Post-Occupancy Evaluation as a Tool for Sustainable Design: Analysis of Hotel Architecture in Northeastern Brazil

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ABSTRACT: This paper analyses the advantages and limits of the Post-Occupancy Evaluation (POE) approach in the construction of a sustainable architectural design. This approach intends to conciliate technical and behavioral analyses, also considering user preferences and ambitions. The recent energy crisis in Brazil has required POE researches to address urgent questions regarding environmental comfort and energy efficient buildings. Presented here are the main results of a POE regarding hotel architecture in Natal, where power economy is always difficult to achieve its intense use, the peculiarities of user behavior, in addition to the use of inappropriate architectural solutions, which do not take climate and landscape conditions into consideration. To overcome government restrictions, hotel administrators adopted punctual/short term actions, rather than long term solutions. The most common action were the replacement of power sources, inadequate power consumption interruptions or reductions, resulting, many times, in comfort deprivation but not in energetic efficiency.
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1- INTRODUCTION

The recent energy crisis in Brazil has required researches to address urgent questions regarding environmental comfort and low energy buildings. The Brazilian population has adapted their way of life in order to overcome such crisis. Housing power consumption has decreased, even after power restrictions were discontinued. The business world has also tried to contribute to this process, taking different actions in order to reduce consumption. Are architects also doing their part, including the demands concerning design decisions? Are the specificity of climate and cultural conditions, as well as building users being considered?

The relation between the electricity consumption at hotels and the building design was studied using Post-Occupancy Evaluation (POE). This approach intends to conciliate technical and behavioral analyses, considering user preferences and desires. POE has been systematically applied by architecture students at Universidade Federal do Rio Grande do Norte (Natal, Brazil) in different case studies (schools, housing, hotels, hospitals), in order to conduct better design decisions. The importance of these academic studies is evident, although the effectiveness of researches on design enhancement will be lost if these data do not result in specifications and objective architectural solutions, which may be used by architects from the very moment of conception.

To illustrate these questions, we present the case of hotels in Natal, where power economy is always difficult to achieve due to its intense use, in addition to the adoption of inappropriate architectural solutions, which do not consider climate and landscape conditions. Reduction of consumption was mainly based on punctual/short-term actions rather than on structural/long-term solutions. This paper demonstrates that most of the hotels in Natal have reduced power consumption by way of makeshift actions, such as the substitution of energy sources or through cuts in the use of some items resulting many times in loss of comfort for the users but not in energy efficiency. Permanent actions, such as architectural and/or building modifications have not been adopted. On the other hand, the profile and habits of hotel users do not contribute to a consumption reduction, especially due to the immoderate use of air conditioning.

2. CONCEPTS AND METHOD

According to Lamberts, Dutra and Pereira (1997), in a simplified way, "energy efficiency should be understood as the achievement of a service with a low consumption of energy. Therefore, a building will be more energy efficient than another one whenever it is able to provide the same environmental conditions with lower energy consumption" [1]. Thus, lower consumption should not mean loss of quality in the services nor in the comfort offered to the users.

As a matter of fact, the energetic performance of a building depends on a series of inter-related factors which range from local climate conditions, architectural characteristics and its climatic adequacy, facilities and equipment system specifications, human factors, especially those relating to cultural issues, interfering in use and comfort conditions (heating, lighting and acoustics), as well as the managing and maintenance strategies adopted by the management staff for the operation of a certain organization.

Therefore, the decision making process when devising the building design is of vital importance, requiring that both architects and installation technician work in a synchronic way. This is considered to be a structural action, due to its relevant influence on the final product, as well as its benefits along the time, in view of the high cost of future modifications. In addition to that, user requirements and ambitions must be taken into account both for the design conception and for post-construction decisions. Unfortunately, these various factors are not always managed in an integrated way, thus resulting in conflicting viewpoints (architects v. engineers v. developers v. users).

