

Post-Occupancy Evaluation of a Scientists Village Complex in the Desert – Towards a Comprehensive Methodology

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ABSTRACT: Post Occupancy Evaluation (POE) is a platform that allows the systematic study of buildings once occupied, so that lessons may be learned that will improve future design. This paper reviews a rare case of cooperation among the different stakeholders in a complex, which includes different accommodation and facilities, and is located in the heart of the Negev Desert Highlands in Israel. The paper shows how different methodological approaches may be combined in POE and how the results may inform the different stakeholders towards upgrading the project.

Keywords: desert architecture, energy consumption, IAQ, IEQ, POE

1. INTRODUCTION

Whereas everyday commodities are being checked and rechecked, serviced and adapted for better performance and customer satisfaction, buildings, which are disproportionately more expensive than cars, audio and other electrical and electronic equipment, are very rarely revisited and reassessed for necessary modifications. This lack of evaluation and study stems from numerous reasons. Under such conditions, every single building remains a unique specimen, design mistakes are repeated, and when some re-evaluation of the building as an end product is undertaken, it is often based on non-systematic troubleshooting.

In comes Post Occupancy Evaluation (POE), a platform that allows the systematic study of buildings once occupied, so that lessons may be learned that will improve future design. The tools employed in POE include plan analysis, monitoring of Indoor Environment and Air Quality (IEQ, IAQ) and thermal performance, and surveys including walk-through, observations, user satisfaction questionnaires and structured interviews. POE researchers are often regarded with suspicion and even hostility, since their work may cause friction between different stakeholders (among them project architect, client, owner, manager and user) and between these and the authorities, expose some of them to liability lawsuits, and others to potential demand for upgrades investments.

This paper reviews a rare case of cooperation among the different stakeholders in a complex, which includes different accommodation and facilities, and is located in the heart of the Negev Desert Highlands in

Israel. The paper shows how different methodological approaches may be combined in POE and how the results may inform the different stakeholders towards upgrading the project.

2. A DESERT CASE STUDY

The case study presented here is the Albert Katz International School for Desert Studies Scientists Village, which includes different teaching, administration and accommodation facilities.

Table 1: Mean daily maximum and minimum temperature, and solar radiation in Sede Boqer.

Season	T _{max} [°C]	T _{min} [°C]	I [kWh/m ² /day]
Summer	32°C	17°C	7.5
Winter	14.9°C	3.8°C	3.5

2.1 Location and Climate

The project is located in the heart of the Negev Desert Highlands in Israel (NL 30.8°, EL 34.7°, altitude 456m above mean sea level). The region is arid, and its climate is characterized by cold and mostly sunny winters, and hot and dry summers with cool-cold nights. Diurnal temperature fluctuation is wide throughout the year, except during heat spells that bring a rapid temperature rise well above the average maximum for the season. Average annual rainfall is 85 mm. Table 1 sums the mean daily maximum and minimum air temperatures and solar radiation on a horizontal plain.

Such conditions provide numerous possibilities for the design of free-running buildings, based on solar heating in winter and cross ventilation, evaporation and radiation for cooling in summer [1].

2.2 The Design

The project was designed by Rahamimoff Architects and Urbanists for the Blaustein Institutes for Desert Research (BIDR). The complex includes an administration core, classrooms, and additional facilities (Fig.1). Its main bulk comprises 84 single units (floor area 28m² each), 10 couples units (34m²) and 13 family units (55m²), housing the School's research students. The design was informed by contemporary research in building adaptation to desert conditions. Buildings are made – from in out - of poured concrete, a layer of rigid insulation, and dressed stone rendering. Ceilings and roofs are made of poured concrete with external rigid insulation and terrazzo tile flooring. Windows are double glazed and fitted with external rolling shutters. So are south facing glazed French windows. North facades are kept practically opaque except for minimal fenestration needed for ventilation and light. Although small in overall size, most of the units are split level to allow better stack and cross ventilation. The two-storey units are fitted with a wind chimney intended to facilitate forced night ventilation in summer.

The project was commissioned at the beginning of the winter semester of 2004-5. As ambient winter temperatures dropped, the new tenants complained about low indoor temperatures. This seemed relatively strange as most of them had been housed up to that moment in mobile homes, with negligible thermal mass, single glazed windows, and negligible possibilities to passively condition them. It was thus decided to undertake a POE study in an attempt to understand the source of such discrepancies between a doubtless high standard of design and construction, and the complaints.

