# A Climatic Envelope Extension of an Office Building – Perception and Reality of the Change in Environmental Conditions

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**Abstract**

Building refurbishment is a key issue to improve energy performance and comfort levels for the building users. However, changes to an existing building envelope or a narrow energy focussed refurbishment to modern standards can result in a compromised working environment.
This paper describes the extension of an administration building at Southampton University through the addition of a new building linked at several levels to the old building through an atrium. Measured aspects of visual and thermal comfort are related to occupant perception and behaviour. The study shows that changes to the building envelope can have a disproportionate impact on the perceived comfort of the working environment in an existing office space. Measures to address this problem are discussed, for example more appropriate relocation of staff and management of expectations concerning the change in performance of the building.

**Keywords:** Building Refurbishment, Building Envelope, Visual and Thermal Comfort, Daylighting, User Perception, Office Building

## 1. Building Envelope Alteration / Refurbishment – Managing User Expectations

Regardless of whether a building is new, old or refurbished the indoor environment requirement is essentially the same and driven by building use and social factors. User expectation of the performance of these three building classes can however be very difficult to address. Users rightly expect a recently refurbished building to provide a ‘step change’ enhancement in indoor environment quality and provide a similar performance to their expectations for a new building. However, identical facades on a new and a refurbished building of apparently similar construction can create very different interior building climates. During building refurbishment there is limited scope to make changes to the often unseen plant or internal ventilation systems. Conversely the plant of a new building will be designed directly in relation to the façade and the building use profile. These key differences between a new and refurbished building are ‘invisible’ to the majority of users and can make managing expectations of a refurbished building’s performance difficult.

Over the last 30 years a range of post occupancy studies of mainly new build commercial buildings have shown that there are often gaps between client and design expectations and the achieved environmental performance [1]. According to post occupancy evaluations carried out by Meir & Hare [2] the key issue for a well functioning building are users that understand its environmental features and actively interact with the building. Their study, which looked at several so-called ‘bioclimatic’ buildings in Israel, found significant gaps between intended system function and user behaviour. Failure to use the buildings in the intended manner led to malfunction and consequently refurbishment, changing them into ‘standard’ buildings. Therefore, it is essential to either produce buildings with passive systems that host well trained users or, where this is not guaranteed, buildings that can be intuitively operated by the users. For example, the function of a window for weather protection, ventilation, daylighting and noise control is well understood by building users.

EN ISO 7730 [3] states that user satisfaction depends largely on the environmental room conditions, namely air temperature, mean radiant temperature, air velocity and partial water vapour pressure (absolute humidity) as well as the occupants' physical activity and the thermal resistance of their clothing. If one or more of these parameters exceed threshold limits the proportion of dissatisfied users in the building rises.

User satisfaction is also influenced by other, more subtle environmental changes which can be problematic to design for, difficult to quantify and predict. Degradation of any one component (e.g. daylighting) can result in a building alteration or refurbishment being perceived as poor or unacceptable even if the overall room quality was enhanced. To address this problem requires care in both the refurbishment design and the management of the process. This latter is critical in changes to a building during which the occupants are kept in place. This paper describes such a change to a building façade at Southampton University and some of the problems which arose.

## 2. Building Envelope Alteration Case Study – University of Southampton

The George Thomas Building at Southampton University was recently extended (2004/05) by creating a climatic envelope with an atrium linking it to an adjacent, new building (Fig. 1 to 3). The old building part has a cellular office structure whereas the new part is essentially open plan. The building houses the university's central administration with the atrium space functioning as reception area, which includes a large reception desk for student services. Photovoltaic cells are integrated within the south facing atrium roof to provide electrical power and solar protection to the building [4]. The atrium interior is hard surfaced with brick and concrete walls. However, the floor is fitted with carpet which prevents people walking within the atrium generating excessive noise and undesirable echo effects.

