantitative performance criteria;

• Elaborating evaluation – testing methods for verification of performance criteria.

In order to present the complex system that defines the performance concept of a residential building, we propose a matrix system for establishing the relationship between the exigent requirements of the residential building users and the legislative requirements, performance indicators and performance criteria presented in Fig. 2.

For the rehabilitation of residential buildings, performance is evaluated through calculation methods, numerical simulations and laboratory experiments, predominantly in the period of technical expertise, energy auditing and design, through experimental techniques and methods of querying user satisfaction during the period of use.

The main steps required for the performance analysis of existing buildings are presented in a logical diagram for explaining the existing, standardized, designed and realized performance evaluation stages (Fig. 3).

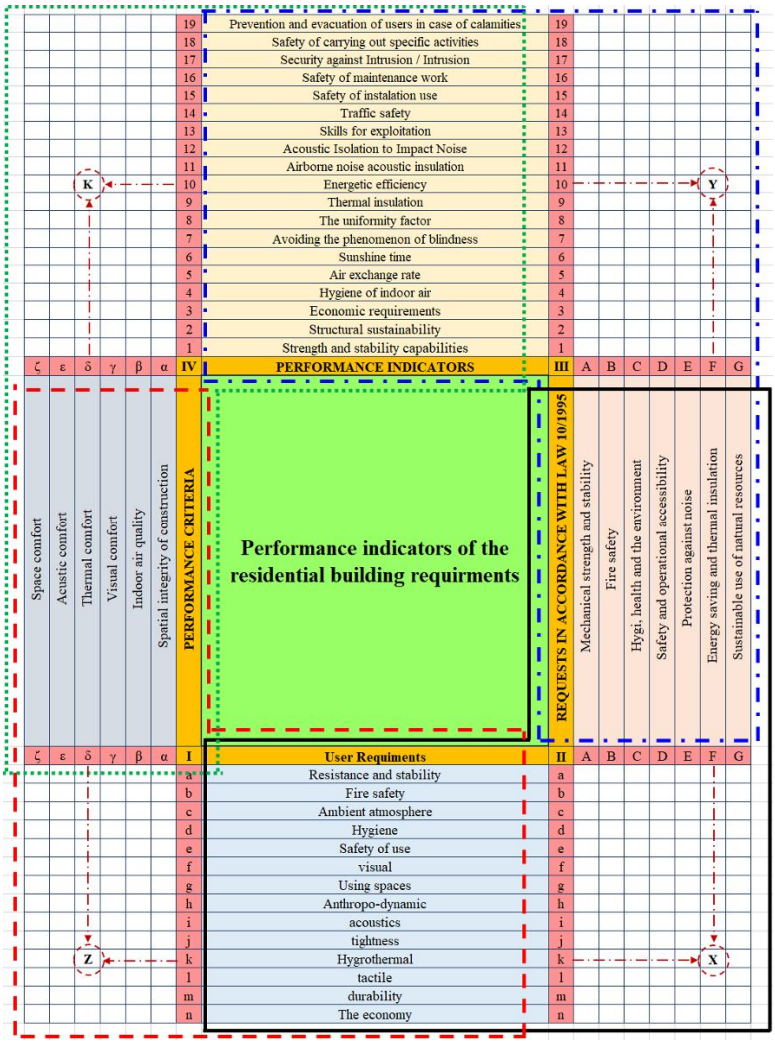

Fig. 2 − Matrix system for the settlement of relationships between residential building users' requirements and legislative requirements, performance indicators and performance criteria.

I. Matrix for determining performance requirements according to user requirements;

II. The matrix for determining the essential requirement according to Law 10/1995 according to the requirements of the user;

