Human and Automated Intelligence in Comfort Provisioning

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Green design is not simply about attaining higher environmental performance standards or "investing" in new values; it is also about rethinking design "intelligence" and how it is placed in buildings. This paper explores the relationship between human and automated intelligence in comfort provisioning in reference to green buildings. The paper concludes that a shift is required from conceptualizing the occupant as a passive recipient of a set of indoor conditions, to the inhabitant who may play a more active role in the maintenance and performance of their building. Further, to enhance engagement, more attention should be spent on developing innovative methods and applications for communicating assertions of agency and responsibility of inhabitants.

INTRODUCTION

Providing and maintaining an appropriate indoor environment with an economy of means has always been an implicit objective of architectural design. The definition of what conditions are deemed acceptable has a history of reassessment and refinement, as do the methods and technologies by which they can be achieved. Indeed it is difficult, if not impossible, to discuss the history or future of comfort provision in buildings without discussing the technological capability available to the design team to deliver it. Fraker and Prowler [1], for example, argued that during the twentieth century, the widespread deployment of energy-intensive mechanical systems that could be located remote from the spaces they served, liberated architects from many prior pragmatic concerns related to comfort provision. Technological innovation led to a shifting of design responsibility in comfort provision from architects to mechanical engineering consultants, and control responsibility from *occupants* to *technology*.

It is also impossible to discuss what constitutes appropriate comfort conditions simply in terms of human physiology - a host of cultural, psychological, behavioural and contextual factors shape a person's engagement and enjoyment of environmental conditions. Yet, over a half century of comfort research and comfort provision has been guided by the search for a universally applicable set of optimum comfort conditions. The consequences of this extend well beyond the direct experience of building users, to the global standardization of comfort criteria and expectations and the erasing of cultural adaptations traditionally deployed in response to adverse climate conditions.

A central issue in the efficiency and effectiveness of buildings to provide occupant comfort is where "intelligence" is assumed - either implicitly or explicitly.

In conventional approaches to comfort:

- 'Occupants' are assumed to be passive recipients of indoor conditions that are maintained within narrowly defined margins by automated, centralized systems.
- Building performance is often invisible to the end-user who in turn is given little opportunity to control or provide feedback on their experience of the indoor environment.

Increasingly, research confirms the importance of having some level of direct control over the environmental conditions in the workplace as being paramount to occupant satisfaction [2,3,4]. This paper explores the relationship between human and automated intelligence in the provision of comfort and how these are manifest in green buildings.

Kell [5] identifies five complementary concepts of "intelligent" building that have evolved over the past thirty years and provide a useful point of departure: *Automated buildings, Informated buildings, Intelligent space management, Passive Intelligence* and *Organisational Intelligence*. For the main part these reflect the changes in technological capability. Kell emphasizes that a common factor in these concepts is a "focus upon making better use of information to improve performance and increase value". Cole and Brown [6] introduce a sixth concept – *Inhabitant*

Intelligence – wherein the building explicitly enables its users to make appropriate adjustments in the environmental conditions in their workplace. This notion represents the primary thrust of the paper.

"EMBEDDED" INTELLIGENCE

Green design is not simply about attaining higher environmental performance standards or "investing" in new values; it is also about rethinking design "intelligence" and how it is placed in buildings. Indeed, many of the concepts described by Kell [5] pertaining to intelligent buildings have inherent relevance in green design.

Automated, Informated & Organizational Intelligence

Over their entire lifecycle, green buildings are expected to use less energy and water, generate less greenhouse gases, use materials efficiently, and produce less waste. Efficient building operation can include the design and commissioning of automated systems to improve the management and control of building services (*automated* intelligence). Moreover, green features such as improved indoor air quality and thermal conditions, abundant natural light, elimination of materials that 'off-gas' harmful chemicals, views to the exterior and plentiful fresh air lend themselves to healthier interiors. The maintenance of healthy environments through linking feedback on building performance with sensing, responsive systems, are concepts that share similar goals with *informated* intelligence.

Additionally, green buildings are often invested with the capability to serve multiple purposes over the course of a day and over the building lifetime, thus optimizing the use of the space and services. This can be considered *organizational* intelligence, in the sense that building capability and potential is integrated with organizational need.

Passive Intelligence

Passive intelligence in green buildings can be characterized in a number of ways, from basic decisions regarding building form and materials, to solar or climate-actuated controls. Furthermore, the intelligence can be how technologies are integrated within an overall energy or building strategy rather than the technologies themselves.