Temperature, humidity and illuminance monitoring was undertaken at a range of locations throughout the building. In conjunction with measured environmental data a post-occupancy evaluation survey was carried out for users of both the new and existing buildings. This was of particular interest as some people were moved from the old to the new building part, whereas others remained in their old offices (Fig. 4). The specific scope of the survey was to determine:

- the impact of carrying-out of an envelope refurbishment on work efficiency in the adjacent offices,
- the user perception of the room climate influenced by the adjacent atrium,
- the user perception of the light levels next to the atrium,
- the general contentment with the office layout and design (related to office type: open plan, cellular),
- the variation in productivity related to environmental room quality.



**Fig. 1 to 3** – George Thomas Building at the University of Southampton: atrium linking the old building part with the new building. (old building to the left on the first photo)

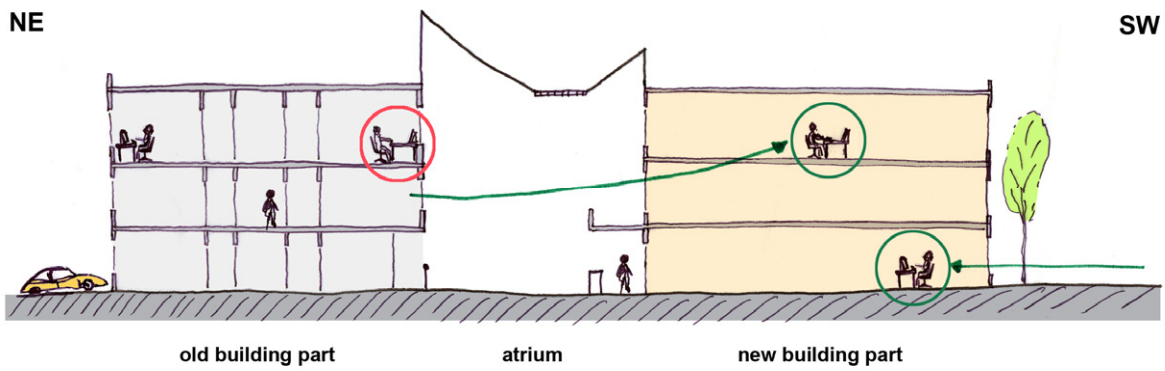


**Fig. 4** – Occupant moving after completion of the atrium extension building.

### 2.1 Refurbishment Questionnaire Structure

The refurbishment questionnaire study was similar in structure to the commonly used 'Building Use Studies (BUS)' which has been applied to over 500 buildings since its inception in 1985 [5]. However, the refurbishment questionnaire differed in its main focus as the intention was to compare a refurbished solution retrospectively with the previous building condition. The questionnaire consisted of eleven questions, structured onto one double sided A4-sheet, which according to experienced surveyors is considered to be the ideal size to encourage users to participate [6]. The survey included questions on:

- evaluation of environmental room conditions at present with the variables: humidity, temperature, noise, lighting and ventilation,
- retrospective evaluation of environmental room conditions before the refurbishment with the variables: humidity, temperature, noise, lighting and ventilation,
- daylighting before and after refurbishment,
- disturbance and influence of the refurbishment on motivation and productivity,
- office design (furniture, building, amount of space, colour scheme),
- office environment (interaction with colleagues, privacy, vision to the exterior),
- possibility and evaluation of importance of personal control of the parameters: temperature, ventilation, vision to the exterior, sunlight control (glare), noise,
- general parameters: period working in building, hours at the desk, age, gender, desk distance to the window.

The refurbishment questionnaire survey was carried out on the 21$^{st}$ / 22$^{nd}$ of June 2005 with 24 people participating in the old part and 56 in the new part of the building. Data was collected by individually addressing the building occupants who had been informed about the survey purpose and date. All users present on the two survey days were interviewed. In line with previous studies such as Probe [1], the survey forms were personally handed out and the users guided through the questionnaire to provide help where required.

### 2.2 Refurbishment Questionnaire Findings in Relation to Logged Data

User contentment in the old building part was found to be significantly lower than that inside the new building, which had only been populated about three weeks prior to the investigation. In the old building people felt strongly disturbed by the construction process and believed that the environmental conditions had deteriorated significantly since the atrium was constructed (Fig. 5 & 6). In order to verify these feelings 19 miniature dataloggers measuring temperature and humidity levels were placed in several offices throughout the building for a one month period (15$^{th}$ of August to the 14$^{th}$ of September 2005 inclusive). Figures 7 and 8 show the measured temperature and relative humidity profiles of two representative offices for a seven day period in late August / early September 2005. The values are typical of the studied summer period and other investigated offices produce similar profiles.