3. TOOLS AND METHODS

A series of studies was planned with the cooperation of the owner (BIDR), the user (students and faculty) and the architects, in an attempt to study the project, its use and operation; to identify possible discrepancies between intended and actual operation modes and the reasons for these; and to suggest possible adaptations and fine tuning.

POE included a series of monitoring periods in different parts of the complex, including air and surface temperatures, relative humidity, light intensity, energy consumption, and qualitative observations of air infiltration. These were considered alongside data obtained through user surveys, observations and questionnaires, focusing on operation issues, as well as potential discrepancies between the need to ensure thermal comfort by passive means and privacy issues. The project was undertaken as part of an education exercise within the Modern Bioclimatic Architecture module of the School, and the results were discussed with BIDR representatives and the architects.

This paper is a first publication of the project and its interim results.

4. MONITORING

Measurements were undertaken in two different types of student accommodation units - a single storey and a split unit (Fig.1-2). To observe the thermal performance of buildings as a function of their design properties, without auxiliary heating or internal loads, unoccupied units were measured. Buildings were heated passively; south facing shutters were opened at approximately 08:30 in the morning and closed at approximately 16:30 in the evening, between Nov.25-Dec.9, 2004. Locations of monitoring equipment are shown on the floor plans and in the sections of the units (Fig.2). In addition to thermal monitoring the possibility of air leakages in the units was undertaken with the help of smoke tests, which were photographed. An additional monitoring period included auxiliary heating by use of a convector automatically operated between 19:00-24:00. This last series included air as well as surface temperature measurements in a two-storey unit. Ambient data obtained from BIDR's Dept. of Solar Energy and Environmental Physics weather station included air temperature, relative humidity, global and diffuse radiation. Cloudiness was identified and quantified by the decreased difference between diffuse and global radiation.



Figure 1: Scientists Village layout and location of monitored (circles) and surveyed (oval) units.

In both cloudy and partially cloudy periods maximum indoor temperatures remained relatively low compared to the rest of the days. Cloudiness affected directly the drop of indoor temperature. However, on Nov.26-27, despite the fluctuations in outdoor temperature, temperatures in both units

constantly fell. Even though full cloudiness seems to have a major effect on this outcome, the fact that both units had just started to be operated (opening and closing shutters for passive solar heating) should also be taken into account. This indicates that both units started the appropriate operation period with little energy stored, thus their thermal mass is still cold from a previous period of non-operation.

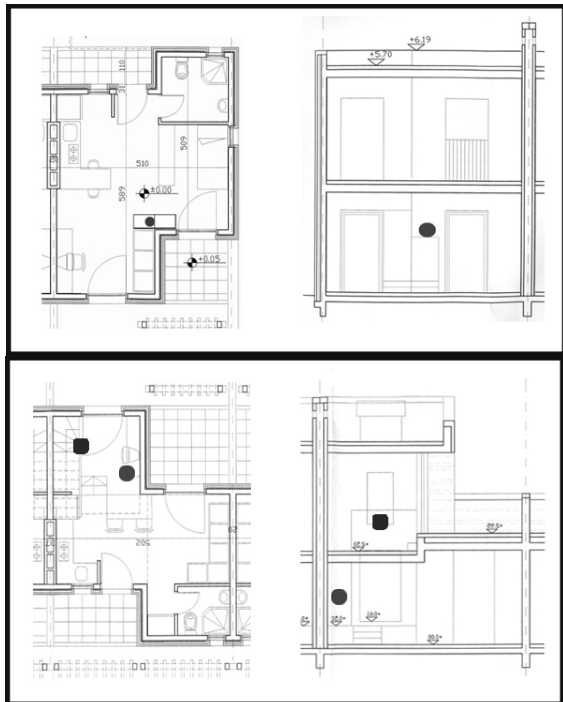


Figure 2: Up: floor plan and section of single storey unit. Down: floor plan and section of two-storey unit. Dots indicate location of monitoring equipment.

