RETHINKING AUTOMATION IN THE SUSTAINABLE BUILDING

Brian R Wood*

Oxford Institute of Sustainable Development, Oxford Brookes University, Oxford, UK
** Corresponding author (brwood@brookes.ac.uk)*

ABSTRACT: Since the first ISARC conference in 1984 and the formation of IAARC in 1990 there has been much development of interest in and understanding of automation and robotics in construction. The 'intelligent building' [1] [2] and the 'learning building' [3] are conceptual examples. Yiu and Yau [4] have published a 'learning model of intelligent home'. At the same time there has been growing interest in the need for 'sustainability' as witnessed by the work of for instance Robert and Brenda Vale and demonstrated in their 'autonomous house' in the 1970s and as defined by the Brundtland Commission in 1989. The UK Building Research Establishment built in 1998 its 'Integer House' (Intelligent and Green') bringing together these strands of thought. 'MEGA house' [5] and AMIGO [6] are examples of further developments. The need to create efficient buildings, including from existing buildings, is greater than ever. This will require buildings that are easily and intelligently maintained. This paper reviews and rethinks maintenance in the developing 'landscape' and leads to a suggestion that user needs should be considered more closely.

***Keywords**: Automation, Control, Occupant behavior, Building performance, Sustainability, Users*

BACKGROUND

Automation and robotics have so far failed to deliver the step-change necessary for the better operation and occupation of buildings; yet the need and potential are great. Science fiction notions of humanoid robots have been about since the days of black-and-white silent movies. The construction industry seems painfully slow to develop and embrace new technologies. In the UK there have been at least eight officially commissioned reports in the nearly 70 years since the second world war berating its lamentable performance: Simon (1944), Emmerson (1962), Banwell (1964), the National Economic Development Office (NEDO) (1964, 1983), Wood (1975), Latham (1994) and Egan (1998). The typical dwelling of today, new or old, exhibits little by way of automation built into its fabric beyond thermostatic control of its heating system, a technology of the Victorian age (1880s), if not earlier.

Sometimes people will speak of the so-called 'intelligent building'. There are various definitions that may be applied; Wong *et al* [2] cited others [7] as identifying 'over 30 separate definitions of intelligence in relation to building'. The Intelligent Building Institution suggested in 1988: 'An intelligent building is one which integrates various systems to effectively manage resources in a coordinated mode to maximise: technical performance; investment and operating cost savings; flexibility' [8]. Such a definition seems to avoid reference however to those aspects that may be considered to represent 'intelligence' of a human kind. McGregor spoke of this when postulating the 'Learning Building' [3]. Do buildings have memories; do they think? This and the work of DEGW and Technibank [1] and of Clements-Croome [8] [9] point up the critical importance of the 'human dimension'. Buildings are for people. This should not be a surprise, yet often architects and developers appear to take little account of what people may want in their buildings and how they may use them.

A study of the Sigma Home at the Building Research Establishment's Innovation Park in Watford [10], shows that people have incomplete and inaccurate ideas of how to control their home environment. Yet Humphreys [11] and others [12] have shown that the availability of personal control over their comfort- to be able to open a window, or turn lights on or off for instance- is key to satisfaction.

At the same time, people have become more sensitised to 'environmental' issues in the sense of 'saving the planet'. Just as there are multiple understandings of what an 'intelligent' building may be, there are many of what a 'sustainable building' may be. The Brundtland definition of sustainability [13] seems to have the greatest degree of acceptance: 'the principle that economic growth can and should be managed so that natural resources be used in such a way that the quality of life of future generations is secured.' For many this means our buildings should be 'green' making minimal use of resources that are in finite, limited or declining supply.

AUTOMATION AND MAINTENANCE

Most buildings in the 'western' world will have some small element of automation in its operation- such as the thermostat to turn heating off or on when a determined maximum or minimum temperature has been achieved. There may be timers also to switch heating on or off at set times, typically at the beginning and end of the 'working day'. Additionally, presence or movement detectors or light level sensors may turn artificial lighting on or off or up or down according to a predetermined algorithm. There may be more sophisticated systems in some buildings where perhaps more individual control may be required, or for instance in a museum where humidity control is needed for optimum conditions for preserving manuscripts.

However, the more there is, the more there is to go wrong, to be maintained, repaired, attended to, even just occasionally to check that it is working correctly. There can be a tendency to equate economic growth with technological developments, and a quest for a more 'western' approach- to lifestyle, diet, fashion, buildings, etc. An observation made by Mahatma Gandhi may be apposite- when asked on visiting Britain what he thought of Western civilisation, he replied that he thought that it would be a good thing. I am also reminded here of the welter of 'gizmology' on offer at a conference of the European Intelligent Buildings Group (EIBG) at the Building Research Establishment [14]. There were solutions there to problems that people didn't know they had. Perhaps that is in the nature of technological innovation; some products will 'take off' and others will die. There is much to be said for keeping things simple.

