Sustainability indicators for the housing market: proposals and applications

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Abstract

In this paper, the concept of sustainability, as applied to the housing market, is discussed and an evaluation methodology of building performance is proposed. Sustainability is presented and evaluated by dividing it in relation to the costs of a building's life cycle, including the location characteristics, convertibility and flexibility, internal living conditions, environmental capacities in operation and environmental capacities during construction, safety characteristics, comfort and the impact of the building in the neighborhood. The paper presents the sustainability indicators and suggests the manner of collection for each one, in order to characterize the existing sustainability performance. Thus, the result is a checklist for application in the housing market. Depending on the indicator, this can be answered by the dweller, researcher and/or measured with appropriate tools. The indicators were applied to four dwellings in the south of Brazil. The results show indicator values between 55% and 69% sustainability for the studied constructions.
Keywords: sustainability, buildings, performance indicators.

1 Introduction

The construction industry has been responsible for significant impacts on the environment. The building's construction, as well as the infrastructure, consumes energy, from the raw material extraction phase through to the deposit of demolition waste. Baldwin (SPERB, [1]) affirms that environmental questions are becoming increasingly important in the context of sustainable development. As can be seen in the Bulletin CIEF [2], several researchers have already

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presented methods for the environmental analysis of a building's life cycle, characterized by the planning phase, construction, maintenance and subsequent demolition, by a process focusing on the consumption of natural resources and waste generation.

In this context, this study focuses on buildings within the knowledge area of the researchers. Sustainable construction is a concept that requires the consideration of sustainable objectives in all decision processes during all phases of a buildings' life cycle, and this research proposes a method to evaluate a building's sustainability index.

The measurement of the building performance is fundamental for sustainable development. The measurements give engineers and architects the necessary information for decision-making and enable the development of improvement actions in the sustainable performance of the built environment.

According to Degani and Cardoso [3], "to know the environmental performance of the buildings its necessary analyze the interaction between the activities developed during all its cycle of life and the environment, identifying the possible environmental impacts associated".

In this way, definitions indicative of sustainability are indispensable in the evaluation of the present performance of the housing stock and inform the decisions about the new buildings that will be incorporated into this stock.

2 Evaluation of the sustainability of built environments

Several studies have been completed in an attempt to understand what constitutes the sustainability of built environments, and how this can be evaluated (Porkka and Huovila, [4]). As a result, internationally respected systematic environmental evaluation tools have been developed in Europe, Japan and the USA. Some are intended to be applicable world wide, but they do not take into account powerful local characteristics and problems.

The approaches studied here contemplated the vision of sustainable sites, efficient water consumption, energy and atmosphere, materials and natural resources, internal environmental quality of the building and the process of planning and innovation (Porkka and Huovila [4]).

Halac and Marchisio [5] propose five sustainability indicators, which according to the authors exceed other rules of environmental evaluation by contemplating the basic concepts of the sustainable development: environmental, social, and economic development. The indicators suggested and applied to the Campus of the *Universidad Nacional Córdoba* are:

1- **Quantic jump and transferability:** this indicator refers to the innovative character that future interventions should have in sustainability terms. The quantic jump signifies a substantial change in comparison with traditional focus and the characterization of transferable and replicable tendencies in other intervention areas.

2- Ethics and social equality: this indicator refers the need to consider the ethics norms and the social justice in different kinds of architecture and city planning interventions and in the forecasts for future projects.

3- Ecological quality and energy conservation: this indicator refers to the need for the responsible use of the natural resources over the life cycle of the architectural and city planning interventions.

4- Economic performance and competitiveness: this indicator refers to the need for sustainable improvement being feasible in relation to real conditions and to be compatible to requests and demands over the project life cycle.

5- Contextual answer and esthetic impact: this indicator refers to the need to express a positive and lasting esthetic impact, as well as the innovative use of space and forms.

3 Methodology

This study had as an experimental field the housing stock of the Passo Fundo city and Ijuí city (Brazil). Four housing units were selected and evaluated for their sustainability characteristics.

The buildings' characterization was accomplished by using photographic records, analysis of the architectural project and the buildings descriptive records, to establish the solar orientation, specification of constructive materials, openings, and lightning, and local visits for the climate data collection, the specification of the internal construction material.

Figure 1: (from left to right) Buildings A, B, C located in the city of Passo Fundo and D located in the city of Ijuí.

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4 Attributes for the calculation of the sustainability indicators

The variables, or attributes, that translate to the buildings sustainability were proposed from the work presented by Huovila and Koskela [6], which suggests a method to evaluate the sustainability, which can be applied to any kind of stuff or constructions.

This method was developed by the VTT Building Technology and adapted by Kohler and Brandli [7], defining the aspects and characteristics inside each attribute category, how the information would be collected and what is value and weight of that evaluation (Table 1).