III. The matrix for determining the essential requirement according to Law 10/1995 depending on performance indicators;

IV. Matrix for setting performance indicators based on performance criteria.

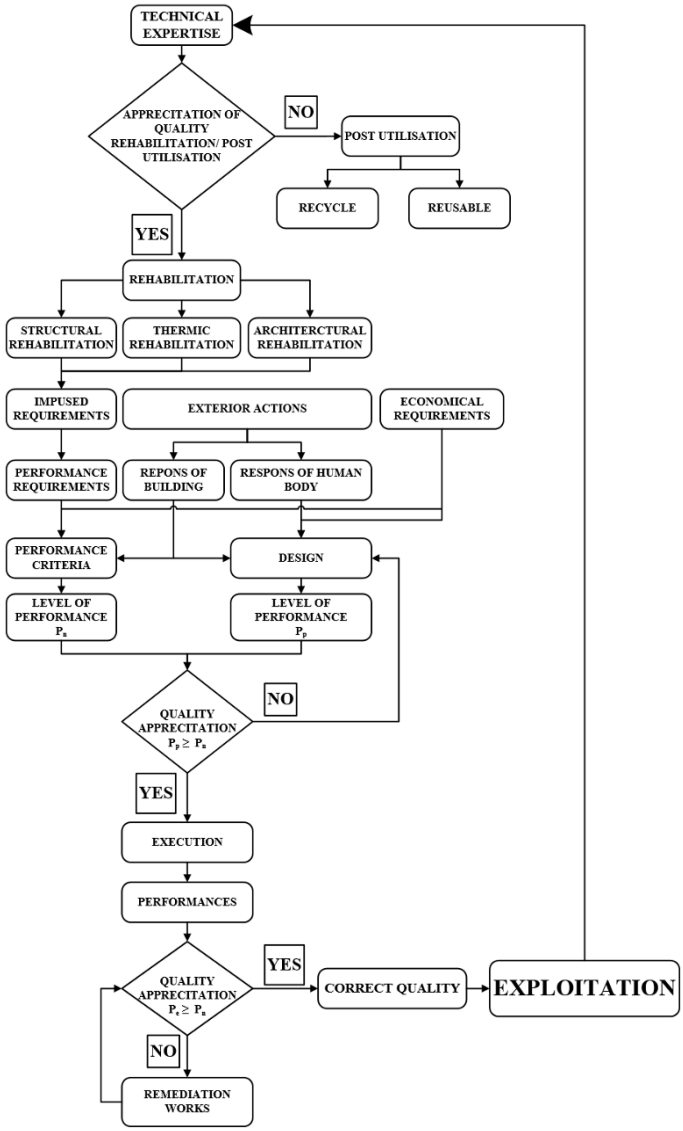

Fig. 3 − The logical scheme of the concept of performance in assessing the quality of existing residential buildings.

The performance conditions for each performance requirement involve clusters of performance indicators that need to be evaluated, designed, and verified after the completion of the rehabilitation work. Performance indicators for residential buildings are shown in Table 1.

Table 1

Calculation Table for Determining the Performance Levels of Residential Buildings Subject to Rehabilitation

PERFORMANCE CRITERIA		α	PERFORMANCE INDICATOR	β	EVALUATION					DESIGN					EXECUTION				
					p_n	p_e	$P_{ev\,i}$	$N_{ev\,i}$	N_{ev}	c_{pr}	p_{pr}	$P_{pr\,i}$	$N_{pr\,i}$	N_{pr}	c_c	p_c	$P_{c\,i}$	$N_{c\,i}$	N_C
SQ	SPATIAL COMFORT	*0.122*	SQ_a - Skills of exploitation	*0.130*															
			SQ_b - Traffic safety: pedestrian and mechanized transport (lifts)	*0.112*															
			SQ_c - Safety of installation use	*0.146*															
			SQ_d - Safety of maintenance work	*0.117*															
			SQ_e - Security against intrusion /burglary	*0.109*															
			SQ_f - Safety of carrying out specific activities	*0.171*															
			SQ_g - Protect and evacuate users in case of calamities	*0.216*															
IAQ	QUALITY OF INTERIOR AIR	*0.135*	ICQ_a - Hygiene of indoor air	*0.469*															
			ICQ_b - Exchange rate	*0.531*															
LQ	VISUAL COMFORT	*0.083*	LQ_a - Sunshine time	*0.475*															
			LQ_b - Avoiding the phenomenon of blindness	*0.256*															
			LQ_c - The uniformity factor	*0.269*															
EE	THERMIC COMFORT	*0.174*	EE_a - Thermal insulation	*0.484*															
			EE_b - Energetic efficiency	*0.516*															
A	ACUSTIC COMFORT	*0.102*	A_a - Airborne acoustic insulation	*0.544*															
			A_b - Acoustic isolation to impact noise	*0.456*															
BI	SPATIAL INTEGRITY OF THE CONSTRUCTION	*0.217*	BI_a - Structural sustainability	*0.444*															
			BI_b - Strength and stability	*0.556*															
C	FIRE SAFETY	*0.168*	C_a - Fire safety	*1.000*															