Technology already exists that would enable a building to become in a sense maintenance-free. Building and energy management systems (BMS, EMS, BEMS) are able to monitor and record a wealth of data. Programmes that analyse that data and convert it in real time to responses 'on the ground' in our buildings are available and in use. In theory at least, a BMS could identify that the temperature in a food chiller unit in a supermarket was rising at a rate that would, if it continued, result in an unacceptably high temperature at which the contents would be unfit for sale. It could then activate a system that would either call up an inspection or implement remedial action [15].

There is evidence however that 'Big Brother' may not provide the best approach to giving people what they need in their working and living environments. While the building through its BMS may be quite capable of self-diagnosis of its problems as they arise, or even of anticipating and thereby avoiding unacceptable performance, people like to be 'in control'. The 'why' question- 'why automation?'- must be addressed. In the same sense that buildings are for people, automation must also serve the building's users- all of them. A building's users may be of many kinds- staff carrying out a range of different activities perhaps, managers, creative teams, people doing detailed financial calculations, cleaners, visitors- and they will all be individuals too. It is hard to meet all those individual needs, so it is understandable to 'default' to 'standard' answers to maybe unasked questions. What is actually wanted; and what is needed?

What do people need from a building? Who should decide, and on what basis? Maslow in 1943 identified a 'hierarchy of need'. Shelter is a basic need, and by and large people have a good understanding of how to provide this- although there have been mistakes, for instance the high-rise 'industrialised' mass housing approach of the 1960s. Above mere 'shelter' people need safety in their buildings, including health and wellbeing, and above that there are hopes for love and belonging that a building may help provide. For many people, their home will be a focus for a fulfilling family life, and the office a place for friendship and a fulfilling work life. When these are not fostered feelings of unhappiness, anxiety and isolation are created.

It is incumbent upon those responsible for building design and operation to take account of human behaviour and people's wellbeing. Automation and maintenance have roles here. A BMS can learn from its loggings so as to switch on heating, lighting, cooling etc at the right time; and calculations can be done automatically at intervals to recalibrate automated responses. An automated 'start-up' can be initiated when one 'swipes in' at entry to the building, or even in response to one's location according to a GPS device. What is important is that the individual decides what they want, so even a 'standard' default setting needs a manual over-ride. The BMS can also check its own operation and call up or suggest appropriate changes.

Building maintenance can also be automated. Sometimes a routine action will be required- for instance regular cyclical checking of air and water quality for legionella, pollutants, etc. The BMS can identify when an individual luminaire has failed and order a replacement. Predictive and condition-based algorithms can be developed and applied. Periodic deep cleans and redecorations can be scheduled and arranged. Works orders can be issued, tracked and paid. Efficient and effective maintenance responses can be facilitated. The key factor is that the individual building occupant gets prompt and appropriate attention, and knows it- this gives an impression of concern for the individual that is real and genuine. Feedback is important.

THE SUSTAINABILITY CHALLENGE

In a world where a sparing use of limited resources is of paramount concern, it may be thought somewhat indulgent to put people rather than planet at the centre. Can people be trusted to use resources sparingly? If people are able to open windows will they 'let all the heat out' (and howling gales in?) Given control over their heating will they turn it up too high? Will they leave lights on? All those outcomes, if they came to pass, would result in extra energy use and be therefore undesirable. However, evidence suggests that people act responsibly and are very adaptive [16]. People in control of their working environments and able to open a window are more likely to work satisfactorily within a wider range of temperatures. They will accept lower winter temperatures (and higher in summer, therefore cutting down on cooling load) and put on (or take off) layers of clothing as a response, thereby using *less* energy not more.

A number of projects in recent years have tried to respond positively to the sustainability agenda. Examples include Robert and Brenda Vale's 'Autonomous House' [17], Bill Dunster's 'BedZED' community and various other 'low energy' or 'zero carbon' developments. The Integer and Sigma houses are attempts to design, build and test prototypes for housing appropriate to the 21st century. There have also been commercial buildings where it has been hoped to embody a greener approach than otherwise 'normal' and from which lessons may be learned and the agenda moved on. The PROBE reports (1995-2002) examined a number of these buildings and assessed their green credentials to see how well they worked in practice.