An analysis of the daily maximum temperatures in and out (Fig.4) showed that during cloudy days (Nov.26-27, Dec.8) or when shutters were opened late (11:30, Dec.5), indoor temperatures dropped. Indoor temperature in the single storey unit was 3.56°C higher (average of 13 days) than outdoor temperatures, while in the two-storey unit's ground level it was 1.25°C and in the upper level it was just 0.07°C higher than outdoor temperatures.

The daily amplitude showed that whereas the ambient daily fluctuation reached 13.18°C (maximum), amplitude in buildings staid between 3.27°C (single storey), 1.76°C (two-storey ground), and 1.56°C (two-storey upper). Daily minimum temperatures in both units staid well above the outdoor ones, with 13.3°C absolute indoor minimum compared to 2.7°C absolute outdoor minimum. Thermal mass and insulation appear to be performing well enough at night preserving the heat that was gained and stored in the daytime. Averages calculated over a period of 13 days show that night indoor minima are higher than the ambient by 10.4°C (single storey), 8.98°C (two-storey ground) and 7.99°C (two-storey upper).

In an additional series of measurements, indoor air and surface temperatures were measured in a two-storey unit between Dec.30, 2004-Jan.01, 2005, with backup heating (2 kW convector) automatically operated between 19:00-24:00. Measurements show that surface temperatures are close to indoor air temperatures with a maximum deviation of no more than 0.5°C between the highest and lowest temperatures at any given moment, indicating that walls and roof are well insulated. Moreover, the auxiliary heating introduced was of marginal influence due to the high thermal capacity of the envelope and internal horizontal and vertical partitions, thus preventing the building to heat up.

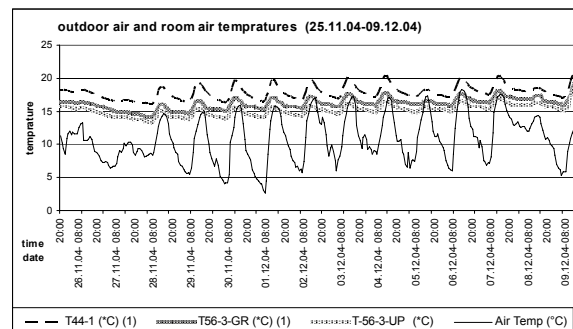


Figure 3: Outdoor and indoor temperatures in two units (Nov.25-Dec.9, 2004).

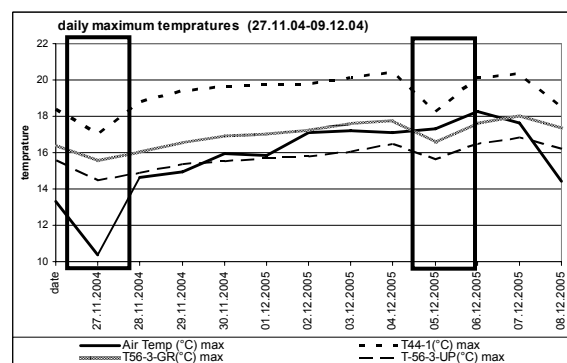


Figure 4: Daily maximum outdoor and indoor temperatures (Nov.25-Dec.9, 2004). Boxes indicate significantly lower indoor temperatures.

Smoke tests were conducted around fenestration, in order to check air infiltration. Air leakage was detected around windows and doors. Horizontal or downward smoke flow indicated inward airflow attributed to wind pressure. Flow patterns indicated that leakage is local and not continuous all around the window frames.

All of the above data indicated that despite the energy and climate informed design of the project, thermal performance was poorer than could have been expected. It was therefore decided to undertake a series of observations and surveys that would allow a better insight of the actual project operation and use.

5. OBSERVATIONS AND SURVEYS

5.1 Solar Access

Observations (later on simulated by CAD tools) showed that the southern façade articulation in terms of volume relations limited the actual solar penetration into the units. Protruding volumes (as may be seen in the two plans in Fig.2) shade recessed south facing glazing, esp. that of the living rooms. Thus, though the overall south glazing area was assumed to be sufficient for solar gains in winter time, the actual solar access was reduced significantly. An additional hindering factor first observed and then simulated stemmed from the relatively thick wall section and the relative position of the glazing (on the inner wall plane). The wall section comprises (from in out) 17cm concrete, 4cm extruded polystyrene, and a 5cm rendering of stone. Thus, though not much thicker than a conventional wall, such a section shades a certain percentage of the glazing positioned on its inner plane, thus effectively lowering its overall size and the amount of solar radiation admitted.