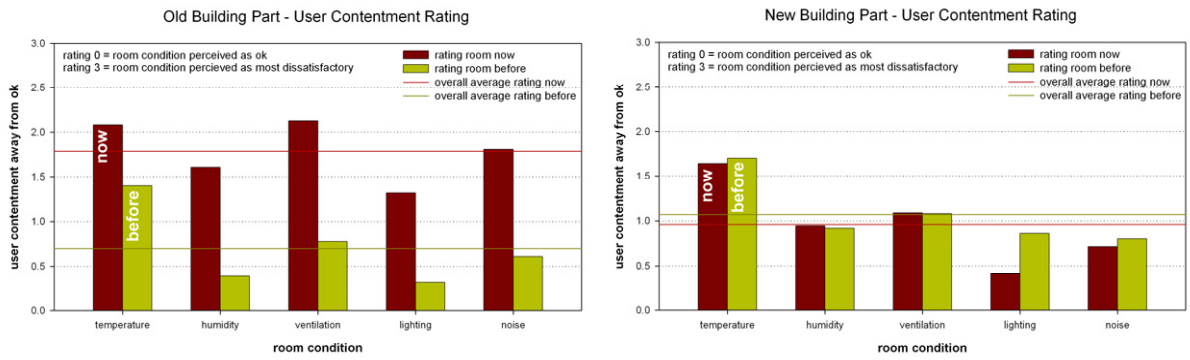


**Fig. 5 & 6** – General user contentment of all users with the environmental room conditions in the old (left side) and the new (right side) part of the building, retrospectively compared to the situation before (for the new building part compared to the office occupied before). The rating is derived of the answers the users gave concerning their feeling about the environmental room conditions. A rating of 0 would mean that the room is perceived as being ok or just right, a rating of 3 that the room is perceived as most dissatisfactory.

The recorded temperature and humidity data reveals a disparity between user perception and reality. Office temperatures in general remained below the recommended upper limit of 27°C for more than 90% of the working time (weekdays 8,00h to 18,00h [7]), despite the outside ambient temperature being around or above 25°C in the middle of the day. In terms of temperature therefore, the building technically performed rather well. For most of the time it remained inside the recommended temperature range for thermal comfort inside office buildings, which is considered to be 20 to 26°C [8]. However, both the questionnaire and user feedback during the monitoring period highlighted excessively high temperatures as a major cause of dissatisfaction (Fig. 5 & 6). This feeling is not supported by the measured data with internal temperatures reflecting the general weather conditions and furthermore showing a smoothening of the diurnal outdoor temperature range. The diurnal temperature range was about 2 to 3°C for the offices on both sides of the atrium and the total temperature range over the entire measuring period around 6°C, which indicates a rather stable condition inside the building. No significant temperature differences between the old and new building part could be identified. However, a rise in average temperature between 0.5 and 2°C (typically 1°C) was observed for each floor up (Fig. 7), indicating the presence of the expected stack effect often observed in buildings with open atria [1].