One approach to achieving more sustainable buildings is a 'low technology' one, exemplified by using local materials, domestic scale, narrow plans with natural lighting and openable windows obviating the need for air-conditioning. Automation would play little part in such an approach- it would be seen as antithetical; a consumer of energy both operational and embodied in its manufacture, transport to site, maintenance and so on. The Vales' 'Autonomous House' and BedZED are light on automation. The Integer House took a more 'high-tech' approach. Energy use is monitored remotely and the cheapest tariff selected for that rate of use at that time. The bathroom has no water-intensive bath; it has a low volume instantaneous-heated power shower; and the w.c. has a low volume flush. Window glass is photo-sensitive and blinds are motor-driven, opening and closing automatically. The house does however have a low-tech 'green' turf roof. The Sigma House was constructed as part of the BRE's Innovation Park and was designed to have 'zero-carbon' emissions [9]. However, difficulties with operating the building, due to poor control mechanisms and poor and misleading induction information, resulted in deficiencies in performance. Excessive ventilation and glazing gave rise to problems related to heating, lighting and privacy. More consideration of how the occupants might actually live in the house was warranted. On the whole, building users cannot be expected to have the same technical facility or commitment to planet-saving as visionary designers.

The PROBE studies examined buildings that had been designed with interesting 'features' from a low energy or otherwise sustainability 'angle'. All fifteen buildings were found to have problems in their operation. In one building cleaners had to telephone from each workstation to have its individual lighting activated, while in another, controls were located in plant rooms accessible only via cat ladders. In all but one, building users and managers had no manuals to illustrate how to use the control systems provided.

What might be ways ahead then? Martinez *et al* [18] have explored greater 'user-orientation' in building design and construction through the use of an automated interactive 'virtual reality' environment. The aim was to 'maximise the user final satisfaction'- a high aim. A design would be made and the user invited to modify it. A range of degrees of immersion of the user in making modifications was explored, from a non-immersive, desktop approach through to 'total immersion' in a navigable virtual reality image. The user would however have limitations in reality, for instance being allowed to move a wall but not to a position where there was a window. Components would be selected by the user from an 'intelligent component catalogue'. This study was followed up by one of its participants through the European Union-funded AMIGO project [6].

AMIGO (Ambient Intelligence for the networked home environment) examined a number of demonstration experimental automated home environments that could perhaps be 'mainstreamed' as robotic smart homes. Wheeled and humanoid bipedal robots were assessed as well as climbing models. A significant advantage of the latter was in avoiding mobility problems of the first two models, which tended to fall over or trip on obstructions.

Another approach to use of automation in housing is exemplified by the Taiwanese MEGA House [5]. MEGA combines Material, Electronic, Green and Automation issues in an 'open building' concept. The key component is the use of Radio Frequency Identification Devices (RFID) embedded in the structure to feed back data on the performance of the building and thereby to inform and activate control and maintenance activities in real time and in an integrated way. AMIGO and MEGA offer possible ways ahead in terms of putting the user at the centre of the automated sustainable low-maintenance building.

OPPORTUNITIES: DECISION SUPPORT

Data is not the same as information. In a previous study (unpublished) a company had amassed a huge quantity of data related to temperatures of individual rooms and discrete zones of office floors. This had been recorded at short intervals through the day and night, seven days a week for a year; but they had no-one to analyse and assess what the data meant, i.e. to turn it into useful information. Thus a member of night security staff would routinely override the 'system' to close windows and shut down lights and equipment which could and should have been dealt with by the BMS installed. And a lot more energy was consumed heating and lighting spaces needlessly. Automation provides an opportunity to support good decision-support systems but humans have to 'buy in' and know how it should work.

In the past these may have been referred to as 'expert systems', but they have much the same relationship as does 'intelligent' to 'automated'. Performance data needs intelligent interrogation to make sense of it.

The 'Autonomous House' cannot be considered fully autonomous if it requires its occupants to travel from Southwell fifteen miles to work in Nottingham or forty miles to Sheffield - that is not 'autonomy'; the house is not complete in and by itself. It is however a good example of trying to move the agenda on and to test theory in practice.

The Integer House demonstrates something of the 'Jevons paradox' or 'rebound effect'- that people 'compensate' for their efficiency or savings. If energy costs go down, people feel less need to economise, and 'spend' the savings on higher comfort standards, represented by higher room temperatures and going about sleeveless through the depths of winter. In the Integer House the focus was on using *lower-priced* energy rather than simply using less energy, and it had many electrical (albeit 'energy-efficient') labour-saving gadgets installed.

It must surely make sense to learn from mistakes, not only from the past but also those that are being made because they are unnoticed or uncorrected. Building management systems provide data that could be put to use more effectively if marshalled and analysed intelligently [4]. The PROBE studies also showed how, just by taking the time to look, to listen to occupants and to think, performance deficiencies could be identified and addressed.

The need and opportunity for user-involvement from the outset has also been demonstrated. It must be worthwhile for the building to operate in ways that give occupants the living and working environments they believe are best for them. Similarly, it must also make sense to design it in a way that makes that possible and likely. Where they can be identified at the design or redesign of a facility it makes sense to involve expected users in developing ideas and making decisions about how to achieve the best building.

