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Evaluation of Buildings in Real Conditions of Use as a Sustainability Criterion

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Abstract

The evaluation of buildings in real conditions of use, or post-occupancy evaluation, is the systematic study of buildings with the objective of determining their performance once they are inhabited; it is a process of review and identification of successes and failures in order to improve the conditions of existing buildings and to feed future designs. Nowadays, the construction industry in Colombia does not have feedback processes regarding the operation of a building. The research presented below proposes the HEPO post-occupancy assessment tool, which is oriented to the analysis of buildings in phase of use, in terms of meeting the needs of the inhabitants, the consumption of resources associated to the use, and the conservation of the qualities of the materials in time. In order to verify the effectiveness of the tool, this is validated in five collective height housing projects in the city of Medellín, Colombia.

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Keywords

Post-occupancy evaluation; Sustainability; Occupant satisfaction; Occupancy Comfort; Energy Consumption Conservation of qualities in time

1. Introduction

The construction sector has shortcomings in terms of the knowledge it has of the operation of the buildings. This is because it does not have feedback processes that allow to identify and evaluate the successes and failures of its product. At the moment, the improvement processes it possesses are focused on the construction phase, which is explained in the intention of perfecting the very same technique that constitutes the most obvious work of the industry, building. However, it is necessary that the implementation of strategies for continuous improvement might be extended to other phases, more precisely, to the time of use of the buildings, because by being the most extensive stage of the life of the buildings, it can provide important information for product improvement.

The most commonly used strategy to predict the behavior of a building is modeling. This strategy is intended, from the design phase, to simulate conditions of use to predict the consumption of resources, the effects of building exposure, sunning and ventilation, the quality of the indoor environment; the impact on these effects and on the resource consumption of the implementation of saving devices, passive technology, insulating materials; the behavior of materials over time; the adaptation of the different familiar conformations to the spatial structures offered, among other factors that affect the well-being and maintenance in time of the buildings and the answers that they offer to the housing needs in order to improve the conception of the projects. However, in spite of the

intended scope, the use of this tool is generally limited to the simulation of the consumption of hydric and electric resources, and, in some cases, the lighting and ventilation conditions of the spaces. Still, the models proposed for these simulations do not necessarily correspond to what is actually presented in the operational phase with several investigations finding substantial differences between the assumptions considered in the modeling and the actual behavior of the buildings (Olivia & Aidan, 2015), which, in some cases, in relation to the energy resource, are expressed in real consumption of more than three times the amount predicted in the modeling (Bordass, Cohen, & Field, 2004).

In many cases, poor performance in collective height housing projects is related to the lack of knowledge about the behavior in real conditions of use, generally due to shortcomings related to the satisfaction of the needs of end users (Leaman, Stevenson, & Bordass, 2010), as David Jiboye (2012) states: "The recurrent failure of housing projects is due to the lack of information and lessons learned from the perspective of end users." Another one of the shortcomings is given in terms of the conservation of the qualities in time since some buildings evidenced maintenance costs much higher than budgeted due to the rapid deterioration of the materials (Leaman et al., 2010); and finally, in terms of actual consumption since, as evidenced in the previous paragraph, there are investigations that demonstrate that the consumptions in phase of use are much higher than what was predicted in the design stage of the project. Likewise, the phase of use, by being the most widespread phase in time in the life cycle of buildings is a phase that has direct relation to the consumption of resources and generation of waste, being responsible for between 12% and 16% of the consumption of potable water in the world, between 30% and 40% of the consumption of global production energy, the generation of 40% of urban solid waste (BENITE, 2011; Singh, Amanjeet; Syal, Matt; Sue C; Korkmaz, 2010) and between 80% and 90% of the emissions generated in the construction industry (Maia Guzinski, 2011).

For all of the above, a post-occupancy evaluation (POE) can be a valuable tool that provides feedback to planners, designers, builders, and housing project managers because it allows to know how the project responds or not to the needs of the residents, their expectations, and from that, be a response to the problems arising from the relationship between a building and the experience that its users have (Wolfgang, 1995). It identifies the economic cost associated with the operation of the building and whether it is achievable and sustainable over time. Also, it allows to test the good use of the materials and the conservation of the qualities in time. Finally, it offers the option to determine the actual consumption of the buildings and with this, the option of developing strategies that allow to mitigate the impacts that the buildings cause to the environment.

Therefore, POE can be defined as:

"the systematic study of buildings with the objective of determining their performance once they are inhabited in a review process that allows to extract lessons from the identification and analysis of successes and failures, in order to improve the conditions of existing buildings and future feedback. " (Vásquez-Hernández, Alejandro; Restrepo Álvarez, Mario 2017)

In Colombia, there are no defined tools for the systematic study of buildings that allow to generate feedback for future projects or as a source of improvement for existing buildings. For the above, the following article presents the development of a tool for Post Occupancy Evaluation (HEPO) for buildings under real conditions of use, as well as the validation of the tool from its application in five residential complexes in the city of Medellín, Colombia.

2. Methodology

The objective of this research was the development of a post-occupancy evaluation tool (HEPO) in order to analyze the buildings under real conditions of use. For this, a bibliographic review of the systems of evaluation of buildings under real conditions of use was carried out. From the analysis of the systems developed and the case studies investigated, a first draft of the tool was elaborated to be discussed and improved through a panel of experts and pilot tests. Finally, the evaluation system (HEPO) was validated in five projects of collective height housing in the city of Medellín.

2.1. Development of the Evaluation Tool (HEPO)

As a starting point, the referential basis on what has marked the tendency in the evaluations of buildings in conditions of use at world level, and the study of the variables contemplated, the tools of survey of the used information and the types of post-occupancy evaluation are taken into account. The bibliographic review that was developed is based on the study of scientific articles that address post-occupancy assessment methodologies published in the last 15 years. The main sources for access to literary production for research were Scopus and Sciencedirect.