5.2 Unit Operation

The passive house needs an active tenant. This is an old dictum dating back to the 1970s. Elaborate and good as the solar design may be, it cannot function properly unless appropriately operated. In the specific case, insulated shutters of south glazing are supposed to be opened in the morning and closed in late afternoon, this in order to prevent unnecessary heat losses. It was therefore decided to observe the actual operation of units, namely the operation of south shutters. The observations were made on morning, noon and evening, over a period of eleven winter days (Dec.2004). Theoretically only morning and evening observations would have been enough, yet knowing the irregular daily routine of the occupants (students) it was felt the additional middle-of-the-day observation might be required.

Three rows in the northern part of the complex were included in this part of research, with 40 two-storey units, of which 34 were inhabited at the time of the research.

5.3 Privacy

An additional factor potentially hindering solar admittance may be attributed to perceptions of privacy and exposure, esp. since most of the south glazing faces paths, and is exposed to passers-by as fences dividing private from public open space were not constructed (despite their being part of the plan). The sense of privacy and security is strongly connected to the occupants' co-operation in the proper operation of a passive solar building, esp. a house, and definitely as far as the extent of operation of shutters and windows is concerned [2].

Architectural design has a major significance and role in creating the feeling of one's control and confidence inside the house. A major design tool in achieving privacy is hierarchy of spaces ranging from public to intimate space. A succession of spaces on different hierarchical levels is one of the tools used to distinguish between public and private, and to control social interaction and visual exposure [3].

One's sense of privacy in and control over the inner space is also affected by windows. It has been found that windowsill height under normal, which is found between 0.8-1m, will severely harm privacy [4]. Blinds are considered to be a solution to the problem of privacy in passive solar buildings. In the specific part of the project the south façade of the units is the main one, and includes roughly 60% of the glazing on the ground floor area. This includes a big glazed French window connecting the living room to a porch and a 75/160 cm window with 25 cm high windowsill above the floor in the working area. All windows and glazed doors have outside rolling shutters.

It was assumed that the privacy issue might have three different aspects, all of them potentially affecting the proper operation of the units:

- *gender-based perception* of privacy and needs;
- *location of buildings in relation to other units* – the southern of the three rows observed faces the back façade of classrooms and administration, whereas the other two face entrances of neighbouring building
- *location of buildings in relation to paths* - tenants will have less privacy in apartments located on junctions of walkways and main paths.

To clarify such issues questionnaires were distributed among tenants. These included closed-ended question about awareness/knowledge of the unit operation, satisfaction from the different spaces in the unit relating to thermal comfort as well as privacy issues and daily routine. Out of the 31 tenant students who participated in the survey, 15 were female and 16 were male, all were single, between the ages of 25 – 35.

5.4 Questionnaire Results vis-à-vis Operation

The working assumption was that male occupants would ascribe privacy less importance compared to their female neighbours. Indeed, 62% of the male graded the importance of privacy in the three first places out of nine categories compared to 73% of the female. Most of the 15 female respondents graded their general sense of privacy in their apartments from very bad to excellent, most of them graded it 'good', 'ok' and 'bad'. However, the answers are distributed through the range from "very bad" to "excellent". As for males, the answers are much more distinct, most of them having graded actual privacy as 'ok', with the range varying from 'excellent' to 'bad'.

Nevertheless, the operation of shutters by males and females reveals that females tend to operate the shutters much better than the males. Noon observations of the south façade indicate 70% open shutters in units occupied by female tenants whereas only 50% of the shutters of the male occupied units are open. This might be explained by the fact that female occupants tend to feel colder than male ones thus they have a good incentive to operate their shutters better during winter. The tenants reported they had difficulty in deciding whether privacy or thermal comfort was more important. These were equally highly graded, while the other parameters in this question received less weight in the occupants' priorities. The results reflect a real conflict between needs and choices.