The attributes of sustainability considered were included in an Excel form, "ATRIB. and INDIC.", and correspond to the following items:

- Legislation, utilized the Director Plan (laws of use and occupation of the urban soil of the city). The indicators data are related to the architectural project of the buildings in the study;

- Building materials, which correspond to some phases of the construction. The materials utilized in the execution are more common in the local market, with the objective of offering more thermal, acoustic and lighting comfort to the user;

- Location, evaluation accomplished locally, verifying the conditions in which the building is found;

- Project Quality, indicators cited are according to the form that shows the Indicator for Evaluation of the Project Quality (SEBRAE), with that, the article, "use/function flexibility" was evaluated according to the building plant. The results correspond to the comparison of the ideal values, with the values performed;

- Use and Maintenance, concerns the ideal consumption of water and energy by inhabitants (base levels taken from data given by the supply companies). The consumed energy in the building was calculated using apartment light bills in relation to the number of occupants in the apartment. The water usage per head per month was calculated from data collected by the building's supply. The solid and liquid wastes were evaluated according to its density, based on hydrossanitary projects. The indicators evaluated in loco were: state of repair, durability and security;

- Environmental Comfort, the indicator of natural lighting and ventilation were evaluated according to the city code of works. The acoustics indicator is related according to the NBR 10152 (ABNT [8]), that sets the levels of compatible noise with the acoustic comfort in diverse environments, however the comfort hygrothermic is related with the form of thermal charge;

Table 1: Method for the evaluation of a building's sustainability. Source: Adapted from Kohler and Brandli [7].

ATTRIBUTE	ASPECT/CHARACTERISTIC	VALUATION	MAXIMUM VALUE	Weight	Total
Legislation	occupation percentage; utilization index; permeability percentage; frontal recoil; left and right spacing.	Predicted in the city legislation – plan director	10		
			Σ/6	1	
Construction material	wall; floor; internal and external finishes; frames; coverage.	Records and local survey, description of the finishes.	10		
			Σ/6	2	
Location	Surrounding characteristics Traffic conditions Communication Neighborhood effects	Low; average; light Light, moderate, intense Reasonable, good, excellent Light, moderate, intense	10		
			Σ/4	1	
Project Quality	Circulation index; Compactness index; circulation index in garages; Wall density; flexibility of use; functionality.	Architectural project survey "in loco". They considered values of benchmarking for each index	10		
			Σ/4	1	
Use/mainten-ance quality	consumption; water consumption; liquid waste; solid waste; repair facility; durability; security	Counts Extract Local survey	10		
			Σ/4	2	
Environ-mental comfort	natural illumination; artificial illumination; hygrothermic comfort; ventilation.	Survey "in loco", thermal charge calculate for each dependence, NBR 101552	10		
			Σ/3	1	
Cost	Inherent costs in each stage of the life cycle: project; construction; utilization.	Market's data, collected by the builder (CUB) and in the condominium (monthly expense of operation)	10		
				2	
				Σ	**100 %**

- Cost, the indicators data of the Project and Construction were supplied by the builder, based in values (CUB) of the month and year that the building was finalized. The cost of the building utilization is related to the expenses form, which concerns the monthly cost of the building corresponding to the research period. The values should be digitized in the red cells. To "monthly expenses" and the "cost/m² (common use)", were calculated through the applied formula and of the existing connection with the form of the facts related with the architectural project. This refers to the Project Quality Evaluation Indicators, identified with the red color. The items collected with the decibelimeter are highlighted in green and the buildings costs evaluations are represented by the blue color. To accomplish the calculations in the form "Thermal Charge" it must be brought up to date the values according to the geographical location of the city. The yellow cells are not filled, for the values are grasped automatically from linked calculations in the forms.

5 Results of the sustainability indicator

The sustainability evaluation of the buildings selected for the study showed that building A obtained the sustainability indicator value of 55%, building B obtained 58%, building C obtained 66% and building D obtained a value of 69%. An extract of the evaluation of building D, which obtained the greatest index of sustainability, is shown in Table 2.

Table 3 presents the value of the indicator obtained for each attribute.

Generally, the sustainability indicator of the buildings researched stayed between 55 and 69%, the ideal being a maximum of 100%. This signifies that the buildings were not planned with respect to maximum sustainability, improvements clearly being made when changes to the standard of the building and to its use have taken place. That means that there is a gradual improvement in the more recent buildings.

6 Final considerations

This research had as its main objective the characterization and measurement of the sustainability concept in civil construction, sub-sector buildings, through the application of an indicator method, considering all phases of the building's life cycle. The results of the research aimed for a "value" of sustainability for each building analyzed, calculated from the total of all the variables evaluated, applying weightings where necessary.

It must be accentuated that is necessary to make a comprehensive study of the analyses about the indicator results and the building's characteristics. Beyond this, it is important to measure the sustainability and compare it with ideal parameters (benchmarking). These parameters should be found and defined.

Table 2: Building D sustainability indicators.