2.2. Validation of the Classification

Interviews were conducted with experts in order to discuss and improve the proposed tool. The expert panel consisted of architects, civil engineers, project managers, builders and building managers. The objective of the exercise was to gather the impressions and observations that the experts had regarding the content of the tool in function to the factors of evaluation as well as the way data was collected. For this, face-to-face interviews were conducted with each of the experts.

After verifying the relevance of the evaluation tool, a pilot test was carried out in order to verify the effectiveness of the evaluation tool. Thus, 20 interviews were conducted with people who lived in collective height housing in order to identify points or terms that could be confusing to the respondents, the average duration of implementation.

2.3. Validation with case studies

Collective height housing projects were selected because they are a typology of widespread use in contemporary cities as a response to the housing deficit as a function of the space deficit, being then understood as the most efficient technical and economic response to the mass consumption of the territory.

A sample of five projects was selected, not under parameters of statistical rigor, but based on the descriptive rigor established by the following: Temporality: projects with a minimum of 2 years of being inhabited; Socioeconomic stratum: it was sought to integrate the different strata in order to review differences in the application of the tool in diverse socioeconomic contexts; Typology of housing: with the objective of integrating social housing with a maximum cap on the sale price (VIP and VIS) and non-social housing: ie, it has no restriction on the maximum sale value, the above according to the denomination in the Colombian context; Links to the surrounding environment: closed and semi-closed projects were chosen; and, finally, the Structural system.

Table 1. Selected projects for the application of the HEPO tool

Project	Temporality (years)	Stratum				Housing typology			Links to the surrounding environment[1]		Structural system	
		2	3	4	5	VIP	VIS	No VIS	Closed	Semi-closed	Aparticated	solid wall
Ciudadela Verona	2	X				X			X			X
Condominio península	2-5		X			X			X			X
Urbanización los colores	10			X			X		X		X	
Faro del velódromo	4			X				X		X	X	

Continued on next page

Table 1 continued

Oasis de los Colores	3				X			X		X	X	
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Table 2. Methodology for the development of the HEPO

	Development of the evaluation tool (HEPO)		Validation of the classification		Validation based on case studies
Method	Literature review	Workshops	Interviews with experts	Pilot Test	Collection of real data (Study of 5 buildings in real conditions of use)
Objective	<ul style="list-style-type: none"> - Determine the factors of interest to be studied in the phase of use of the buildings. -Identify the strategies of the data collection. -Identify the types of POE in the covered articles. 	<ul style="list-style-type: none"> - Discuss the list of factors identified and determine which of them are relevant to be evaluated in our region. -Determine the data collection strategies. -Develop the perception survey, the investigator's tool and the monitoring mechanisms. 	<ul style="list-style-type: none"> - Feedback on the list of factors to be evaluated in a building. -Validate if the collection tools are suitable. 	<ul style="list-style-type: none"> - Test if the developed survey is clear and intuitive, and its development is easy and agile. -Detect unexpected problems with the application of the perception survey. 	<ul style="list-style-type: none"> - Validate the tool based on the actual results that shows the identification of successes and failures in buildings. -Feedback on the evaluation tool.

3. Post-occupancy Evaluation tool (HEPO)

3.1. Development of the tool proposed on the-The state of art-

In the literature review, it was found that evaluation factors of interest during the phase of use of buildings are 37, being the most studied: thermal control (Huber, Koch, & Busko, 2014; Marianne & Paddy, 2011; Voelker, Beckmann, Koehlmann, & Kornadt, 2013; Wilkinson, Reed, & Jailani, 2011; Xue, Mak, Cheung, & Chao, 2016; Zalejska-Jonsson, 2014)

(Huber, Koch, & Busko, 2014; Marianne & Paddy, 2011; Voelker, Beckmann, Koehlmann, & Kornadt, 2013; Wilkinson, Reed, & Jailani, 2011; Xue, Mak, Cheung, & Chao, 2016; Zalejska-Jonsson, 2014), acoustic control (Adewunmi, Yewande; Omirin, Modupe; Famuyiwa, 2012; Cubukcu & Isitan, 2011; Davis, 2011; Hassanain,

¹The way in which buildings are related to their environment often determines the appropriation of the place by the tenants as well as the citizens. Nowadays, the generalization in the designs of the buildings as private spaces that provide a barrier of contact with the outside is common, this being a reason why it is considered pertinent to evaluate the behavior of the projects that have a much more ample relation with the environment, and this is why the study of closed complexes (the existence of a natural or physical barrier that prevents the access of outsiders to the residential complex) and semi-closed complexes (designation of residential units with commercial areas in their first level) was considered of great importance.

2016; Mundo-hernández & Valerdi-nochebuena, 2015), lighting control (Bonde & Ramirez, 2015; Horgen, Sheridan, & Sheridan, 1996; Muhamad et al., 2015) and the quality of indoor air (Hassanain, 2016; Lee et al., 2012; Liang, Chen, Hwang, Shih, & Lo, 2014). The percentage of appearance of each aspect in the investigation is presented in Figure 1.