A comparison of privacy perception between the three rows included in the survey, reveals that the only row where privacy was graded as 'excellent' is the southern one. However, the number of people that replied 'excellent' and 'bad' is equal in this row, and additionally there is one reply of 'very bad'. That might be explained by the fact that the row is not homogeneous regarding each unit's relative location, a fact to be elaborated further on. The similarity of the answers between the north row and the middle row as opposed to the southern row supports the assumption that the south façade is the indicator for the feeling of privacy. The middle and north row are located differently, the north one facing a large open space to its north side, yet in both rows the south façades face the next southern row and walkway. The south façade of the southern row is facing the back wall of utilities, therefore replies of occupants in it are different.

Yet the observations show there is no difference between the rows in operating the shutters. It was originally assumed, based on an analysis of the layout and the questionnaires, that the southern row will show better operation of shutters (higher percentage) due to their being perceived as enjoying more privacy. However, it was found that there is a clear tendency of the same operation patterns during the day, irrespective of the location of the row.

Units located on a main junction of walkways or on the 'drainage point', where all walkways meet leading to a central area/direction, were assumed to be in a bad location regarding privacy. Units located at the dead-ends of paths and those facing the back wall of the facilities were marked on the layout plan. Interviewees were asked to grade their satisfaction from privacy in the working space, right next to a big glazed window, where tenants spend a lot of time.

Tenants of units located on the main walkways and junctions perceive their privacy as relatively poor, as opposed to tenants of units living in the more remote western section and those in the southern row facing the blocked wall of administration and classrooms. The latter consider their units as of a relatively good degree of privacy, grading privacy as 'excellent'. It should be noted that most of the tenants living in the "good" location are male, a fact which probably affects results. Observations of shutter operation show an opposite trend to what might be considered logical: tenants of units on the main walkways and junctions perform slightly better in relation to the operation of the other units.

This opposite trend remains when checking the operation of the shutters with respect to the priorities of thermal comfort and privacy. Tenants who stated thermal comfort as their first priority, are operating the shutters slightly worse than those declaring privacy is the highest priority. Some of those grading thermal comfort as most important and claiming to be aware of proper operation practices, left shutters closed throughout the day. No clear trends were found. The observations show a varied operation of the shutters: some tenants perform very well, while others do not open their shutters at all. There seems

to be little or no correlation between stated priorities and actual unit operation.

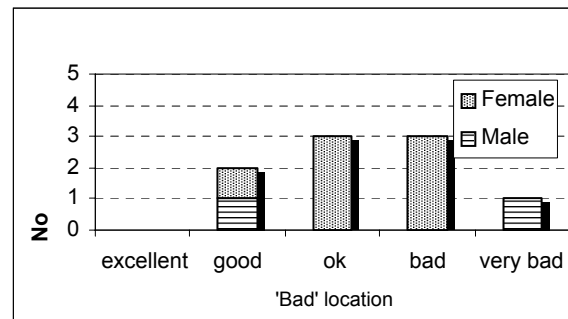
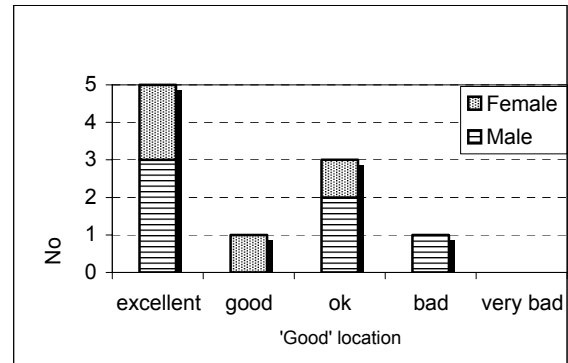
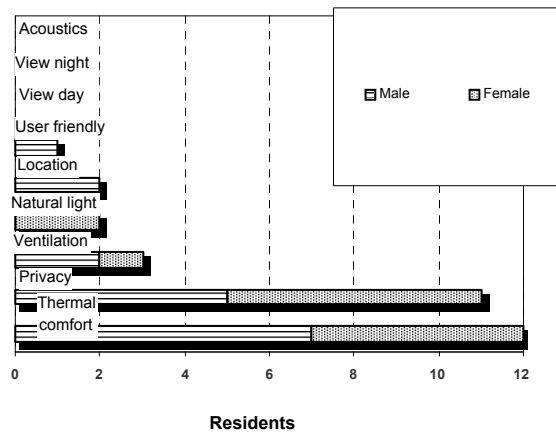
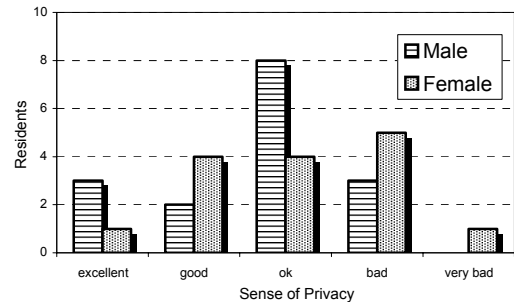