IDENTIFICAION DATA				
BUILDING:	SÃO PAULO		ADRESS	RUA SÃO PAULO, 63
GROUND AREA:	1000	m²	ZONE DIVISION:	NÚCLEO CENTRAL/ZONA MISTA
TOTAL BUILDING AREA:	5.169,57	m²	OCCUPATION:	RESIDENCIAL
PAVEMENT QUANTITY:	7		YEAR OF CONSTRUCTION:	2001

ATTRIBUTES	INDICATIVES	FORESEEN ON LEGISLATION / IDEAL	PERFORMED	VALUE	WEIGH	TOTAL
LEGISLATION	OCCUPATION PERCENTUAL	≤ 75 %	63 %	10,00		
	UTILIZATION INDEX	0,00 (solo criado)	5,17	10,00		
	PERMEABILITY PERCENTUAL	≥ 15 %	12,19 %	0		
	FRONTAL RECOIL	≥ (0,00m a 4,00m)	5,58 m	10,00		
	LEFT SPACING WITH OPENING	4,28	5,58 m	10,00		
	RIGHT SPACING WITH OPENING	4,28	5,58 m	10,00		
			∑ / 6	50,00	1	8,33
CONSTRUCTION STUFF	WALL		6 FUROS	7,50		
	FLOOR		PARQUET	5,00		
	INTERNAL FINISHING		REB. PINT. MÉD	10,00		
	EXTERNAL FIISHING		REB. PINT. MÉD	10,00		
	FRAMES		ALUMÍNIO	7,50		
	COVERAGE		LAJE C/ CER.	10,00		
			∑ / 6	50,00	2	16,667
LOCATION	SURROUNDING CHARACTERISTICS	Baixa	100,00 %	10,00		
	TRAFFIC CONDITIONS	Leve	100,00 %	10,00		
	COMMUNICATION	Bom	66,00 %	6,60		
	NEIGHBORHOOD EFFECTS	Moderado	66,00 %	6,60		
			∑ / 4	33,20	1	8,300
PROJECT QUALITY	CIRCULATION INDEX / QUANTITY OF PAVE	9 a 12 16,40	7,23 %	4,407		
	COMPACTNESS INDEX / UNITY PER PAVEN	100 % (ideal)	55,99 %	5,599		
	CIRCULATION INDEX IN GARAGES	5,6 % (ideal)	5,60 %	0,00		
	WALL DENSITY / UNITS PER PAVEMENT	22,00 % (ideal)	4,14 %	1,882		
	USE FLEXIBILITY/FUNCIONABILITY	100 % (ideal)	6 FUROS	7,500		
			∑ / 5	19,39	1	3,877
USE AND MAINTENANCE	ENERGY CONSUMPTION ONSUMPTIO	kWh/percapita < 77,65	125,24 kW	6,00	fonte demei	
	SYSTEM	Tradicional 5,00	5,00 %	5,00		
	WATER CONSUMPTION ONSUMPTIO	m³/percapita < 4,00	5,72 m³	8,00		
	SYSTEM	Tradicional 5,00	5,00 %	5,00		
	LIQUIDS DETRITUS / reutilization	Sem reapro. água cinza e pluvial	25,00 %	2,50		
	SOLIDS DETRITUS	Rede pluvial s/ estação tratamento	25,00 %	2,50		
	REPAIR FACILITY	Médio	66,00 %	6,60		
	DURABILITY	Alta	100,00 %	10,00		
	SECURITY	Alta	100,00 %	10,00		
			∑ / 9	55,60	2	12,356
ENVIRONMENTAL COMFORT	NATURAL ILLUMINATION	Dormitório 1,594	0,176	2,00		
	ACOUSTIC (db)	Dormitório 35,00 - 45,00	52,10	8,00		
	HYGROTHERMIC COMFORT	Dormitório 80	129,43	0,00		
	VENTILATION	Dormitório 1,063	0,176	2,00		
			∑ / 4	12,00	1	3,000
COST	PROJECT (CUB/m²)	0,030 - 0,059 0,030 - 0,059	0,0300	8,00		
	CONSTRUCTION (CUB/m²)	0,50 - 0,79 0,50 - 0,79	0,7600	6,00		
	UTILIZATION (CUB/m²)	≤ 0,0057 ≤ 0,0057	0,0056	10,00		
			∑ / 3	24,00	2	16,000
			∑			68,533

Table 3: Sustainability indicators.

ATTRIBUTE	A	B	C	D
Legislation	7,67	7,33	9,00	10
Construction Materials	13,33	12,50	16,67	16,66
Localization	5,77	4,95	5,80	8,30
Project quality	4,54	4,53	4,37	3,87
Use/maintenance quality	11,60	12,35	12,35	12,35
Ambiental Comfort	3,00	3,00	3,00	3,00
Cost	9,33	13,33	16,67	14,66
TOTAL	55,25%	58,00%	65,86%	68,86%

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