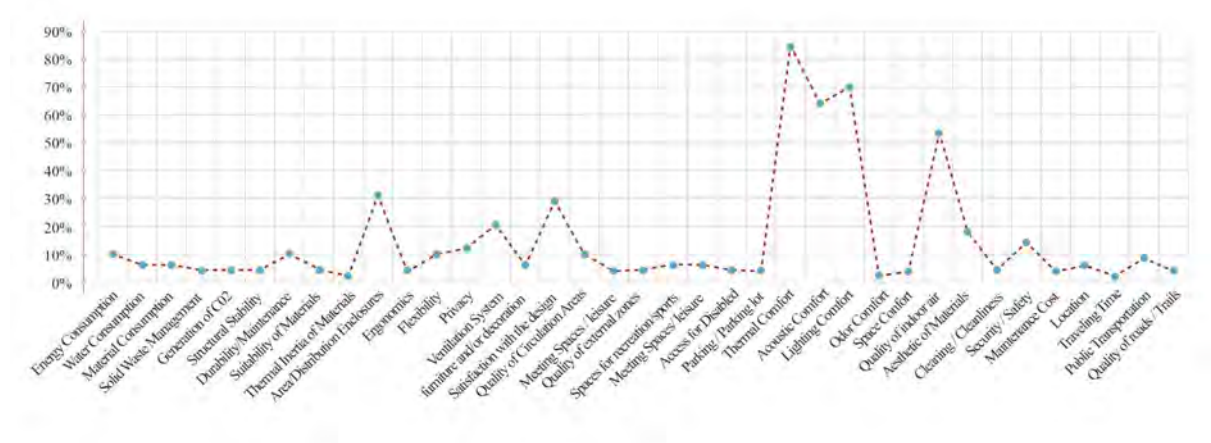


Figure 1. Study factors on buildings in conditions of use. **Source:** Vásquez-Hernández, Alejandro; Restrepo Álvarez, M. F. (2017). Evaluation of buildings in real conditions of use: Current Situation (Fig 1). Recovered from: Journal of Building Engineering.

In order to collect information on the operation of buildings under real conditions of use, the following tools are usually used: perception, through which the appreciation that the users have over the study factors is investigated, the application of questionnaires to inhabitants and users of buildings being the most frequently used tool (Yang, Santamouris, & Lee, 2016); monitoring, from which direct measurement of the study factors is susceptible to this procedure; and observation tools, in which the researcher obtains his own appreciations about the factors analyzed. Depending on the intention and object of post-occupancy research, the study factors discussed are analyzed within different levels of depth and rigor. Preiser (1995) and Turpin-Brooks (2006) identified three types of post-occupancy assessment that are directly related to the level of depth of the study: post-occupancy assessment of indication, research and diagnosis.

The post-occupancy assessment of indication is a superficial analysis that may include rapid assessment processes through surveys of the inhabitants of a building; the post-occupational assessment of research has an approach that is performed in more detail and depth than the previous one using interviews and questionnaires, and which is usually done in several buildings in order to determine a common pattern; and finally, the diagnosis has a rather broad orientation when considering a relationship between objective measurements made to the physical environment with the subjective responses of the occupants, which is the reason why surveys, monitoring and observations are carried out.

All the information collected about the state of the art of the existing post-occupancy tools was reported by the authors of this article in the review article *Evaluation of Building in real conditions of Use: Current Situation* (Vásquez-Hernández, Alejandro; Restrepo Álvarez, 2017)

After collecting information in the state of the art and the workshops, the following was identified as lines tending to be defined and limited in the process of development of the evaluation tool: scale of application of the tool, methods to be used to collect information and factors to be evaluated.

3.1.1. Scale of Assessment HEPO

Determining the functioning of a building requires the compression of the housing process, since housing is not only the space that is located from the entrance door to the rest of the places, but it is also those spaces beyond its private space, as is the case of corridors, amusement and meeting zones, both in the residential complex and its immediate surroundings. Therefore, it is necessary to analyze the different scales of a house, and these are the ones shown in Table 3.

Table 3. Scale of Assessment HEPO

Scale of Assessment	Scale Components
Private space	Enclosures that create the housing unit, such as: dining room, bedrooms, bathroom, etc.
Semiprivate space	Common areas within the same tower, such as corridors and stairs.
Semipublic space	Common spaces within the residential complex but outside of the towers, such as: parks, lobby, front desk, etc.
Public space	Immediate surroundings formed by roads, such as: public facilities, parks, among others.

3.1.2. Strategies for the collection of information

The purpose of the Post-Occupancy Evaluation Tool (HEPO) is to cover both objective and subjective aspects of building, interlinking the monitoring data with the perceptions that the inhabitants have about the spaces they inhabit. It is because of the above that three strategies that allow to collect the desired information of the building are proposed, and these are:

3.1.2.1. Occupant satisfaction survey

Determining the satisfaction of the occupants requires a subjective evaluation based on qualitative methods developed from the psychology and that allows to know the perception that the residents have about the space they inhabit. For that activity, the methodology of Likert was applied, a strategy that evaluates attitudes and opinions, and whose objective is to measure the degree to which an attitude or disposition of the respondents is given before a series of inquiries with the objective of measuring the satisfaction of the respondents. The survey applied in the research used 5 levels, where 1 is the negative adjective (Very unsatisfied) and 5 is the positive (Very satisfied).

3.1.2.2. Walkthrough

This instrument aims to investigate problems present in the buildings from a non-participating external perspective in order to have a neutral perception about the operation of the building and, thus, to give feedback on the evaluation study of the building from an outside view.

Tours are made through the housing complex with the purpose of identifying successes and failures in the operation of the building, for which the technique of photographic registration and observation notes was used, and in this way, justifying the perception obtained by the researcher. This strategy aims to perform objectively without the opinions, feelings and emotions influencing the study of the operation of the building, as well as capture messages or ideas that can be omitted, either voluntarily or involuntarily by users and residents.

3.1.2.3. Monitoring

The performance of the interior physical environment of a building influences the perception of comfort of its occupants. The level of physical comfort depends mainly on the following four factors: thermal conditions, lighting, indoor air quality (IAQ) and acoustics. Thus, by monitoring the temperature of the house and materials, noise level and illumination, it is sought to confront the perceptions that the users provide about these aspects. For the above,

data were taken from the houses at the time residents were approached with the perception survey; it was necessary to use the following instruments: sound meter, infrared thermometer, ambient thermometer and light meter.