For the performance of such an effort, it is very important the approach known as Post-Occupancy Evaluation (POE), which studies buildings or built estates during its utilization process, that is from the moment they have undergone the conception/ design/construction phase and finally starts to shelter human beings in their various activities. The POE becomes part of the building production process, providing a feedback for the design cycle, aiming at practical results and altering the object being studied at short, medium and long terms [2] [3].

In addition to this, the attention given to the opinion of the various agents involved in the environment being studied both producers (designers, builders, developers) and manager (administration, maintenance and others), as well as users, enables that the confrontation of different opinions eliminate many doubts and gaps in data collection.

From the viewpoint of energy efficiency in hotel buildings, it is necessary to consider a few specifications in that activity:

- Hotels operate 24 hours a day, with load peak times at early mornings, late afternoons and evenings preferred times for showers and meals.
- Most of the guests are tourists / temporary guests (in Natal the average of local guests is insignificant). Therefore, they do not have any links with the place, since they are "just passing by". Far from their social environment, they do not develop a feeling of pertinence or collective responsibility towards the lodging means being utilized.
- Considering the differences for the various categories, they pay a fairly high price for their temporary stay, and consequently tend to be quite demanding in relation with comfort and good services.
- The public comprised by businessmen and convention participants behaves in a different way from leisure tourists when concerning demand level and items and the way space and equipment are utilized.
- From the energy efficiency viewpoint, it is possible to reduce the arbitrary comparisons among hotels, by establishing a few control variables, such as: main function, size, comfort standards as per classification by EMBRATUR (Brazilian Tourism Authority), energy consumption category, or, yet, some architectural variables, in accordance with the purposes of the research.

Considering all these assumptions and the methods/techniques available for utilization in this study, the option was for the performance of a technical survey, measurement (dimensions and furniture), photographic and graphic documentation (architectural design, outline), application of questionnaires to users (guests) and interviews (with managers and designers).

3. THE CITY OF NATAL AND THE RESEARCH

Located on the northeastern coast of Brazil, Natal is a medium size city which has undergone a significant demographic growth during the last two decades, increasing its population from 400 thousand to 750 thousand inhabitants between 1980 and 2000. The city is situated at latitude 5°45'05'' and longitude 36°12'05", and has an inter-tropical climate, characterized by high temperatures (annual media around 28°C) and air humidity (annual media around 78%), and constant southeast winds. According to a NASA report (1997), Natal has America's purest air among cities which have more than 200 thousand inhabitants. There is around 24m2 of green area per inhabitant (in bigger cities such as Sao Paulo, the media is 4m2/inhab.). The Dunas Park (the second largest Brazilian urban park) represents 1,172ha of an Atlantic forest reserve. The bio-climatic aspects of urban form are adequate in an expressive part of the city, as a result of urban plans which prioritized hygiene and comfort conditions. All these environmental advantages contribute to the diffusion of a positive image reinforced by slogans like "Natal, the sun city" and "America's purest air".

Tourism is now the main local income source. It is essentially based on local natural attractions, such as beautiful dunes, unpolluted seaside, bright sun and a cool breeze throughout the year.

A strong territorial marketing has attracted a large number of visitors, permitting the local hotel industry to rapidly grow and diversify its offer of services. In 2000 there were 167 accommodation units (including hotels, flat services, hostels and youth hostels) mainly located in the coastal zone, expensive and environmentally sensitive neighborhoods (chiefly the

beach areas known as Ponta Negra, Praia do Meio and Praia dos Artistas). Local hotels initially operated by local business groups, now include important international chains. Leisure tourism is predominant, although hotels directed to businessmen and business events have lately being created. The Via Costeira (Coastal Route) concentrates, along 11 kilometers, 12 hotels of different sizes and categories, including the only 2 “five star” hotels in town. All those buildings are located by the seaside and comprise approximately 2000 rooms. That is the area focused by this study.

This study is based on a research regarding hotel architecture in Natal in 2000 [4], added of data pertinent to the effects of the serious energy crisis occurred in Brazil between May and December 2001, which included mandatory power consumption reduction imposed to all consumers (residences, industries, commerce and service) by the Federal Government. That crisis had a significant impact on the power consumption behavior of the whole population and changes in the management of businesses in general, implying in the need to reassess the hotel situation by way of a specific research [5].

