Paper n° 425: Development of an interdisciplinary approach to the assessment of occupant-(building-environment) interactions: Case study of an atrium housing block in warm climates

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Abstract

Recent reviews of studies dealing with comfort research methods have highlighted a great turn in the approaches developed to investigate the indoor (thermal) environment and the complex occupant-building interactions. They come to the conclusions that the occupant's behaviour towards an optimum (thermal) comfort is not only objective, physiological and rational, quantified by thermal index and heat balance models, but also embodied with intricate subjective, psychosocial, and cultural aspects, perceived through post occupancy evaluation and user's survey.

The object of this paper is to show how developing an interdisciplinary approach to the assessment of indoor (thermal) environment confronted to occupant's preferences reveals to be a complex exercise, when the occupant's behaviour redirects some assumed rational scientific beliefs, leading the research towards a more environmental – behaviour problem.

This paper reports a post-occupancy evaluation of a retrofit atrium housing block located in the dense urban centre of Algiers. An interdisciplinary approach was developed aiming to assess user's perception and satisfaction of indoor thermal comfort, not only combining objective approach through in situ measurement campaigns but also subjective appraisal through user's survey and observations. As a consequence, assumed beliefs of rational responses of an uncomfortable indoor environment found in atrium buildings, especially due to thermal stratification during summer comfort, were soon revised by the performance of occupant's behavioural actions to achieve social comfort in terms of intimacy and wellbeing.

Some answers from the user's survey validated results of the assessed indoor comfort in terms of the evaluation of the thermal environment, PMV indices and adaptive models, but others show that tolerance to thermal discomfort was less essential than achieving response to social wellbeing as a socio-behavioural phenomena.

Keywords: Interdisciplinary approach**, c**limatic parameters; aspects of comfort, behavioural adaptation,

1. Introduction

Generally research dealing with atrium buildings starts by developing the impressive effect such type of transitional space generates in term of functional and aesthetic assets, but soon they put forward the environmental problem that could be perceived such as thermal stratification, the inadequacy of daylighting distribution, indoor air pollution and sound propagation. To assess these environmental inconvenient, post occupancy evaluations are often developed, coupling physical assessment and user's surveys. The object of this paper is to show how developing an interdisciplinary approach to the assessment of indoor (thermal) environment confronted to occupant's preferences reveals to be a complex exercise, when the occupant's behaviour redirects some assumed rational scientific beliefs, leading the research towards a more environmental – behaviour problem. At the end this paper presents results from an on going research that deals with the evaluation of the indoor environment of an atrium

2. Work background

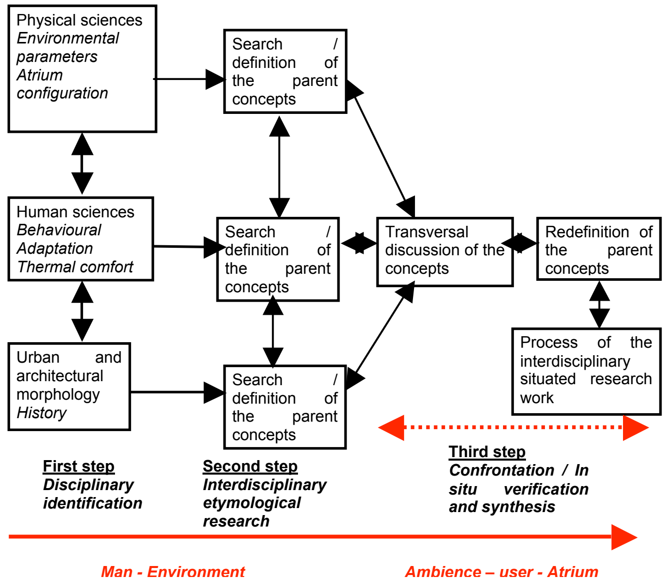
Atrium space is often described as a free running intermediate space, with an environment lying between a climatic influencing world outside and a closely controlled realm inside, (Baker, 1988). This state confers to the atrium space a complex and dynamic physical environment. This complexity is reflected in the developments of so many methodological approaches to evaluate with accuracy its environmental characteristics and energy performance. Some are based on monitoring procedures alone, [1], other combine in situ measurement with simulation either to validate the in situ measurements findings, or to develop parametric studies through computer