3.1.3. Post Occupancy Evaluation Tool (HEPO)

Once the evaluation axes, the interest scale and the tools for the HEPO information survey are defined, the relationship between these variables is presented in Table 4.

Table 4. Post Occupancy Evaluation Tool(HEPO)

Thematic axes of evaluation	Evaluation factors	Scale of evaluation				Evaluation tools			
		Pri-vate	Sem- iprivate	Semi- public	Public	Occupant-satis-faction survey	Walkthr- ough	Monito- ring	
Consumption of resources	Consumption of energy	Consumption of energy per apartment	X	X			X		X
		Existence of saving devices	X	X			X		X
		Bioclimatic design	X		X			X	
	Consumption of water	Consumption of water per apartment	X	X					X
		Existence of saving devices	X	X			X		
		Re-circulation design	X	X				X	
Socio-spatial aspect	Thermal comfort	Thermal perception	X	X			X		
		Measurement of ambient temperature at different times	X	X					X
		Measurement of contact temperature in materials	X	X					X
		Measurement of airflow	X	X					X
		Measurement of environmental humidity	X	X					X
		Existence of wind currents (crossed circulation)	X	X					X
	Acoustic comfort	Acoustic perception	X	X			X		

Continued on next page

Table 4 continued

		Noise measurement at different times	X	X					X
		Identification of nearby noise sources	X	X	X	X	X	X	
		Existence of acoustic barriers	X	X	X			X	
	Lighting comfort	Lighting perception	X	X			X		
		Need to protect against direct sunlight	X					X	
		Measurement of illumination	X						X
		Non-disturbing natural light entrance	X					X	
		Need of artificial light (time and place)	X	X			X		
	Spatial comfort	Satisfaction with the laundry area (area and independence)	X				X		
		Satisfaction with bathrooms (check possibility of simultaneous uses)	X				X		
		Satisfaction with the kitchen	X				X		
		Distribution of housing	X				X		
		Capacity of the rooms to harbor the minimum furniture	X					X	
		Sufficiency of storage areas	X				X		
		Satisfaction with the size of the house	X				X		
	Odor comfort	Perception of odors	X	X			X		

Continued on next page

Table 4 continued

		Identification of sources of annoying odors nearby	X	X	X	X			
Flexibility		Possibility of ambiguous use of premises and buildings	X					X	
		Possibility of transformation	X					X	
		Existence of emerging uses	X					X	
Perfectibility		State in which the apartment was delivered vs. current state	X				X		
Existence of spaces		Existence of leisure and meeting places			X			X	
		Perception and use of leisure and meeting places			X		X		
		Existence of places for recreation and sports			X			X	
		Perception and use of recreation and sports venues			X		X		
Accessibility		Perception of quality of the public transportation system				X	X		
		Perception of the availability of the public transportation system				X	X		
		Infrastructure for pedestrians and cyclists			X	X		X	
		Infrastructure for people with reduced mobility			X	X		X	
Housing alternatives		Perception of density		X	X		X		

Continued on next page

Table 4 continued

		Gradation of scale (densification models)		X	X			X	
		Independence of vertical circulation		X	X			X	
		Independence of horizontal circulation		X	X			X	
Socio-cultural aspect	Relation of the house with the environment	Systems of enclosures			X			X	
		Visual control	X	X			X	X	
		Diversity of uses on first floors			X			X	
		Privacy	X	X			X	X	
		Space control (use of spaces)			X	X		X	
		Nearby facilities (Playgrounds, courts and social venues)				X		X	
	Security	Security Perception			X	X	X		
		Cases of delinquency			X	X			
	Social relations	Meeting the neighbors		X	X		X		
	User guide	Operating manuals	X	X			X		
		Transformation or reform guides	X				X		
	Socio-economic aspect	Maintenance costs	Cost of cleaning and maintenance routines required	X	X	X		X	
Cost of the administration					X		X		
Perception of the cost of the administration					X		X		
Productive housing		Use of housing in productive activities	X					X	
		The use of housing in productive activities is permitted	X					X	

Continued on next page

Table 4 continued

			The design makes it possible to use housing in productive activities	X					X	
Conservation of qualities in time			Frequency of required cleaning and maintenance routines	X	X	X		X		
			Aesthetic appearance of materials	X	X	X			X	
			Aesthetic perception on materials	X	X	X		X		

3.2. Validation based on the case study

HEPO Allows to collect three types of information, the first one is the corroboration of the actual consumption of hydric and electric consumptions of the buildings in phase of use. The second, the calculation of satisfaction indexes by study factor and residential satisfaction index, calculated from the perception of the users and quantified by Likert scale. Also, because the tool elicits open comments from the respondents and enables them to be collected, it allows identifying possible causes of dissatisfaction. Finally, it evaluates the conservation of the conditions of the qualities of the materials through time. The following is based on the evaluation categories of HEPO, the information that can be obtained with the tool.

3.2.1. Consumption of resources

As shown in Table 5, HEPO determines the actual consumption in both the house and the complex.

Table 5. Consumption of water and energy in the projects addressed

Results \ Residential Complex	Ciudadela Verona	Condominio Península	Urbanización los colores	Faro del velódromo	Oasis los colores
Electric Resource					
Electric saving devices (lighting)	48.15%	66.67%	33.33%	70.00%	36.84%
Energy average (Kwh/month) per capita	28.68	43.27	43.68	44.41	54.72
Hydric Resource					
Hydric saving devices	11.11%	45.16%	25.00%	20.00%	10.53%
Average consumption (m ³ /month) of houses with saving devices	3.28	4.25	3.36	4.00	3.38
Average consumption (m ³ /month) of houses without saving devices	3.05	3.57	3.73	3.90	3.98
Water average (m ³ /month) per capita	3.08	3.87	3.61	3.89	3.98

Through HEPO, the actual consumption of both apartments and buildings is determined, and with this, the possibility of establishing hypotheses that are implemented in the conception, and, thus, determine the effectiveness of the strategies used to reduce consumption.