Figure 5: Questionnaire results. Top to bottom: privacy perception by gender; tenants' priorities by category and gender; satisfaction from degree of privacy in the working space, according to "Good" (third from top) and "Bad" location of unit within the complex, by gender.

6. CONCLUSIONS

6.1 Design, Construction and Operation

Although the project has followed the guidelines and concepts of environment informed, energy conserving design, there are several issues that have not been addressed or solved. First of all, the southern façade articulation and the relation of wall thickness and glazing position have created a lower than optimal solar access and admittance, thus lowering the buildings' ability to heat up sufficiently. Secondly, the thermal mass provided by the concrete envelope and internal partitions seems to be too high to allow adaptation of indoor temperature to needed levels, even with the use of auxiliary backup. Infiltration, esp. through the wind chimney on the roof, causes heat losses, which only worsen indoor conditions.

Having said that, it is important to clarify a number of issues and stress the advantages of the project. The units were commissioned shortly before monitoring. The period preceding the monitored one tended to be unusually warm, thus units were operated under summer mode, even as days were getting shorter and nights colder. Thus, the beginning of monitoring, coinciding with a sudden drop of temperatures, found the units' thermal mass significantly colder than should be under regular conditions. Considering the overall temperature uniformity as indicated by the negligible differences between air and surface temperatures, one may say with a high degree of confidence that such units can provide indoor thermal comfort if properly operated on a continuous base over seasons. However, such operation proved to be less than self-evident.

6.2 Design, Privacy and Operation

Surveys did not establish a significant correlation between privacy and proper operation of the units. Questionnaires showed that privacy and thermal comfort are equally important. However, the observations did not match the questionnaire results and cannot reflect the inverse relationship between the perception of privacy to the way tenants operate their units and shutters. 29 tenants stated they operate their units as should, yet observations show great variability. The observations did show a clear trend in lack of shutter operation (50%), which may stem from a compromise between contradicting needs - privacy and thermal comfort. Lack of fences between private porches and public walkways may have also affected perceptions of privacy and thus operation of shutters, adversely affecting solar gains and thermal comfort within units. Further research is needed in order to better understand behaviour patterns.

The Scientists Village units are of a quality and standard much higher than those common to student accommodation. These create high expectations, which in turn cause tenants to be more critical than usual. The design was that of a passively heated and cooled complex, assuming the tenants' full cooperation in appropriately using and operating the units. The surveys though showed that not all students living in the complex units feel committed to

the idea of passive heating. Doubtless, instructions (provided to each new tenant) are not sufficient for the tenants to commit themselves to the idea. Whereas the "carrot" of a more comfortable living unit is not enough, the "stick" of electricity bills higher than the units provide for does not seem to provide a significant incentive. It might be necessary to present the rationale behind and potential of the project to each new wave of tenants. Energy efficient building is hardly just a technology – it truly is a way of life and a tool to achieve a bigger goal, thus this kind of building should be nurtured by education and not left to self-explanatory tools.

We see the potential of these dormitories to serve not only their tenants but to assist as an existing model for establishing future standards for buildings. Overall, we think the importance of this research is in its stressing the vital nature of the privacy issue in such projects, where a big portion of the building is transparent. Dealing with privacy solutions is essential to prevent a key obstacle in the operation of the energy efficient building and eliminating this parameter from dictating the indoor climate.

Lastly, it is important to stress that unlike most other POE cases, this project enjoyed the full cooperation of all stakeholders: the architects regarded POE as an important feedback tool to allow them to evaluate the actual performance of the project and correct possible flaws; the BIDR authorities saw POE as a tool allowing the study of the reasons for student tenants complaints, aiming at possible upgrade and retrofit that could save energy and money in the long run and limit complaints; the tenants considered the project as a possible way of solving everyday problems, and the base for a constructive dialogue with the architect and the owner.

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