programs such as CFD, [2, 5]. Although the atrium buildings are felt to be ill adapted to warm climates, studies presents some well adapted cases located in Mediterranean climate, [2].
Thermal stratification as the principal characteristic of atrium indoor environment generates a multi zone air distribution and a vertical air temperature gradient. In warm climates the thermal gradients may vary from 2°C to 14°C, and air temperature under the glazed roof could reach at 4pm 40°C to 44°C, [2].
The thermal stratification depends on the atrium characteristics, such as, 1) The atrium shape and configuration, 2) The ratio of the glazed roof, 3) The openings locations and dimensions, 4) The walls thermal inertia, 5) The ambient climatic parameters such as solar radiation and air temperatures and finally 6) The occupation.
Although overheating is the principal environmental problem in summer comfort studies put forward the discomfort perceived during colder season at the bottom level of the atrium space particularly in deeper shape, mainly due to downdrafts of cold air. Even if including an atrium into a building is seen as a qualitative value for its functional, aesthetical and passive energy resources, not so many researches are dealing with indoor quality environment and user's perception and satisfaction of comfort. When occurring they all deal with post occupancy evaluation of retrofit buildings to estimate the users comfort sensations and space nuisances, [4].

3. Methodology

3. 1 Interdisciplinary work procedure as a theoretical approach

Because of the particular complexity of the case study in terms of contextual setting, building typology, historical assets and user behaviour, and in ad equation with the objectives of the thesis work, the approach is interdisciplinary, confronting different disciplines such as physical sciences, human sciences and finally urban and architectural morphology, as developed in the graph 1 below.
With the object to develop a complementary interdisciplinary research, the different parent concepts afferent to the general problem of the confrontation of the atrium indoor environment to the user's behaviour and satisfaction towards comfort are defined transversally in the different branch of knowledge; each branch being related to each other with the object to insure the epistemological sense of the concept
This constitutes the first theoretical step of the work process, as the second practical step deals with the verification in situ of the different defined concepts, identifying procedures and foreseeing results. These two steps of the process lead logically to what is so called an interdisciplinary situated research.
The graph n°1 below presents the interdisciplinary work process.



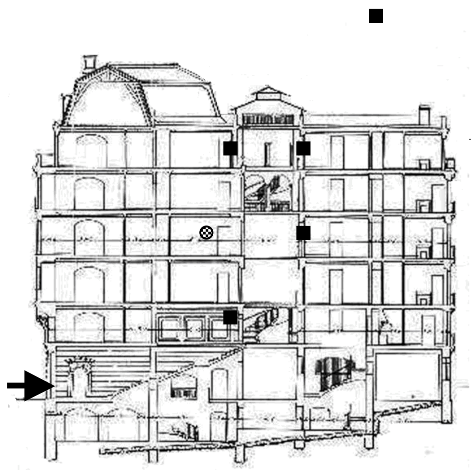
Graph 1: Development of the interdisciplinary approach

Different steps of the in situ verification are held in chronological order as follows:

3. 2 Monitoring and user's survey:

Two campaigns were held, the first in summer 2005 and the second in the early autumn 2006. Different procedures were developed:

3. 2 1 Environmental assessments
1) Concerning the indoor thermal environment 8 fixed HOBBO automatic stations were localised respectively one on the entrance door to the atrium, and two on each balconies of the second and fourth levels. One other station was localised on the terrace, to measure outdoor environment parameters, (refer to picture n°2). The measured physical environmental variables are, air temperatures, air velocity, relative humidity and solar radiation. The summer campaigns lasted 5 days, the autumn campaign 6 days. Data were measured every minutes but hourly exploitation was done. This can be seen on picture 2 and 3 below.



Picture 1: Cross section on the atrium building and probes location

2) To measure the central thermal stratification, a beam localised under the glazed roof was used to hang two bi function TESTO probes, one about the first level of the atrium and the second under the roof level. They measured air temperature and upward wind velocity. Due to the programming procedure of the TESTO, the measures were taken every minute during two discontinued days. This occurred during the autumn campaign.
3) To assess the thermal sensation of the occupants, physical variables were measured following the Class II requirements, (de Dear, 1998). The probes were held on a tripod at 1,1m high, coinciding with the survey campaign. The variables were, air temperature, globe temperature, air velocity and relative humidity. These were used to calculate the PMV index. This was performed during warm conditions in the autumn campaign.