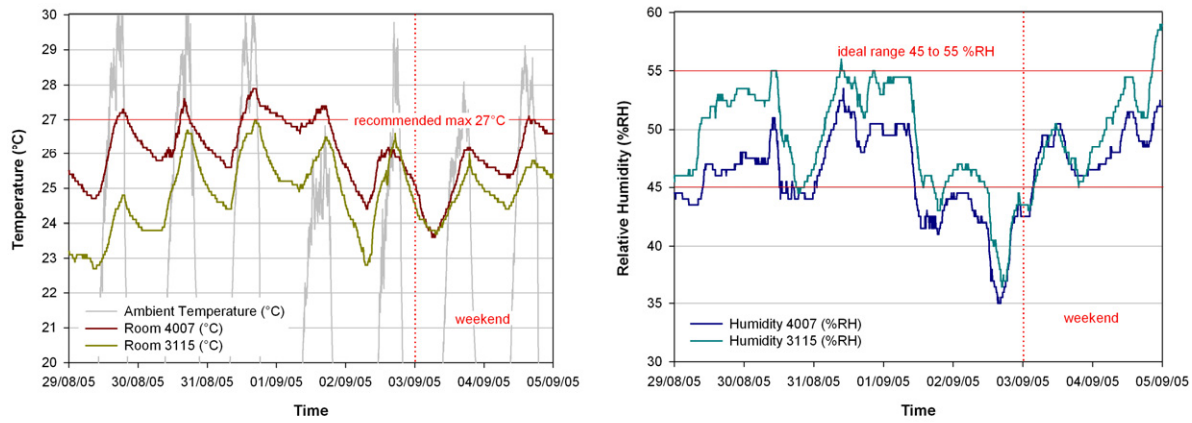


**Fig. 7 & 8** – Room 4007 (2nd floor, old building part) and Room 3115 (1st floor, new building part): temperature (left side) and humidity values (right side) in 5 minute intervals from the 29th of August to the 4th of September inclusive.

Many building users felt the air to be too dry whereas the monitoring indicated that the relative humidity was above the recommended lower limit of 35% [9] for practically all the working time (>97% of working time) and with the exception of two short period intervals never exceeded the proposed upper limit of 65% [9]. Generally the relative humidity remained in the recommended optimum range of 45 to 55% [9] for approximately 60% of the working time. Again, no significant differences in relative humidity values could be found between the old and the new building part. The atrium facing offices on the first and second floor of the old building had an average relative humidity of 47.4% over the measuring period and the corresponding offices in the new building part an average relative humidity of 47.0%. However, in the old building part the users were highly dissatisfied with the indoor air quality, claiming the air being rather dry (Fig. 6).

Office users in the old part of the building which became enclosed by the new atrium were generally dissatisfied with the refurbishment. In terms of environmental parameters, this is attributable to a low airflow rate resulting in higher sensory pollution levels. In contrast to the new offices on the other side of the atrium these offices do not possess a mechanical ventilation scheme and can only be naturally ventilated to the atrium, which results in lower air-exchange-rates than before the refurbishment, as natural wind pressure on the façade is now missing (Fig. 9 & 10). This agrees with studies carried out by Wargocki et al [10] which show that a decreased outdoor airflow rate results in an increased percentage of dissatisfied people. According to CEN CR 1752, Annex C the minimum ventilation rate for cellular offices in a non low-polluting building should be 1.2 L/s m² floorspace in order to achieve a category C thermal environment with a predicted percentage of dissatisfied (PPD) below 15% [7]. This design criterion for ventilation is unlikely to be met in the current situation, causing users to falsely perceive that excessive office temperatures were being reached. Measured temperature data showed that atrium facing offices in the old building with an average temperature of 24.9°C were within temperature limits for 89% of the working time (24.5°C +/-2.5°C for a category C building).