Utilizing the POE, detailed evaluations were performed at 6 hotels located on the Via Costeira and its immediate extension (Roberto Freire Av.). In view of the difficulties in comparatively analyzing accommodation means comprising so diverse features, some criteria were established in order to curb possible distortions: all hotels have practically the same geographical orientation, facing the ocean, with most accommodation units favoring the dominant wind, without significant barriers around them. The buildings are mostly oblong shaped, with a maximum of six stories, most of them scaled in accordance with the site topography, having similar building characteristics (only varying in interior design and finishing) including the lay-outs and accommodation unit dimensions (Figures 1 and 2).

Figures 1 and 2: Typical hotels in the area.

Two major hotels were selected (in excess of 200 accommodation units), presenting a luxury (five star) international standard, which shall be described as ”A" and "B"; 2 medium size hotels (between 100 and 200 accommodations), one of them is directed to leisure activities, having a “four star” standard, and recognized as an environmentally “correct” (hotel "C") and another “three star” hotel dedicated to leisure and business tourism (“D”); and finally, 2 small size hotels (approximately 50 accommodation units). One of them is dedicated to hotel personnel training activities, being for this reason quite famous for the quality of its services (hotel "E"). The other one is a typical economy class hotel ("F"), catering for businessmen and event participants. The aim is to verify how these hotels reacted to the energy crisis and what actions were taken for their adaptation to a new situation. The resulting data are presented as follows.

4. RESULTS

4.1. Environmental characteristics and comfort conditions

As widely known, architectural characteristics and its appropriateness to the local climate are fundamental aspects for a good natural thermal and luminous performance at buildings and, hence, to their electrical consumption. Most of the studied hotels display an oblong shape, oriented/turned to east/west (greater north/south axis) Although this disposition favors the sea view (east side) it also contributes to expose their larger façades to direct solar radiation, thus increasing the thermal gains inside the buildings. In consonance with their politics to favor the sea view, hotels tend to over use glass panes, which do not provide due protection and contribute to heat absorption.

The specialized literature indicates that hot and humid climates require large openings for wind penetration, which is a fundamental resource for the decrease of heat sensation. Crossed ventilation with openings for hot air exhaust would be the best indication. However, such device is seldom found in hotels, particularly in the rooms (among the studied hotels, only hotel “C” utilizes it, by way of a movable device on the door facing the circulation). Large

glass panes offer little privacy in the rooms, which are essentially resting places, thus requiring the use of curtains and glass films. In spite of the sea breeze, doors and windows remain closed, requiring the use of air-conditioning and artificial lighting within the rooms. One of the hotels has fixed windows, presuming it will not be necessary to open them, even in case of electric power failure.

Comfort problems were also detected in the lobby areas. In hotels “C”, ”D” and "E” the lobbies are provided with natural ventilation, while the other ones utilize closing elements made of metal or concrete structures and many glass panes. Despite the blue sky and ocean view, these spaces are turned into real “hothouses” in case of failure of the artificial cooling system.

Another problem is in the kitchen. At hotels it operate in three shifts, utilizing heat-generated equipment which is generally dark and hot. The mechanical exhaust system does improve this uncomfortable situation for the staff working there. Only at hotel “E” (a model hotel school) the kitchen is comfortable (clear and well ventilated).

In general, the constructive material used in the buildings doesn't contribute to better comfort conditions, specially the outrageous use of armed concrete and glass. It is a reflex of the international architecture that predominates in the hotel design, without respect for the climate particularities. Notwithstanding the fact that it has been demonstrated that this type of architectural design is not appropriated to the local characteristics, it is continuously utilized. The architectural formalism is such that one of the hotels has an entire apartment wing facing the side which is opposite to the dominant wind direction, just for the sake of the view offered by its beautiful water park. Consequently, the use of artificial conditioning becomes mandatory and not optional, as it should be. Considered by many as a symbol of status and comfort its mandatory utilization is favored by the hotel regulating legislation [6] for accommodation means graded above three stars.