To determine the degree of satisfaction of performance indicators for residential building valuation, the following reports are proposed:

$$P_{\text{ev}} = \left(\frac{p_{\text{ev}}}{p_n} \right) \geq 1; \qquad P_{\text{pr}} = c_{\text{pr}} \cdot \left(\frac{p_{\text{pr}}}{p_n} \right) \geq 1; \qquad P_c = \left(\frac{p_c}{p_n} \right) \geq 1 \qquad (1)$$

where: P_{ev} is the verification report on satisfaction of exigencies at the building evaluation stage; P_{pr} – verification report on satisfaction of exigencies at the design stage of the rehabilitation works; P_c – verification report on satisfaction of exigencies after completion of the rehabilitation works; p_{pr} – the level of performance proposed in the design phase of the rehabilitation works; p_c – performance level after completion of rehabilitation work; p_n – the standardized performance level; c_{pr} – coefficient of increase of the level of performance above the minimum norms; cc – increase/decrease coefficient of performance level due to execution.

The values of these reports mark when the performance requirement has been met, an over unity report being defined as the achievement of this desideratum at the ideal level (Hoblea, 2015). Higher values imply higher costs, but in some cases for practical reasons, values equal to 1 cannot be obtained, and it is necessary to overcome them.

In order to assess the quality of a building, the concept of performance expressed in the report in Fig. 4 is used.

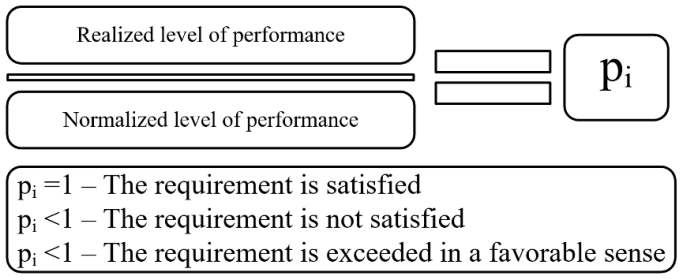

Fig. 3 − The logical scheme of the concept of performance in assessing the quality of existing residential buildings

To determine the degree of satisfaction of the performance criteria for residential buildings, the following reports are proposed:

$$N_{\text{ev},i} = \frac{\sum P_{\text{ev}} \beta_i}{\sum \beta_i} \cdot 100; \quad N_{\text{pr},i} = \frac{\sum P_{\text{pr}} \cdot \beta_i}{\sum \beta_i} \cdot 100; \quad N_{c,i} = \frac{\sum P_c \cdot \beta_i}{\sum \beta_i} \cdot 100, \quad (2)$$

where: $N_{ev,i}$ is the satisfaction verification report of the performance criterion for the building evaluation stage; $N_{pr,i}$ – the satisfaction verification report of the performance criterion for the design phase of the rehabilitation works; $N_{c,i}$ – the satisfaction report of the performance criterion after completing the rehabilitation works; β_i – coefficient representing the degree of importance of the performance indicator and expresses the proportion of each performance indicator.

In order to determine the performance level of the residential building, the following reports are proposed:

$$N_{ev} = \frac{\sum N_{ev} \cdot \alpha_i}{\sum \alpha_i}; \quad N_{pr} = \frac{\sum N_{pr,i} \cdot \alpha_i}{\sum \alpha_i}; \quad N_c = \frac{\sum N_c \cdot \alpha_i}{\sum \alpha_i}, \tag{3}$$

wher: $N_{ev,i}$ is the performance level verification report at the building evaluation stage; $N_{pr,i}$ – the performance level verification report at the design stage of the rehabilitation works; $N_{c,i}$ – the performance level verification report after the rehabilitation works; α_i – a coefficient representing the degree of importance of the performance criterion and expresses the proportion of each performance criterion;

The obtained score aims to compare possible rehabilitation options for optimizing performance and cost and can be used as the method of classifying the building into a performance class (Hoblea, 2015).

The correlation of the obtained values reveals an extremely complex system of analysis. The systemic approach is thus defining for the analysis of the whole process that takes place at the stages of the interrogation of the beneficiaries, the realization of the pre-feasibility and feasibility studies, the multidisciplinary conception, the actual realization after the finalization of the concept, the exploitation and post-use of the analyzed object, the construction itself, starting from the necessities, exigencies and requirements of the users, subsequently assessing the way it responds to the purpose originally stipulated and for which it has been realized under a functional, structural, informational and aesthetic aspect (Hoblea, 2015) from the point of view of the defining levels of a building.

3. Determination of Distribution Coefficients of Indicators and Performance Criteria for Determining the Performance Level of the Building

The study determined the value of the α coefficients for the distribution of the performance criteria within the building performance level and β for the

distribution of the performance indicators within the performance criteria. The values were determined with the help of a questionnaire completed by 20 persons involved in the rehabilitation of residential buildings.