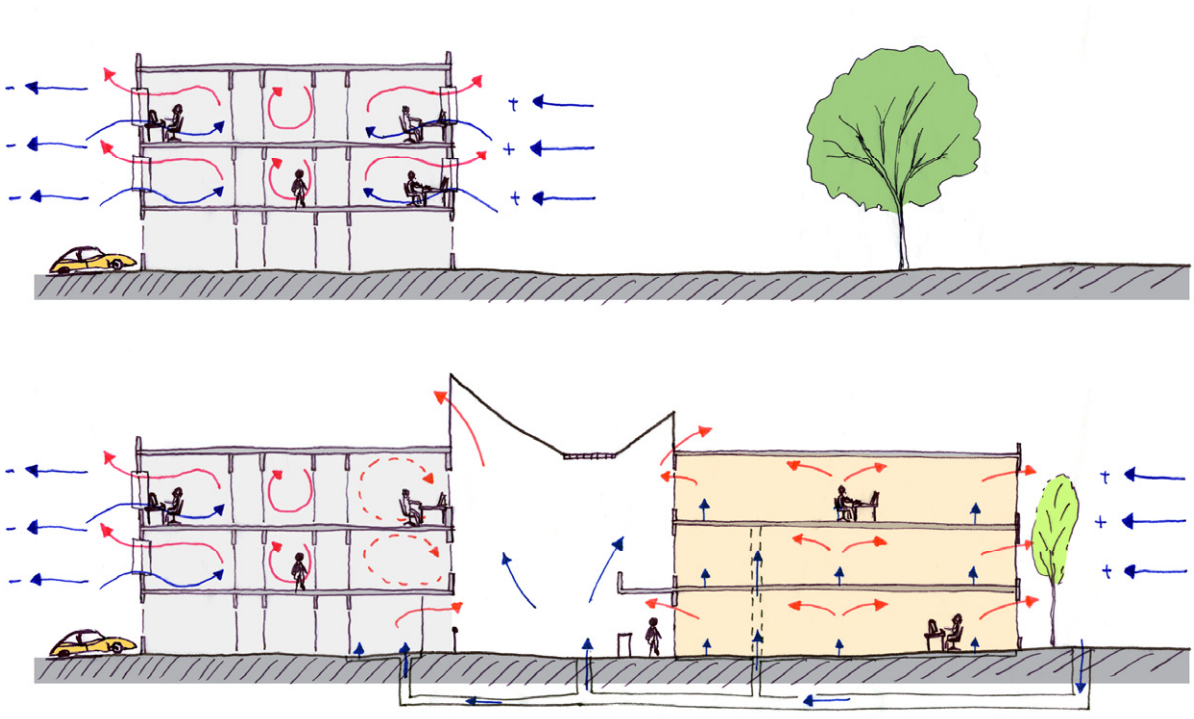

**Fig. 9 & 10** – Ventilation scheme before and after construction of the atrium extension.

Prior to the atrium construction the southwest façade of the old building was not obstructed by other buildings, allowing the occupants a view outside onto a green space (Fig. 9). Furthermore, daylight could penetrate deeply into the office space. Luminance measurements conducted with a luminance camera at half-hourly intervals in an office room on the second floor (Room 4007) throughout the months of July to October have shown that the back part of the 4.5 m deep office had very poor daylight levels. The atrium's compromising effect on daylighting compared to before is clearly visible in the returns of the user survey. In the old building part the occupants believe that the daylighting conditions are rather poor now and used to be 'good' or even 'very good' before the refurbishment (Fig. 11). Interestingly, the questionnaire results of the 19 occupants that moved from this building to the new building part display a rather different picture (Fig. 12). The retrospective evaluation of the daylighting situation is much more evenly spread. Furthermore, the average evaluation is rather similar to the evaluation of the present situation inside the new building, which is somewhat surprising as the true level of daylighting in the deep open plan offices is rather low. However, the artificial lighting is well designed with direct and indirect components, delivering a uniform general lighting.

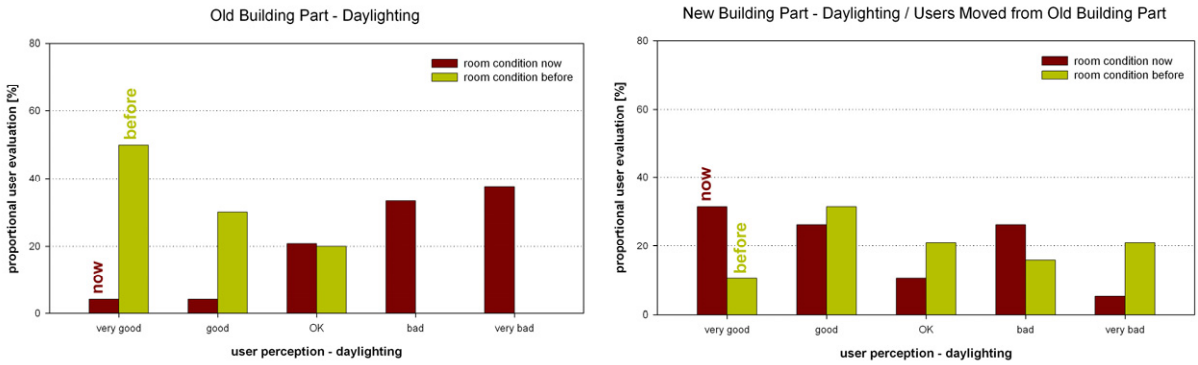


**Fig. 11 & 12** – User evaluation of the daylighting conditions in the old (graph 1) and the new (graph 2) part of the building, retrospectively compared to the situation before (for the new building part compared to the office occupied before).