Since many green buildings apply the "passive intelligence" to improve building performance, this concept in particular serves to reassert the importance and role of architectural design decisions in the provision of comfort. Hartman [7] suggests that the "history of the green building movement to date shows a subtle but persistent bias by architects away from the application of more advanced technologies in the comfort systems that serve buildings." In North America, there has been a discernable pendulum swing over the past two decades away from a fully mechanically controlled environment back towards one that is largely provided passively. This has been driven by the combination of perceived environmental and occupant-productivity benefits and a cultural antipathy to reliance upon mechanized building systems. More recently, there is a tendency to deploy mixed-mode approaches – raising the expectation of a greater and more effective synergistic relationship between simple, climate or occupant-activated controls (*passive* intelligence) and advanced, automated technologies (*automated* intelligence). In all cases, the ways and extent that occupants are considered an integral part within the overall control system is critical.

Intelligent Space Management

While space management has always been a key issue in organizational effectiveness, the concept has only recently been incorporated into the green building discussion. The flexible use of space is important from both the standpoint of rapidly changing organizations and work practices, and consequences of extreme weather and temperatures on indoor comfort conditions. Green building strategies that rely on intelligent *space management* include: flexible, adaptive work environments; efficient use of floor space; optimizing facility use at different times of day; refined control zones and technologies that maximize occupants' access to adaptive opportunities, *e.g.* under-floor air distribution.

"HUMAN" INTELLIGENCE

Comfort provisioning and control have always been, and will remain, a critical performance requirement of buildings considered "intelligent" or "green" or both. Given that traditional "intelligent" patterns of building use by local culturally adapted populations re-introduced into the workplace, e.g., seasonal dress codes, siestas, heat holidays, have largely disappeared[1], the key issues of debate are the technical means by which comfort is attained. Issues here include the extent to which system complexity matches management capacity, the degree of involvement of the occupant, and the integration of comfort with the full spectrum of other architectural requirements. Moreover, comfort is not just an outcome of the physical environment but as Brager and de Dear argue, "[i]t is our very attitudes about comfort – both on an individual and cultural scale - that influence our basic

[1]Some of these strategies are now starting to be revisited, e.g.. Japan's "CoolBiz"

need for (or aversion to) mechanical heating and cooling" [8].

Building occupants' wellbeing, comfort and productivity are closely linked with their real and perceived control over interior environmental conditions [9]. When occupants have more perceived control over their indoor environment, as is common in naturally-ventilated buildings with operable windows, they are more likely to tolerate less-than-ideal conditions [10]. Although not conclusive, there appears to be differences in the significance of control over the different environmental modalities and their influence on overall comfort. Cohen, *et al* [11] argue that natural ventilation is firmly associated with manual control and that an operable window is "a safety valve for the alleviation of discomfort" and the "very act of opening a window by its nature makes an important psychological contribution to the perceived effectiveness of the ventilation." However, simply *providing* operable windows, for example, is clearly insufficient in designing naturally conditioned buildings. The location, design, distribution and their comprehension by end-users can profoundly affect performance and use.

Accommodating Human Intelligence

Cohen *et al*. [11] examine how the buildings in the UK *Post-Occupancy Review of Buildings and their Engineering* (PROBE) research project are coping with emerging intelligent building technologies and the degree to which these influence energy performance and occupant satisfaction. A key observation is from their studies is that "[n]otwithstanding all the implications of supposedly advanced automation, our experience is that the best intelligence in most buildings lies in the occupants themselves" and that the "challenge for designers and manufacturers is then to support them with appropriate and understandable systems with readily-usable control interfaces, which give relevant and immediate feedback on performance." In other words, buildings in and of themselves cannot be "intelligent" but can support intelligent patterns of behaviour.

It is widely known that building performance in use often differs markedly from that anticipated or predicted during design. This performance gap results not so much from the building design and technology itself, but rather from the differences between assumed and actual patterns of occupancy, the use of controls, and building operation and management. Based on a wealth of experience in evaluating actual building performance, Bordass and Leaman [12], point to *overly-complex* building systems as a major deterrent for efficient and effective building operation. Their work suggests that high-tech buildings are relatively complex to operate, so dedicated management is essential if they are to achieve optimal performance. A key lesson is, therefore, that the environmental success of a building depends on matching technological and management sophistication.

INTERACTIVE ADAPTABILITY

The issues raised above may have more fundamental roots in the way that contemporary design conceptualizes and provides for the interactive process between users and building systems.