Fig. 4 shows the share of performance criteria in determining the level of performance of dwelling buildings. It is noticed that the highest share is given by the performance criterion related to the spatial integrity of the construction and the lowest share is the visual comfort.

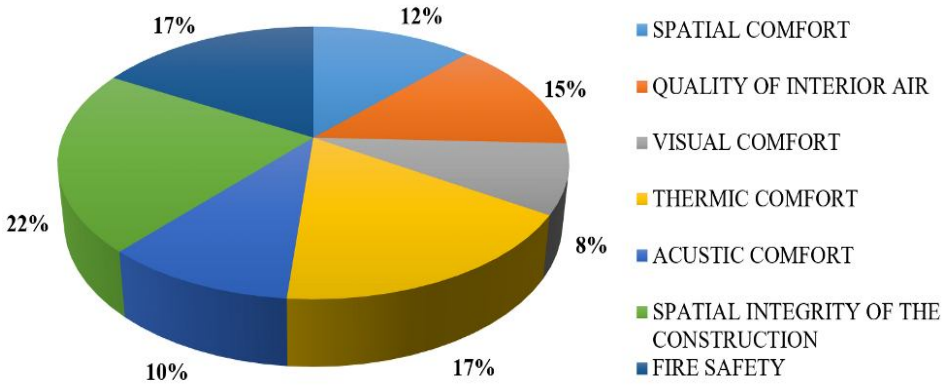

Fig. 4 − Coefficients for the distribution of performance criteria in determining the performance level of existing buildings.

Fig. 5 shows the proportion of the performance indicators in defining the spatial comfort performance criterion. It is noted that the highest share is given by the performance indicator related to the protection and evacuation of users in case of calamities and the lowest share is represented by the safety of the pedestrian traffic with mechanized means of transport.

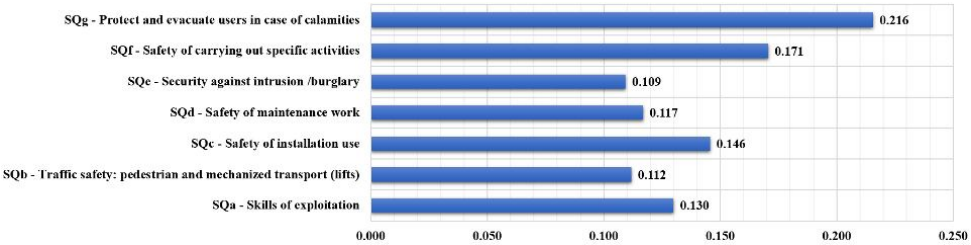

Fig. 5 − Coefficients of distribution of performance indicators within the performance criterion – spatial comfort.

Fig. 6 shows the proportion in which the performance indicators take part in defining the indoor air quality performance criterion. It is noticed that the highest share is given by the exchange rate performance indicator and the lowest share is represented by the hygiene of the indoor air.

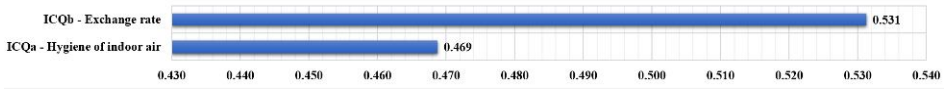

Fig. 6 − Distribution coefficients of performance indicators within the performance criterion – indoor air quality.

Fig. 7 shows the proportion in which the performance indicators take part in defining the visual comfort performance criterion. It is noticed that the highest share is given by the performance indicator related to the duration of sunshine and the lowest share is represented by the performance indicator for avoiding the blindness phenomenon.

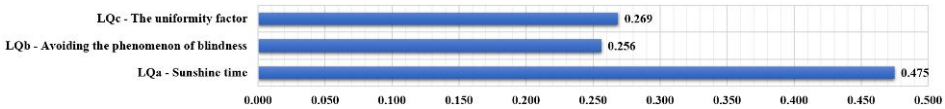

Fig. 7 − Coefficients of distribution of performance indicators within the performance criterion – visual comfort.

Fig. 8 shows the proportion in which the performance indicators take part in defining the thermal comfort performance criterion. It can be noticed that the highest share is given by the thermal efficiency performance indicator and the lowest share is represented by the thermal insulation performance indicator.

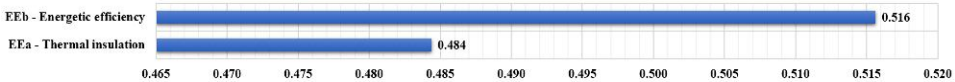

Fig. 8 − Coefficients of distribution of performance indicators within the performance criterion – thermal comfort.