CONCLUSIONS

Buildings are not performing well. This is due in part at least to failure to involve building users in the design process. Architects' education and training continues to encourage a detached 'professional' attitude where the approbation of one's peers is more valued than that of the client who pays the bills (including that of the architect) and those for whom the building exists- its users, today and tomorrow. If the dictum that 'form follows function' is to be seen to be so then more attention needs to be given to firstly ascertaining the required functionality and then ensuring its delivery, at handover and continuingly in use.

We need buildings to work well. A happy and comfortable worker is a productive worker, so it makes good economic sense to deliver a good working environment. That means good appropriate temperature and humidity and the ability to control it. This also makes it more likely that less energy and other resources will be used, thus helping to 'save the planet'. A worker who is happy and feels appreciated will also accept greater deviations in environmental conditions. People that have been involved with the design of their workplace will have 'buy in' also to making it work. What is automation for? Automation can help buildings function better. However, ill-considered automation that imposes conditions on building users is unlikely to be appreciated, and people may work against it. A number of instances of buildings where people have struggled to overcome the deficiencies in their design and operation have been described here, and the comparative ease with which they could have been avoided or at least minimised given earlier consideration. Each of these examples from practice has within it the possibility of being fed forward into the design of better buildings in the future.

People's inclinations and motivations are generally toward the good, for themselves and their colleagues. Attention has been given in recent years to leaving behind a history of adversarial relationships and trying to create harmonious working arrangements between building constructors and designers. Perhaps the opportunity to create more dialogue between building designers and users should now be grasped. It may mean more humility on the part of designers and a re-ordering of values and priorities to place functionality over aesthetics. Buildings are for people.

REFERENCES

[1] DEGW (London) and Technibank (Milan), "The Intelligent Building in Europe" *British Council for Offices. College of Estate Management,* Reading, 1992.

[2] Wong, J.K.W., Li, H., and Wang, S.W., "Intelligent building research: a review" *Automation in Construction* **14** (1/2) pp. 143-159, 2005.

[3] McGregor, W., "Designing a 'Learning Building'" *Facilities* **12** (3) 9-13, 1994.

[4] Yiu, C.Y., and Yau, Y., "A learning model of intelligent home" *Facilities* **24** (9/10) pp. 365-375, 2006.

[5] Cheng, M-Y., Lien, L-C., and Tsai, M-H., "*An introduction for MEGA house" Proceedings of 25th International Symposium on Automation & Robotics in Construction,* ISARC, Vilnius Technical University, Lithuania, pp. 52- 57, 2008.

[6] Balaguer, C., "Towards robotic smart homes" *Proceedings of 24th International Symposium on Automation & Robotics in Construction,* ISARC IIT, Madras, pp. 3-8, 2007.

[7] Wigginton, M., and Harris, J., "Intelligent Skin." *Architectural Press,* Oxford, 2002.

[8] Clements-Croome, D.J., “What do we mean by intelligent buildings” *Automation in Construction* **6** (5/6) pp. 395-400, 1997.

[9] Clements-Croome, D.J., (ed.) “Creating the Productive Workplace.” *E. & F.N. Spon,* Oxford, 2000.

[10] Stevenson, F., and Rijal, H.B., “Developing occupancy feedback from a prototype to improve housing production” *Building Research & Information* **38** (5) pp. 549-563, 2010.

[11] Humphreys, M., *“Field studies of thermal comfort compared and applied”* Building Services Engineering **44**, pp. 5-27, 1976.

[12] Wood, B.R., “Building Care” *Blackwell*, Oxford, 2003.

[13] World Commission on Environment and Development (WCED), *“Our common future”* Oxford University Press, Oxford, 1989.

[14] Wood, B.R., “Intelligent building care” *Facilities* **17** (5/6) pp. 189-194, 1999.

[15] Smyth, H.J., and Wood, B.R., “Just in time maintenance” *Proceedings of COBRA ’95: RICS Construction and Building Research Conference,* Edinburgh, RICS, London, 1995.

[16] Nichol, F., and Kessler, M., “Perception of comfort in relation to weather and indoor adaptive opportunities” *ASHRAE Transactions***, 104**, pp. 1005-1017, 1998.

[17] Vale, B., and Vale, R., “The New Autonomous House” *Thames and Hudson*, London, 2000.

[18] Martinez, S., Salgado, A., Barcena, C., and Balaguer, C., “User-oriented inter-active building design” *Proceedings of 23rd Internatiional Symposium on Automation & Robotics in Construction* , ISARC, Tokyo, pp. 442-447, 2006.