From the direct measurements of the consumptions that are obtained with HEPO, the decrease or increase that can be given is determined, being able to identify causes and at the same time finding a starting point for the

development of new strategies that are successful in the reduction of consumption.

In the same way, HEPO allows to interweave variables that determine factors that increase or decrease energy and water consumption, finding information such as consumption of resources according to the direction of the site, consumption of resources according to the type and quantity of energy and water saving devices per capita consumption of buildings, among others.

3.2.2. Satisfaction of Needs

Since the data acquired with the perception scores are collected from the likert scale, establishing a satisfaction scale of 1 to 5, HEPO determines a satisfaction index (SI) by evaluation factor, knowing that the classification of satisfaction and the weights result in a weighting that account for the degree of resident satisfaction. The IS values calculated in HEPO are based on the formula proposed by Dominowski (1980).

$$Satisfaction\ Index\ (SI) = \frac{\sum_{i=1}^5 (a_i)(x_i)}{5 \sum_{i=1}^5 (x_i)} \times 100\% \quad (1)$$

In the equation above, the variable a_i is the constant representing the weight assigned to any indicator (i), and x_i is the variable that represents the relative frequency assigned to any indicator (i). The answer for (i) is 1, 2, 3, 4 and 5, with 1 being the negative adjective (Very unsatisfied) and 5 being the positive (Very satisfied). The scale of evaluation defined to determine the level of resident satisfaction was determined by the investigators based on the analysis of the data resulting from the field work. The determined ranges are as follows:

- SI between 0-50% implies that the occupants are very unsatisfied.
- SI between 51-60% implies that the occupants are unsatisfied
- SI between 61-80% implies that the occupants have a neutral opinion.
- SI between 81-90% implies that the occupants are satisfied.
- SI between 91-100% implies that the occupants are very satisfied

Figure 2 is the way HEPO presents the satisfaction index for each of the evaluation aspects integrated to the tool.

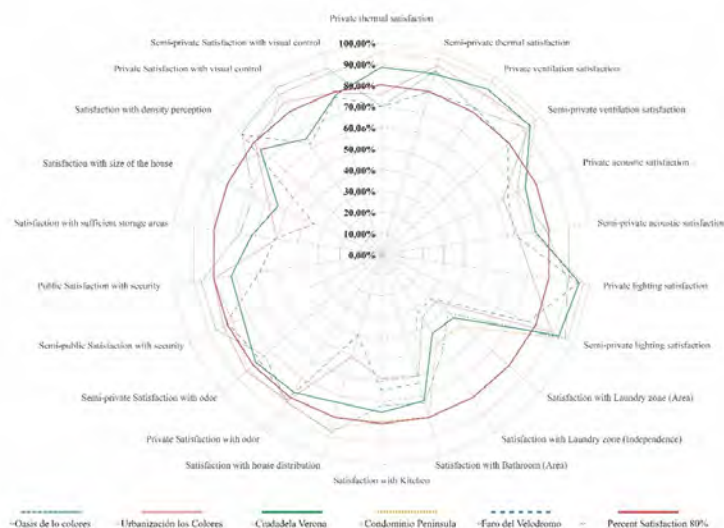


Figure 2. Perception of well-being in housing

Likewise, HEPO determines the *residential satisfaction index*, which is no more than the total amount of the satisfaction index of the components and is calculated with the equation proposed by Mohammad Abdul Mohit (2010).

$$SIr = \frac{\sum_{i=1}^{N1} di + \sum_{i=1}^{N2} Si + \sum_{i=1}^{N3} pi + \sum_{i=1}^{N4} sei + \sum_{i=1}^{N5} ni}{\sum_{i=1}^{N1} Di + \sum_{i=1}^{N2} Si + \sum_{i=1}^{N3} Pi + \sum_{i=1}^{N4} SEi + \sum_{i=1}^{N5} Ni} \times 100\% \quad (2)$$

Where SIr is the residential satisfaction index; N1, N2, N3, N4 and N5 are the numbers of variables selected to scale in each component of the housing, while Di, Si, Pi, SEi and Ni represent the actual score of a respondent in the i^a variable in the component. Di, Si, Pi, SEi, and Ni are the maximum possible ratings of the I^a evaluated variable. From the above, values such as those presented in Figure 3 are obtained.

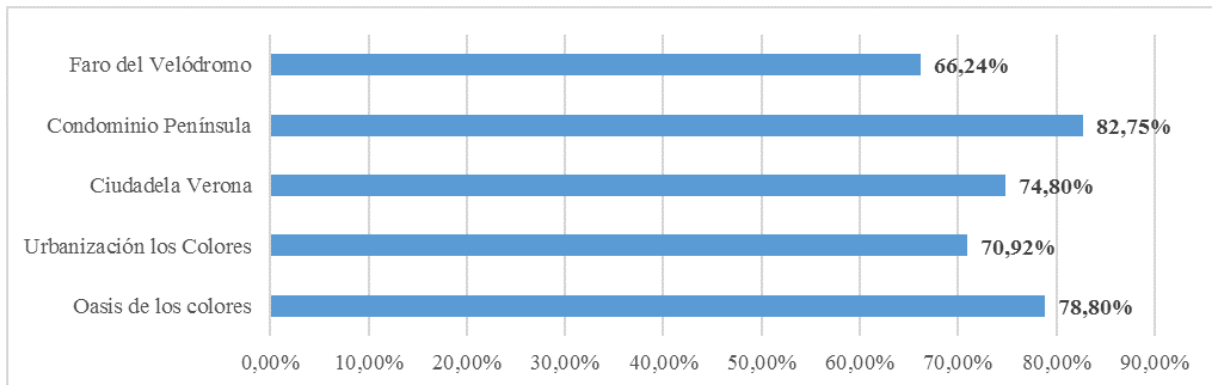


Figure 3. ResidentialSatisfaction Index

Figure 3 Residential Satisfaction Index

The way in which HEPO determines the indexes presented above is based on the detailed investigation of the perceptions of each one of the factors evaluated; this form of evaluation allows us to know which aspect generates dissatisfaction and which, on the contrary, are adequate for residents. For example, the information generated by the spatial satisfaction index is presented in table 6, as can be seen. HEPO breaks down each of the factors, and although it is only shown here from the private space, it is possible to know perceptions about other scales of evaluation in detail.