Of all surveyed environmental parameters the perception of noise was hardest to quantify as the possibility of noise control was ranked from very important to not important with strong individual variation. However, as can be expected, on average the users of the open plan area felt the possibility of noise control somewhat more important than the occupants of the cellular offices. Interestingly the open plan office users were rather satisfied with the current noise levels in their offices (Fig. 6), whereas the office users in the old building part were unhappy with current noise levels (Fig. 5). Two reasons were given by these people for their negative evaluation; (1) the noise levels they encountered during the construction work outside their windows and (2) the concern that the atrium space would cause noise pollution in the future. However, to date there is no evidence of this noise pollution issue arising. As the atrium facing windows of these offices remain open for most time of the day, disturbing noise levels from the atrium do not seem to be a key issue. Therefore, it is likely that the negative feeling concerning noise resulted to some extent of the negative perception of the other environmental room conditions.

Additionally to their perception of the environmental room conditions the users were asked to give their opinion about their specific office in terms of design, spacing and ergonomics and to state their personal satisfaction with their building. Although the old part of the building has a cellular office structure and the new part open plan offices the levels of user satisfaction with their own offices were similar for both sides of the building (Fig. 13 & 14). Users were equally satisfied with their furniture, their personal amount of space and its layout in terms of ergonomics and also showed similar levels of satisfaction with the total amount of office space and its colour scheme in general. This similarity in perception was not expected as the old offices have not been redecorated for many years, whereas the users of the new building have received a brand new office environment. This indicates that the discontentment the users in the old part of the building showed towards their present environmental

room conditions (Fig. 5) did not transfer to their personal environment. However, as figures 13 and 14 show, when asked about the general building design, the users in the old building were rather less positive with their building than the users in the new part. In contrast, the users that moved from the old to the new building part had essentially the same opinion about the building design as the other people in the new building part. This suggests that the group of users that remained in their old offices was generally unhappy with the building alteration and perhaps felt to have been excluded from the design process.


**Fig. 13 & 14** – User satisfaction with the present office conditions in terms of ergonomics, spacing and design in the old (graph 1) and the new (graph 2) part of the building.

## 3 Conclusions

The negative perspective of office users who had previously enjoyed unobstructed south facing views and are now linked to a new building via an atrium is not entirely unexpected. The retrospective opinion of users in this location prior to the refurbishment differs markedly between those who relocated to the new building and those who remained. The clear shift in opinion highlights one of the problems of building alteration or refurbishment – managing expectation.

The benefit of the refurbishment to all users was perhaps ‘oversold’ and many users in the old building have now become over-sensitive to aspects of building performance. Daylighting and ventilation in the atrium enclosed offices has been compromised following refurbishment, leading to a perceived degradation of the working environment, despite improvements in other areas such as a more controlled diurnal temperature range. Retrospectively these occupants view all aspects of building performance prior to refurbishment in a much ‘better light’ than colleagues who relocated to the new building.

This study highlights the need to ensure that following refurbishment a user’s office environment should not, in any way be degraded. Degradation in only one aspect is likely to outweigh all achieved improvements. If a negative perception of a refurbishment becomes established this can rapidly erode all the benefits that the refurbishment brings and building services managers may find themselves exposed to more complaints than before. In the investigated refurbishment, daylighting and airflow were always going to be compromised to a certain degree by the introduction of an atrium. A better management strategy would perhaps have been to relocate users from the south side of the old building into the new building. The temporarily vacated offices could then have been refurbished internally and staff brought in from surrounding poor quality buildings that were scheduled for demolition. Such an approach would have minimised the number of users for whom the refurbishment resulted in a degradation of office environment.

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