3. 2 2 Comfort evaluation
In order to evaluate the comfort sensation and the behavioural adaptation, a user's survey took place in the different flats, regarding their location either on the atrium or on the different nearby streets. The questionnaires consisted of three sections, regarding:
1) The use and way of life dealing essentially with social aspects such as of privacy and intimacy
2) A comfort assessment of the different aspects of perception, satisfaction and adaptive actions to achieve comfort and
3) The personal data of clothing and activities to calculate comfort indices such as the PMV values and the adaptive comfort standard, ACS. Questions on sensation and satisfaction were rated on ASHRAE Standard 55 thermal seven point's scale, from (-3) to (+3).

4. Context and building

Dating back to the eve of the 20th century, about 1905, the case study is a free running housing block located in the dense urban fabric of Algiers, Algeria, (refer to picture 2).

Picture 2: localisation of the building in the dense urban fabric of Algiers, (Ref Google Earth)

Algiers climate is of Mediterranean type, with warm summer and mild winter. Peak temperatures in summer can reach 32,4°C in august, and 19°C in December. Due to its coastal setting, Algiers benefits from the cooling influence of the diurnal sea breeze. The combined effect of high air temperatures with high relative humidity in summer season leads to thermal discomfort.
The atrium is deep with dimensions of L*W*H equal to 12*6*21m. It is orientated diagonally to the north south axis, from northwest to southeast, allowing direct sunlight to the atrium by early morning to the façade facing east and late afternoon to the façade facing west. The ratio of glazing is 50%, as a result of an ill refurbishment in the 80s.

The natural ventilation is made possible by inlets and outlets found at the entrance door and under the roof, (refer to picture 3).

Picture 3: Upward view of the atrium, south east façade, autumn campaign 2006

5. Results and discussion

5. 1: Atrium Indoor environment / Evaluation of the thermal stratification

The thermal stratification is assessed through the evaluation of the air temperatures variations and the hourly values of the thermal gradients, Tg, between the fourth level, (16m) and atrium level. As presented in the graphs n°2 and n°3 below, the thermal gradient presents a great difference depending on the swing of the ambient air temperatures. As we can see in the summer campaign the Tg reaches 2°C at 2pm when the outdoor air temperature is of 28,1°C, whereas the atrium temperature is of 27,9°C. These results can be observed in the fig 2 below.

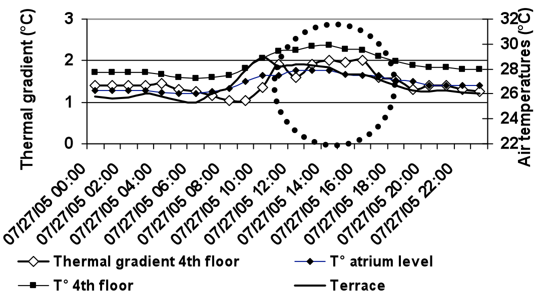


Fig 2: Summer campaign 05, thermal gradient and air temperatures, Tg = 2°C

On the contrary during the cold conditions of the autumn campaign, Tg is equal to 5,2°C at 1pm, when the outside air temperature is of 16,1°C and the atrium temperature is 17,7°C. This determines a stratification of air temperatures more important than those found in warm conditions, as shown in the graph n°3 below.

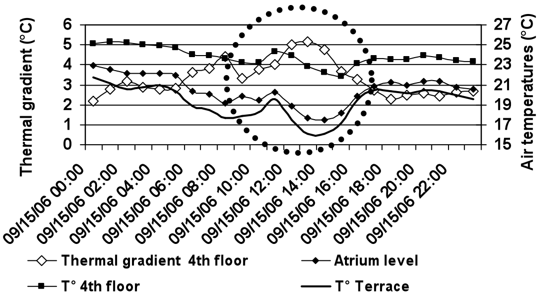


Fig 3: Autumn campaign 06, thermal gradient and air temperatures, Tg = 5,2°C

The thermal gradient is higher during colder conditions than these found during summer conditions; these findings counteract some results found in other studies as developed below.