Table 6. Related enclosures with spatiaIdissatisfaction

Space Desired	Bedrooms	Bathrooms	Laundry Zone	Social Area	Kitchen	Other
Oasis de los colores	30.00%	16.67%	26.67%	5.00%	15.00%	5.00%
Urbanización los colores	27.27%	4.55%	50.00%	0.00%	18.18%	0.00%
Ciudadela Verona	35.19%	9.26%	48.15%	3.70%	0.00%	3.70%
Condominio península	23.53%	11.76%	35.29%	8.82%	17.65%	2.94%
Faro del velódromo	18.18%	9.09%	54.55%	18.18%	0.00%	0.00%
Average	26.83%	10.27%	42.93%	7.14%	10.17%	2.33%

HEPO also allows the acquisition of open answers that allow the identification of causes of dissatisfaction aiming at feedback processes. The following statement from one of the surveyed residents illustrates this type of information that can be collected:

"I do not like that the laundry area is integrated to the kitchen. This generates that the clothes might get impregnated with odors from the food that is prepared there. If it is the case, and there is no more space, it would be much better that they were separated by a wall ... " (A. Álvarez, personal communication, September 2nd, 2016)

HEPO is supported in many instruments in order to acquire as much information as possible about the building, and thus to know its operation. The photographic registry is a key for this tool, since it allows to support what is expressed by the residents and also to identify possible successes and failures of the houses. Figure 4 is an example of this, since it shows the need to use alternative places, such as the balcony or the living room to hang

the laundry due to the scarcity of space. That is, emerging uses that do not correspond to the design premises, due to the insufficiency of the space offered by the building for such use in the fulfillment of the function.

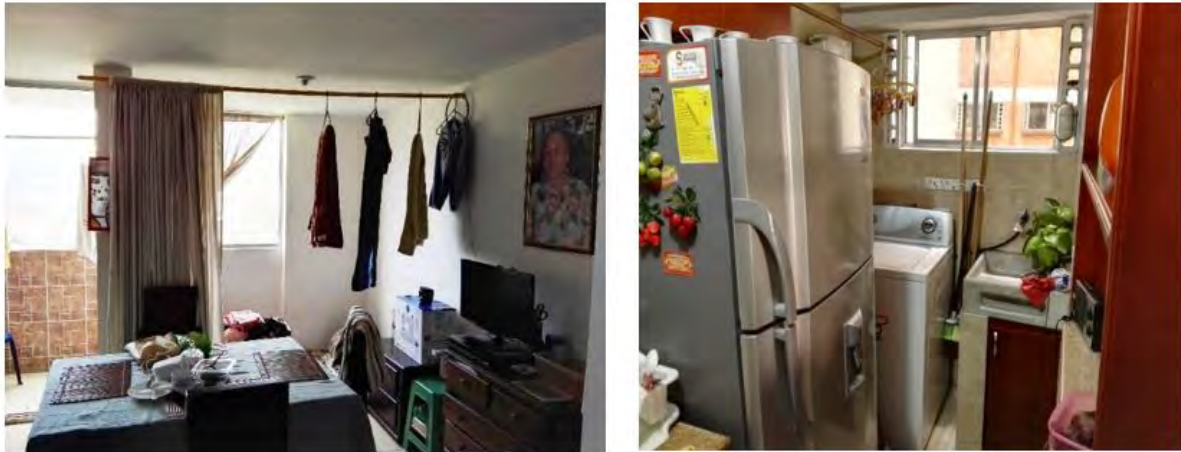


Figure 4. Need of adequate spaces to hang the laundry

3.2.3. Conservation of qualities in time

Evaluating the conservation of qualities over time is a new aspect in the post-occupancy evaluation carried out so far. HEPO addresses this factor because of the importance of knowing what the behavior of the materials is and how this affects the operation of the buildings in aspects such as behavior of the materials before specific atmospheric agents of a place, before the interaction with fauna and flora of the place, possible causes of accelerated deterioration, real routines of necessary preventive and corrective maintenance and associated costs, difficulty in cleaning routines and associated costs, material behavior to minor domestic interventions made by the inhabitants in the process of appropriation, ease of repair of minor deteriorations, and consumption of resources associated with material maintenance.

HEPO collects information from residents and administrators, and relying on the observation of the researchers at the same time. Information such as perception about the quality of materials is critical to determining causes of dissatisfaction and identifying materials with weaknesses, or more likely to be associated by residents as defective products. The Figure 5 presents the perception of the qualities of the materials in different evaluation scales; however, the information can be disaggregated to arrive at the perceptions about specific finishes.