All those factors about the building architectural form and use are determinant points for the inappropriate thermal and luminic conditions generally found in the studied hotels, excepting a few punctual samples. They hamper the achievement of energy efficiency, particularly regarding the use of air conditioning, thus demanding compensation actions or stratagems in order to manage the power consumption, as shall be demonstrated ahead.

4.2. Energy consumption and actions to reduce it.

In order to discuss this topic, hotels were sub-divided into three categories, according to their energy consumption rate in January and February (high occupancy season) 2001, thus defined:

- Large consumers – hotels "A" and "B" which consumed more than 10 kwh/m2/month (total consumption over 200,000 kwh/month);
- Medium consumers – hotels "C" and "D", which consumed between 7 and 9 kwh/m2/month (total consumption between 50,000 and 100,000 kwh/month);
- Small consumers – hotels "E" and "F", which consumed under 6 kwh/m2/month (total under 30,000 kwh/month).

In spite of the evident diversity in their demands, the Brazilian Government ordered the hotel industry to reduce their power consumption by 20%, between May and December 2001. Utilizing contrivances of various sorts (Table 1), all hotels managed to reach such goal. It should be emphasized that hotels B and C resorted to the use of solar energy (collecting plates). Such systems had been installed before the outbreak of the energy crisis, so that, in spite of already having a relatively lower power demand, they had to cope with the challenge of reducing it to a still lower level.

The options for decreasing power consumption (Table 1) have been grouped in six types: (i) general control of power use, (ii) equipment acquisition or replacement, (iii) modification of installations, (iv) lighting, (v) air conditioning, (vi) water heating, (vii) power cuts by sections.

In addition to that, the interviews demonstrated that success of any economy target also depended on the conscience of the staff members concerning the need for their active participation in detecting and eliminating unnecessary load points.

Table I: Energy economy actions

Adopted measurements		**Consumers**		
Action	**Type**	**L**	**M**	**S**
General equipment	Power management	1		
	Use diesel fuel generator in PT	2	1	
	Change low efficiency equipment	3	4	
Electric installations	Check automatic circuit-breakers in rooms	4		
	Install automatic circuit-breakers in rooms		2	
	Check electric installations		2	
Air conditioning	Turn-off air conditioning in PT		2	1
Water heating	Remove water-heating sources		4	
	Turn-off water heating in PT			3
Lighting	Substitute light bulbs for more economical types		3	2
	Reduce lighting points in exterior/common areas		3	2
	Reduce lighting in common areas		3	3
Circuit-breaking	Turn-off power in empty rooms			1

- figures indicate efficiency evaluation (from 1=best and so on);
- PT = peak time (period of highest power consumption, between 5 and 8 p.m.)

To reduce the electricity consumption, large consumers were preoccupied with: general actions (incorporation of energy management system), equipment replacement (more efficient diesel-moved energy generators, change of electrical kilns and stoves by others, that use gas) and installations modifications (careful electrical revision in the sectors of more consumption). Although these actions, particularly the former, were able to provide a fast

achievement of the proposed targets, they represented a significant initial investment. In such cases, interventions in the lighting system was considered to be unnecessary, due to the fact that they represented only 6 to 8 % of the total power demand in those buildings.

Regarding the medium size consumers, the main actions devised to curb consumption concerned the equipment, control of air conditioning use (turned-off at peak time), water heating (elimination of heating points at sinks and counters), installations (installation of automatic circuit-breakers in the rooms) and lighting (replacement of light bulbs by more economical types, elimination of lighting points, lights at common areas and external spaces kept on for a shorter period).

For the minor consumers though, many of these practices proved to be economically unfeasible, therefore, the consumption reduction was obtained by way of actions such as turning off air conditioners and water heating devices at peak times and modifying the lighting system.