Relationships between occupants, and between occupants and building systems are interactive and multi-directional, not linear or predictable as in the conventional approach. In traditional comfort studies, the strong emphasis on technical standards and applications that produce automated services with reduced control mechanisms obscures the social dimension of comfort. Contemporary design can shape a new context of comfort to address an active 'inhabitant' who responds to environmental conditions, adapts, and works with system controls to adapt the system to his or her own needs. This suggests a re-orientation of the approach to comfort in which the goals and objectives of the building systems and the inhabitants are equally engaged and equally attended to. A complex web of heterogeneous interdependencies thus replaces the conventional approach that values the optimization of building systems above the complex and changing needs of inhabitants.

The successful performance of green buildings depends in a large part on variation and diversity in environmental conditions, where both the building systems and inhabitants interact and adapt in response to changing external conditions and needs. This process has been described by Cole *et al*. [13] as 'interactive adaptivity' and refers to the ongoing, bidirectional dialogue between building and user in which the outcome is not predetermined by building design parameters or performance metrics, but is rather an evolving process. A necessary correlate to interactive adaptivity is open communication and dialogue between all the components of the system. As Leaman and Bordass [14] suggest "clear design intent" is critical to inhabitants' understanding the meaning and function of building features and systems.

CONCLUSION

This paper has contrasted the notions of automated and human "intelligence" in comfort provisioning with particular reference to green building. Passive approaches to design are placing a greater responsibility on occupants in building operation.

Shifting responsibility for comfort conditioning into the hands building occupants assumes that:

- Systems are readily accessible and comprehensible to building users and clearly accompanied by a willingness to use them.
- Users will make appropriate and intelligent choices when engaging with controls available to them.

Within this context, it is clear that a shift is required from conceptualizing the *occupant* as a passive recipient of a set of indoor conditions, to the *inhabitant* who may play a more active role in the maintenance and performance of their building. This further suggests that to enhance engagement, more attention should be spent on developing innovative methods and applications for communicating both the new context and the need for assertions of agency and responsibility of inhabitants. The key is that the communication and interaction are bi-directional, where the experience of comfort and the building systems performance are both dependent on a form of ongoing dialogue in which the outcome is determined not by pre-existing building design parameters and performance metrics, but rather by the process of interaction itself.

REFERENCES

1. Fraker, H., and Prowler, D., (1981) *Project Journal: Teaching Passive Design in Architecture*, University of Pennsylvania, Philadelphia, PA

2. Heerwagen, J. and R.C. Diamond (1992) Adaptations and coping: occupant response to discomfort in energy efficient buildings. *ACEEE Summer Study*, Asimolar, California, ACEEE.

3. Baker, N. (1996) The Irritable Occupant: recent developments in thermal comfort theory, *Architectural Research Quarterly*, 2, Winter, 1996

4. Leaman, A. and Bordass, W., (1999) Productivity in buildings: the 'killer' variables. *Building Research and Information*, 27(1) pp. 4-19

5. Kell, A.R., (2005) The Global Development of Intelligent & Green Buildings, ibexcellence, Beijing, 29th March, 2005 www.ibexcellence.org/images/pdfs/akbeijing05paper.pdf

6. Cole, R.J., & Brown, Z. (2009) Reconciling human and automated intelligence in the provision of occupant comfort, *Intelligent Buildings International* 1, 39-66

7. Hartman, T., (2006) What is the Role of Advanced Technologies in Green Building Design? *IHomes and Buildings*, Spring 2006, pp.17-19

8. Brager, G.S., and de Dear, R.J., (2003) Historical and Cultural Influences on Comfort Expectation. IN: R.J. Cole and R. Lorch (eds.) *Buildings, Culture and Environment*, Blackwells, Oxford.

9. Heerwagen, J., (2000) Green Buildings, organisational success and occupant productivity, *Building Research and Information* 28: 5/6, pp 353-367.

10. Humphreys, M., and Nicol, F., (1998) "Introduction to adaptive comfort", ASHRAE Technical Data Bulletin 14(1), ASHRAE Winter Meeting, 1998, January

11. Cohen , R., Ruyssevelt , P., Standeven, M., Bordass, W. and Leaman, A. (1999) *Building intelligence in use: lessons from the Probe project*, Usable Buildings, UK.

12. Bordass W. and Leaman, A., (1997) Future Buildings and their Services: Strategic Considerations for Designers and Clients. *Building Research and Information,* 25: 4, pp. 190-195

13. Cole, R.J., Robinson, J., Brown, Z. and O'Shea, M. (2008) 'Re-contextualizing the notion of comfort', *Building Research & Information*, 36:4, 323-336

14. Bordass W. and Leaman, A., (2007) Leaman, A. and Bordass, B. (2007) Are users more tolerant of green buildings? *Building Research and Information*, 35(6), 662–673