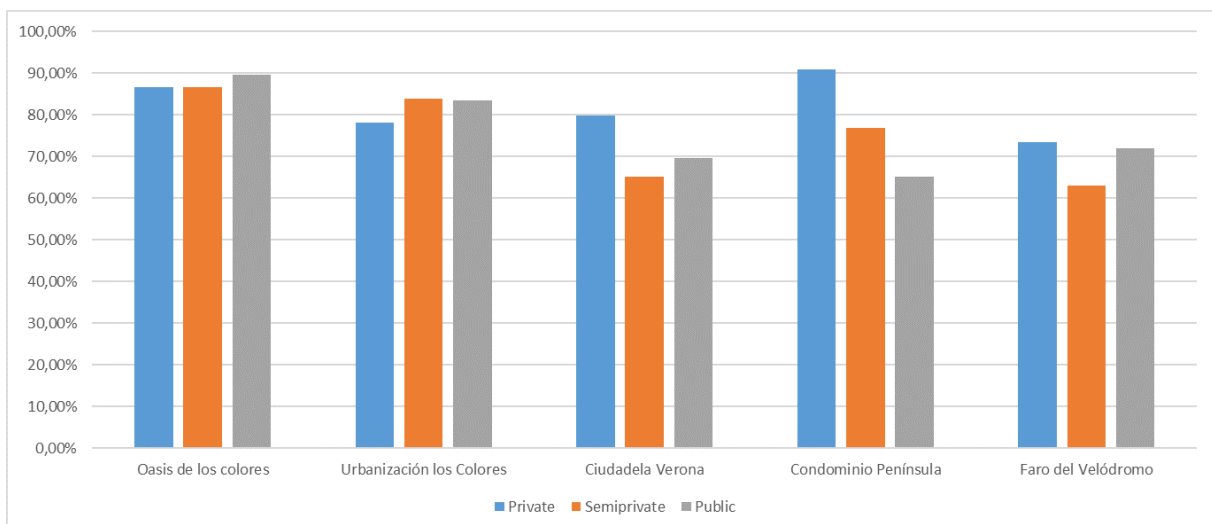


Figure 5. Perception about the aesthetic and quality materials.

As an example, in the projects addressed in the case studies it was found that, on the private scale, floors, mainly laminated wood floors, are the most frequently related to accelerated deterioration and unconventional cleaning routines that merit a specific user guide. The collection of open information also allowed to identify the causes of the perception of the respondents with more precision. As a way of illustration, the following comment makes part of one of the perceptions of the users:

“This floor is very annoying. I have to constantly change it because it clogs up when I do household cleaning and, as if that was not enough, for example, the tile constantly peels off in the joints with other types of material. I am tired of fixing it.” (F. Calle, personal communication, August 16th, 2016)

On the semi-private scale, the walls are the elements of the building related to greater deterioration, while the green areas are in the semi-public areas. The processes of observation and investigation with residents and administrators allowed to identify inappropriate use as the main causal in both cases. (Fig. 6).

HEPO allows to know the variables that generate greater cost of maintenance of the building caused by the rapid or frequent deterioration of the spaces. The green areas, for those residential groups that own them, are the fastest item that deteriorates due to the nature of this space, and the lack of awareness on the part of the residents can be added to this. This is why more frequent maintenance in order to keep the qualities in time becomes necessary. Following this, the elevator, which is an element of great importance for residents, requires monthly maintenance due to safety regulations, but when accompanied with misuse, it becomes essential to do preventive maintenance with more frequency.



Figure 6. Conservation of quality in time

According to the opinion of the administrators, many of the problems of the materials are largely due to the builders. In accordance with the words of the administrator of the residential complex “Reservas de la Maria II”:

“The builders do not do right by quality. They promise a lot and when it comes to the truth, they do not install the promised products or the appropriate ones for use, generating claims in the phase of use, and, therefore, it has become a headache for residents. Likewise, the final touches installed in the common area are not of good quality, even knowing that the price paid to live in the residential complex is not economic. In addition, the terminations of common areas are never communicated when the project is being sold, so when the building is delivered and the residents look at the terminations, in many cases discomfort for quality is generated.” (G. Vergara, personal communication, November 5th, 2016)

4. Barriers for the implementation of the HEPO

Characteristic of the data sources:

Since the data of interest given is related to the interaction of spaces with atmospheric agents and with social systems, meaning how people live, it is required to have gathering information tools that demand that these people get involved, both from the willingness to supply information through interviews and/or surveys, as well as to allow the personnel in charge of the evaluation to enter the private premises generating barriers to the execution of the tool on many opportunities. These are:

-Perception of insecurity or mistrust: Since people see a stranger walking around and taking photographic records of the residential complex to carry out the implementation of the tool, they tend to feel uncomfortable and insecure. This is usually seen in high strata and closed residential complexes rather than in low and open strata.

-Lack of communication regarding the study in the building: Although the study was communicated through the bulletin boards of the residential complex, this is a space that normally is not given any attention, when addressing the residents. Such people do not know about the activity and generally doubt if it's truthful or not.

-Moment of implementation of the tool: During the day, there are time frames in which people do not want to be approached because they have house work or just want to rest.

-Extension of the surveys: Knowing the operation of a building involves investigating as many factors as possible, many questions are generated to cover the largest amount of information

. Technical and economic characteristics: -Disconnection between the phases of design-build and the phase of use of the building: There is not necessarily a connection between the managers of both phases because while there are the builders in one, there are the managers of the residential complex and the owners of the buildings in the other, so that is why it is not clear who is going to benefit from the study and, therefore, who should pay for it.

Benefits are not evidenced

- On the side of the technical teams: Normally, they do not value the feedback given on the buildings once they are in phase of use, evidencing the lack of interest to evaluate the designed products.

-On the side of the administrators and residents: Neither the administrators nor the residents perceive any benefit about the evaluation of the operation of the building, mainly due the lack of culture regarding the improvement of the existing buildings because they believe that this learning will only be implemented in future projects, and that their building will continue the same.

5. Elements for the successful implementation of the HEPO

During the process of application of the post-occupancy assessment tool, aspects that allowed the systematic study of each of the buildings to be fully developed were carried out. Thus, after a process of experimentation and identification of the barriers, actions that were successful during the field work were implemented. These are:

-For the barriers on the perception of insecurity, the back-up of a recognized entity in the city (University, company, etc.) that provides reliability to both the building managers and the respondents is necessary. Also, the accompaniment of the security company of the residential complex or the neighbors is a good strategy to generate confidence and security in the respondents of the surveys. Referral campaigns between the same neighbors and through the administrator is a strategy that allows to include more people and generate, at the same time, interest and confidence in them.