Two years after the crisis, it is noticed that in the organizations classified as minor or medium consumers, power consumption rates have again increased by approximately 10%, although not reaching the prior levels. This is certainly due to the actions taken at the time, although some actions have been kept to this date, others have been cancelled because they resulted in less comfort for the guests. On the other hand, the large consumers still keep their costs reduced to this date, and sometimes reduced to an even lower level, due to the magnitude of the actions taken. Such decrease, however, concerns only the energy supplied by the local power utility, since the operation of these hotels is increasingly more dependent on non-renewable energy sources, such as diesel fuel (generators) and butane gas (kitchen and water heaters).

However, even after the power consumption contention period was over, due to the lack of a specific energy code, the local power utility has contracted individual agreements with different companies defining a point-to-point load demand, above which the cost of the service is considerably raised. In view of this, these organizations have avoided consumption above the agreed amount, by simply programming the best time to turn their most powerful motors on and utilizing secondary sources during peak utilization periods. Due to such actions, electric power comprises only 5% of the total expenses of the hotel while at the medium and small hotels this percentage varies between 7 and 15%.
In all cases, however, artificial cooling (central, mini-central and individual units) represents the “great villain”, consuming between 30 to 40% of these resources.

This kind of evidence increases the importance of the architectural design role as a tool to reduce or prevent the need for artificial cooling, what could decisively decrease these costs. However, it should be pointed out that in no instance, architectural actions (construction modifications) were adopted to conform to energy crisis. When inquired about this matter, some managers cited the difficulties for the performance of structural modifications in the buildings due to cost and time constraints and the inconveniences caused to the guests.

Another factor to be seriously considered is the afore mentioned EMBRATUR regulation requiring that guests must be offered the option to use air-conditioning in the rooms of hotels classified as 3, 4 and 5 star accommodations and requiring artificial cooling in the lobbies and common areas at 4 and 5 star hotels, even when concerning leisure, seaside hotels. According to architects who have been inquired about this, such demands have had a decisive influence on hotel architectural designs due to the fact that in order to invest in cooling devices hotel owners reduce the funding for other details, and sometimes simply discarding solutions that could be environmentally more adequate.

4.3 Users behavior

In this context, the investigation of guests’ habits was fundamental. The survey was concerned with users habits, comparing the way they performed their activities at home and at a hotel. It should be pointed out that most guests came from more temperate regions in the country (south and southeast) and from abroad (Italy, Portugal, Argentina) and only 20% of these lived in the Brazilian Northeast. The analyzed items included the use of air conditioning, artificial lighting and hot showers.

Concerning artificial climatizing, 11.67% of the guests informed that they did not use air conditioning in the rooms, and 56.67% gave an affirmative reply to this question. On the other hand, 50% of the guests informed that they had that equipment at their homes, using it frequently or occasionally. Cross referencing this information (Table 2), it is noticed that 58.4% of the guests change their habits when staying away from home (shaded area in the table). Among those who do not have such devices at home, 43.2% use them when staying at a hotel.

Table II: Use of air-conditioning at home and at a hotel.

AIR-CONDITIONING IN A HOTEL	AIR-CONDITIONING AT HOME		
Usage Pattern	Yes	No	Total
Always	35.0	21.6	56.6
Occasionally	10.0	21.6	31.6
Never	5.0	6.6	11.7
TOTAL	50.0	50.0	100.0

Concerning shower heating, although 13.3% of the sample informed that they preferred cold showers, most of them make an option for warm or hot showers. 50% of those stated that they keep the same habits as at home (see table 3, particularly the shaded area). It should be noticed, however, that a great deal of interviewed guests stated that they tend to lower the shower temperature (36.6%) when staying in this region.

Table III: Shower/bath temperature at home and in a hotel (in %).