Fig. 9 shows the proportion in which the performance indicators take part in defining the acoustic comfort performance criterion. It can be noticed that the highest share is given by the sound insulation performance indicator at the aerial noise and the lowest share is represented by the performance indicator for the acoustic insulation at impact noise.

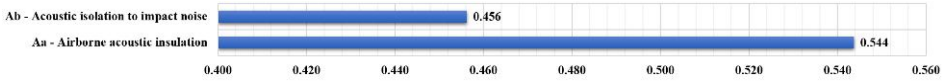

Fig. 9 − Coefficients of distribution of performance indicators within the performance criterion – acoustic comfort.

Fig. 10 shows the proportion in which the performance indicators take part in defining the spatial integrity performance criterion of the construction. It is noticed that the highest share is given by the performance indicator related to the resistance and stability capacity and the lowest share is represented by the performance indicator referring to the structural durability.

Fig. 10 − Coefficients of distribution of performance indicators within the performance criterion – the spatial integrity of the construction.

Fig. 11 shows the proportion in which the performance indicators take part in defining the fire safety performance criterion. The performance criterion is defined by a single indicator so it participates with the maximum value in defining the performance criterion.

Fig. 11 − Coefficients of distribution of performance indicators under the performance criterion – fire safety.

4. Classification of Buildings in Performance Classes

Rehabilitation of existing buildings involves the analysis of each performance indicator and the establishment of measures of setting equal or higher parameters than those normalized.

Following the determination of the performance level of existing N_i residential buildings through the above-mentioned algorithm, we propose a classification of residential buildings according to the performances of all indicators by classifying buildings into performance classes. The performance class is a rating that takes into account all the performance indicators provided in Table 2, and integrates the existing classifications, ie seismic risk class and energy class, by the indicators evaluated.

Table 2
Table for Classifying Buildings in Performance Classes

Building rating	N_i	Intervals N_i	Performance class
Red dot (Ex .: Very high risk of earthquake and exploitation collapse, buildings with extremely low energy efficiency, etc.)		0,...,25	
Red dot, (Ex .: earthquake risk, buildings with extremely low energy efficiency, etc.)		26-35	
One star (Eg: High earthquake vulnerability, buildings with low energy efficiency, etc.)		36-65	★
Two stars (Eg Moderate earthquake vulnerability, buildings with moderate energy efficiency, etc.)		66-90	★★★
Three stars (Eg: Reduced earthquake vulnerability, buildings with good energy efficiency, etc.)		91-100	★★★
Four stars (Eg: earthquake safe, buildings with very good energy efficiency etc.)		101 ÷110	★★★★
Five stars (Ex .: Very safe for the earthquake, buildings with very good and very rare energy efficiency, etc.)		> 111	★★★★★

5. Conclusions

The performance of residential buildings is the result of performance criterion that quantifies users' demands. The characterization of buildings only seismically and energetically is incomplete, so that for defining the performance of buildings it is necessary to quantify all the criteria that define its performance and the grading of buildings in performance classes.

Within the rehabilitation process it is necessary to fit the buildings into performance classes in the assessment phase, in the design phase of the rehabilitation works (by imposing a level of performance) and after completion of the execution. In this way, residential buildings can be built into performance classes, and the performance of a building can be appreciated.

REFERENCES

Şerbănoiu I., *Metode de organizare şi programare în construcţii*, Ed. Societăţii Academice „Matei – Teiu Botez”, Iaşi, 2009.

Ciornei A., *Cum concepem construcţiile civile,* Ed. Junimea, Bucureşti, 2000.
Hoblea A., *Managementul performanţelor totale în construcţii de locuinţe colective,* Ph.D. Diss., "Gh.Asachi" Technical University, Iaşi, 2015.

PERFORMANȚA CLĂDIRILOR REZIDENȚIALE

(Rezumat)

Actul de evaluare în cadrul procesului de măsurare a performanţelor şi comparare cu criterii de performanţă prestabilite conduce la concluzii despre cât de performantă este o construcţie. Performanta cladirilor rezidentiale este rezultanta performantelor criteriilor ce cuantifica exigentele utilizatorilor. Caracterizarea cladirilor doar din punct de vedere seismic si energetic este incompleta, astfel ca pentru definirea performantei cladirilor se impune cuantificarea tuturor criteriilor ce definesc performanta acesteia si incadrarea cladirilor in clase de performanta. Clasificarea cladirilor rezidentiale se impune in toate fazele ce definesc proceseul de reabilitare.