-In the absence of communication of the study, a publicity campaign is necessary showing the objectives, content and duration of the tool in the communication media of the building (bulletin boards, co-owners meetings, flyers) and through vociferation.

-Identify the best moment of the day for the development of the survey. For this, it is necessary to know the culture of the region and sector since there are time frames in which residents do not want to be approached to conduct surveys. Likewise, the development of web applications for the acquisition and communication of information is an excellent strategy for this problem.

-In order to face the disconnection between the phases, it is possible to carry out strategies of diffusion from the universities in all the careers related to the conception of a building, so that there might be a greater number of

citizens knowledgeable in the systematic study. Likewise, informative talks, courses, and others for professionals who are in constant relation with the phase of use of the buildings is an ideal strategy to face this problem.

-In the absence of evidence of benefits, it is essential to empower administrators and builders throughout the study process, showing them the benefits of the building evaluation and provide an analysis of the residential complex so that they could evaluate their successes and failures and so that they could implement action plans for the existing buildings and future projects.

6. Benefits of the implementation of the HEPO

HEPO shows the correspondence and discordance between the designed and the inhabited space, as well as the possibility to verify what can not necessarily be done in the design and construction phase in real conditions of use, allowing conclusions and feedback on the consumption, preservation of qualities over time and satisfaction of needs.

From the environmental point of view, HEPO allows verification of the actual consumption of water, electricity and materials associated to the use of the buildings, which might give the opportunity to implement actions to reduce these environmental burdens, as well as having feedback so that future projects might have products/houses that require lower maintenance costs, thus generating the possibility for poor families to maintain their home.

From the perspective of the administrators and homeowners, HEPO allows to identify the residents' dissatisfaction with the building; it clearly identifies the possibilities that are available so that the spaces might be better adapted to the needs of the inhabitants; it improves satisfaction with the property and allows a valuation of the product over time as it has a differentiating point over others. Likewise, it gives the administrator tools to promote improvement and saving actions in the building, generating decreases in consumption by having a real knowledge of the operation of the building.

From the perspective of the builders, HEPO allows to evaluate its product, identifying successes and failures, and thus, having real inputs to develop a better product, allowing to have positive perceptions of the users compared to the buildings built by the company, as well as the option to differentiate from the competition by offering better buildings, generating repurchase, status in social circles and fewer aftermarket numbers.

7. Discussion

In the construction industry, the use of procedures that allows feedback on the operation of buildings under real conditions of use is not widespread, which makes it necessary to establish clear requirements before the real estate construction sector in order to understand that the housing has a social purpose which is the habitability and therefore cannot be that the only reason for its existence is purely a financial profit from a constructed object and a profit received from it, but also to know whether the object developed (buildings) provides good levels of habitability, generates well-being and is efficient in the consumption of resources.

The construction sector must commit itself to a social utility and this is to provide habitability; compromising to an environmental reason, and part of it, is to know the consumption they are causing in the phase of use of the buildings; and committing to design projects with adequate maintenance costs, which will allow its inhabitants to keep them in time. Colombian legislation already has regulations for buildings to be committed to energy and water efficiency in the use phase, and although such legislation does not address other relevant issues such as materials, maintenance costs of the buildings, among others, is a first approximation to ensure efficient and effective buildings.

The construction industry is characterized by its fragmentation in each of its stages (planning - design - construction - operation), given that one stage is rarely involved in the next, causing problems with the final product and since there is no a continuity of the philosophy of conception of the project and the one in charge of each one of the phases impresses its seal; there are no feedback actions between the different moments of a project and the designs

and models have no correspondence, that is why HEPO becomes a tool that helps to integrate each of the phases mentioned above, it also becomes a way to generate an appreciation of the perception that users have about building through satisfaction indexes, but it is fundamental that in order to understand the operation of this type of works, it should not be limited to evaluating only the indicators, but it is necessary to study in detail each of the variables that compose them.

One of the implications of the results of monitoring by visit is that because of the time limitation of the information taking process, either by the non-presence of people, time of the day or the lack of interest in the development of the study; which implies the punctual data collection, which does not fully represent the behavior of the buildings in the variables analyzed, making it essential to use information acquisition technologies in real time and with constant frequencies that allows to record and study the variables over a prudent period of time.

8. Conclusion

The document presents the development of a system of evaluation of buildings for the Colombian real estate sector mainly applied to collective height housing. This evaluation tool is composed of 13 thematic axes that are subdivided into 18 categories of evaluation. The validation of the classification tool revealed that the concepts of evaluation are clear and do not generate doubts using vocabulary that matches the intuition of the respondents. The results of the field work revealed that the classification system is clear and the terms are well defined.

The Post-Occupational Assessment tool (HEPO) aims to investigate the operation of a building. It is because of the above, that it was structured in such a way as it allows the combination of different tools, and in this way diminishing the subjectivity generated from the individual-based appreciations, and on the other hand, socially shared impressions are obtained, compiled from qualitative and quantitative data. Conceived to be applicable during the phase of use of the projects, HEPO concretizes the transversal approach of sustainable development integrating the three fundamental aspects of its definition: environmental, economic and social.

A continuity line of the tool could include the development of a web application that allows to gather the information in a more agile way and that, at the same time, eliminates the barrier on the time that the survey is applied. Also, the development of a benchmarking platform would allow constant referencing between the different stakeholders, thus enabling feedback among all sectors.

In addition, this assessment tool could be the starting point for developing a Colombian standard for effective capture of successes and failures, management, and analysis of buildings. Once the data is standardized, statistical analysis can be carried out easily in order to reduce occurrences of errors and improve performance levels of buildings.

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