SHOWER/BATH IN A HOTEL	SHOWER/BATH AT HOME			
	Hot	Warm	Cold	Total
Hot	6.7	6.7	5.0	18.4
Warm	30.0	36.7	1.7	68.4
Cold	3.3	3.3	6.6	13.2
TOTAL	40.0	46.7	13.3	100.0

Perhaps the option for a less heated shower is due to the origin of the visitors (temperate regions). Regarding the use of air conditioning, however, their lack of climatic adaptation is added to the poor natural ventilation within the apartments, the difficulties in maintaining privacy and security if doors and windows are kept open at night and even to a need to get the most out of their money, as indicated by one of interviewed guests:

"I am paying for this comfort, therefore I am going to use everything I am entitled to. If the cost of air conditioning, hot shower, sauna, Jacuzzi is included in the hotel price, then it is evident that I want to use these facilities."

Regarding that matter, hotel "C" seems to be in an advantage position. Using a market campaign that explores its ecological" orientation (was awarded a local prize for waste recycling) it has attracted a different public, which is demonstrated when the survey results are analyzed by hotel (Charts 1 and 2).

Chart 1: Use of artificial climatizing.

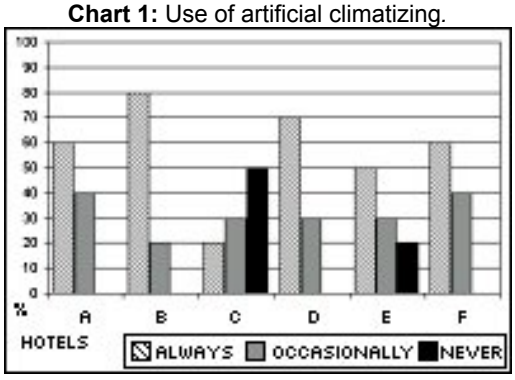
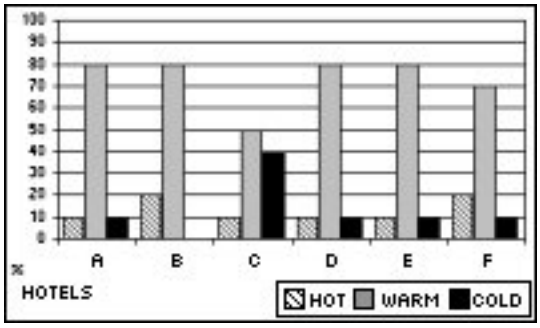


Chart 2: Hot shower



Such situation is repeated regarding the use of artificial lighting in hotel rooms during the day: 45% of the sample answered that they never used it while 16.7% informed that they always turned it on. In this case the design of the window frames and the type of curtains make a difference. Also important is the chambermaids attitude when by leaving the curtains open, they let natural light into the rooms, thus precluding the guest's tendency to turn the lights on right after entering the room.

FINAL CONSIDERATIONS

In general terms, it may be said that despite the fact that the Brazilian power crisis demanded a considerable consumption reduction and that this was a nationally achieved goal, in the hotels evaluated here, that reduction was either of a palliative nature actions or due to the substitution of sources, so that little was changed in terms of total power utilization. Therefore, specific characteristics of each category being considered, electric power consumption in these establishments is still relatively high, that is, they continue to present low energy efficiency standards.

For elaborating a diagnosis that allowed for such conclusion, the development of POEs proved essential, thus indicating that although this consumption is closely related to the guests' behavior patterns, it is directly determined by architectural design features and by the legislation concerning hotels. In several of these buildings, the visual appeal of the grounds is emphasized at the expense of environmental comfort attributes (inadequate orientation, lack of solar protection in façades, and other factors), cross-ventilation is not generated in hotel rooms and there are numerous directly insulated glass panes. Hence, for achieving actual energy efficiency, structural/constructive reforms in buildings would be necessary, some of which would be very simple ones (change of window frames), others more complex/costly.

Such findings reinforce the importance of architectural design and point towards the need for implementing an Energy Code to parallel that, which regulates construction in general for every Brazilian municipality, so that plans are only approved, especially when concerning complex buildings, if within a maximum consumption limit defined for that location and activity. Furthermore, in view of the large potential of renewable energy sources – notably solar and wind power – in the Northeast of Brazil, it is necessary that that the use of such alternatives by the hotel industry be appropriately explored and encouraged.

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