We see that Tg values in summer conditions are not high compared to other findings in warm climates, where it varies from 2°C to 14°C depending to the glazed surface ratio, the height of the atrium and the openings at the roof level. The highest values are found in the case of non operable windows under the roof.

It is true that thermal stratified zones characterise the atrium indoor thermal environment with a heated upper zone influenced by solar heat gain trough the skylight and a lower zone which experiences less fluctuations, especially in summer comfort. But in colder conditions and reduced solar radiation, the air temperatures at the atrium level are slightly above the ambient outdoor temperatures.

We can say that the thermal gradient in summer comfort is less severe than in winter comfort, as reflected in the autumn campaign. This finding is validated with the satisfaction votes found in the user's survey, especially in winter season, as it is developed below.

5. 2: Evaluation of comfort from the comfort temperatures

We can also evaluate comfort or neutral temperature deducted from the adaptive comfort standard, ACS, [3]; this standard is proposed as an alternative model to the PMV based method in ASHRAE standard 55 for free running building, assuming that comfort / neutral temperature (T_{com}) is correlated to mean monthly outdoor temperature ($T_{a,ou}$t) by the equation (1) below

$$T_{com} = 0,31 * T_{a,out} + 17,8 \qquad (1)$$ [3]

According to Brager and de Dear, [3], we can determine the mean comfort zone band of 5°C for 90% of acceptability, ranging from the optimum comfort temperature, as revealed in the table1 below:

Table 1: Evaluation of the comfort temperature T_{com} and the comfort zone band

Campaigns	T_{com}, °C	Mean comfort zone band $T_{com} \pm 2.5$ °C
Summer	25,8	$23,3 < T_{com} < 28,3$
Autumn	25,1	$22,6 < T_{com} < 27,6$

From results in the table above, we can see that atrium space presents discomfort either in summer or autumn seasons depending on the location of the atrium zones. The upper zone presents discomfort in warm season whereas atrium ground level presents uneasiness in colder conditions. This finding is validated with the satisfaction votes found in the user's survey, especially in winter season, as it is developed below.

5. 3: Summer and winter comfort / Users satisfaction votes

Among other questions users were questioned about their satisfaction upon comfort experienced during cold and warm seasons; surveys were performed inside the flats, from atrium level to the fourth level. The answers were rated on a seven scale points from very satisfied, (+3) to very unsatisfied, (-3), with no comments at (0).

Concerning summer comfort, refers to graph n°4, they voted very unsatisfied, (-3) for 14% and unsatisfied, (-1) for 57%, whereas they voted neutral, (0) for 29%.The users of the forth floor revealed very unsatisfied in summer comfort, this state is in phase with the general belief that atrium building is in adapted to summer comfort. It was mentioned by users that satisfaction meant acceptability with the thermal conditions.

Concerning winter comfort, refers to graph N°6, persons living in the flats on the atrium level voted at 67%, unsatisfied, (-1) and expressed no comment, (0) at 33%. They identified the deep configuration of the atrium as a constraint to the provision of the solar radiation. We also observed that louvers on the atrium were often shut in search for privacy and intimacy.

On the contrary, concerning summer comfort persons from the atrium ground level, expressed no comment, (0), for 67%, and revealed satisfied, (1) for 33%. These results corroborate what has been found concerning the thermal stratification and air temperatures variation during both the summer and autumn campaigns above.

The vote from people living on the fourth floor shows also dissatisfaction for winter comfort. Even if they voted satisfied, (1), with 57% they also voted unsatisfied, (-1) with 14%, slightly unsatisfied, (-2) with 14% and finally very unsatisfied, (-3) with 14% These unsatisfactory votes are compromised as the voting persons lived in flats situated directly under the terrace and suffered from rain infiltrations due to derelict state of the terrace isolation.

5. 4: Comfort evaluation / PMV index

It is during the autumn campaign that the PMV index and the user's survey were developed. The thermal conditions of the room were measured after the questionnaire at a distance less than 1,5m. The PMV data were calculated through the RAYMAN 1.2 program, [6].

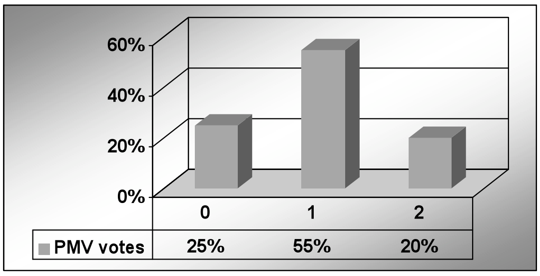


Fig 4: Distribution of MPV votes in ASHRAE standard

From Fig 4, we can see that the PMV votes range from neutral, (0) with 25% to satisfied, (+1) with 55%, than a total of 80% found in the central categories of ±1. This is slightly above what is developed in the ASHRAE standard 55-92, (1992), which says that the three central categories of the thermal scale between (±1) express at least 70% of people that feel their thermal sensation acceptable. 80% is also the average of people that have voted about their thermal perception at the time of the survey in the central categories of ±1, of the ASHRAE scale of seven points. This result corroborates the former PMV results.
Ranged by floor levels, as shown in Fig 5, we find that at the atrium level the PMV votes range in the average point of (+2) with 67% with an average value lying between 1,6 and 1,9. Concerning the fourth level the PMV ranges at 82% in the central categories of ±1.

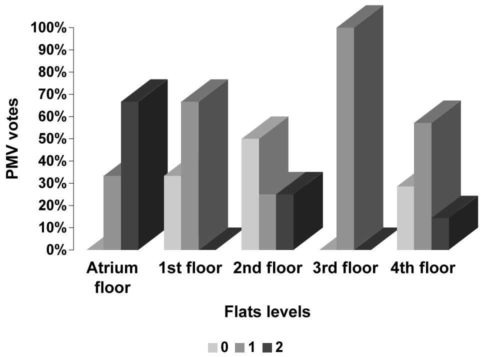


Fig 5: Distribution of PMV votes by floor levels

It is true that the survey has been dispensed during an intermediate season and thus may not be of value in assessing thermal sensation during summer and winter comfort but it nevertheless gives arguments for further investigations in the same field.

6. Behavioural adaptation and comfort

Although the results from both in situ campaigns corroborate the findings of the state of the art concerning the thermal stratification and the comfort indices, it is nevertheless worth speaking about the behavioural aspects of the research. It occurs from the user survey and the in situ observations that occupants performed some behavioural actions that counteract somehow the primary needs for lighting and cross ventilation inside the surrounding flats. This happens especially during summer comfort when it was observed that occupants rather prefer to achieve some wellbeing in their day to day living, in search of intimacy and privacy, depriving in some way their environmental comfort. The louvers remained closed even at the darkest moment of the day during the autumn campaign, retrieving the penetration of natural day lighting into the flats.
Some behavioural situations have even lead to some misleading in the monitoring process; as it was hard to make occupants put aside some of their behavioural habits of their day to day life, even though the object of the work has been well discussed with them, to achieve their cooperative help.

7. Conclusion

One objective of this paper is to determine the user perception and satisfaction about the atrium indoor environment, on the basis of the results of measurements campaign and users survey.
From the measurements campaign we found out that although a thermal gradient can be measured in the atrium, it is not so extreme comparing the results of other research. However, an interesting finding is that the gradient is more important during colder conditions compared to warm conditions. This state is also expressed in the user's survey answers about their satisfaction of the atrium indoor environments in both winter and summer. As they find it, cold in winter in the below flats and comfortable in the upper flats.
These results could be of importance to counteract the general assumption that atrium buildings are not adapted in warm climates due the thermal stratification found in summer comfort.
Another important objective of this paper is to verify to which extend one research can deal with a complex environment especially human, following an interdisciplinary approach. The experiment shows us that the complementary finding in each field of research, in terms of physical sciences, human sciences and finally architectural morphology, assume a complementary demarche to achieve the assessment of the complex relationship that entertains Man with his environment. Although one principal finding is that the human factor is the principal actor of an interdisciplinary situated work of research, conferring the wealth and sensibility to the rational aspect of the work.
This aspect gives arguments for further investigations in the same field of research

8. References

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