A matrix tool for assessing the performance of intelligent buildings

G. Sutherland and G. Stavrakakis
Technical University of Crete, Greece

D. Kolokotsa
Technological Educational Institute of Crete, Greece

S. Karatassou and M. Santamouris
National Kapodestrian University of Athens

ABSTRACT

Techniques and technologies for use in designing, constructing and operating intelligent buildings are well known or available on the market and many intelligent buildings have been built. However, just how intelligent these buildings actually are in comparison to conventional buildings is often a question. Due to the lack of a commonly accepted method and pertinent supporting data, the assessment of the overall performance of intelligent buildings cannot be carried out. It remains difficult, if not impossible, to carry out a fair comparison between different buildings in term of intelligence. As a result, the construction industry proceeds without adequate knowledge about the best practice in intelligent building.

The concept of intelligent building appeared initially in the early 1980s. Since then, the definition of intelligent building has been evolving with different emphasis, mainly driven by the development of relevant technologies and the changing needs for the built environment. This has resulted in differing notions of what constitutes an intelligent building.

For the purpose of assessment the definition of an intelligent building has been reviewed and refined. Based on the adopted definition, a matrix tool has been developed. The objective of this tool is to provide facilities managers with an effective methodology for improving the energy and indoor environmental performance of their building stock. With appropriate development, the methodology could also form the basis of voluntary or regulatory methodology for building intelligence accreditation.

1. INTELLIGENT BUILDING DEFINITION

Intelligence in buildings is a much misused word and usually implies that a microprocessor is incorporated in the intelligent device (Levermore, 2000). Different definitions of intelligent buildings exist. According to the research conducted by Wigginton and Harris (2002) there exist over 30 separate definitions of intelligence in relation to building. Early definitions of intelligent building focused almost entirely centered on technology aspect and did not suggest user interaction at all. Wigginton and Harris (2002) and Robathan (1994) revealed the necessity of buildings to respond to user requirements.

Two typical definitions are: “One that incorporates the best available concepts, materials, systems and technologies integrating these to achieve a building which meets or exceeds the performance requirements of the building stakeholders, which include the owners, managers and users, as well as the local and global community” (EIBG, 1999) and “One that provides a productive and cost-effective environment through optimization of its four basic components - structure, systems, services and management - and the interrelationships between them” (IBI, 1998).

For the purpose of developing an evaluation methodology and tool, and in order to take account of building use and operation, the intelligent building is defined as one which:

- provides a productive and cost-effective built environment through optimization of its four basic components - structure, systems, services and management - and the interrela-

tionships between them (focusing on the benefit of the owners, i.e. creating the desired indoor environment);
- maximizes the efficiency of its occupants (focusing on the benefit of the occupants, i.e. impact of meeting desired indoor environmental conditions on occupants);
- permits effective resource management of resource with minimum life costs (focusing on the benefit of the environment, i.e. through minimum environmental impact whilst maximising economic impact).

The evaluation methodology and tool takes into account the following three basic elements:

- the built environment should be productive, safe, healthy, thermally, aurally and visually comfortable.
- the building has potential to serve future generations: sustainability, or adaptability over the life cycle of the building and safeguarding the earth and environment resources.
- the construction of the building can be attained within some cost constraints whilst retaining market value.

2. METHODOLOGY

The methodology for the development of the tool focused on the definition of the intelligent building, the investigation of the barriers to the effective market penetration of SMART building technologies and the identification of the necessary mechanisms for overcoming these barriers. This methodology resulted in the identification of the necessary performance indicators for evaluation of the intelligence of a building. A rating procedure was then implemented. The procedure is two tier, resulting in either a simplified tool for practical implementation by facilities managers, or a detailed tool which could be used in the certification of buildings. In the first instance, the tool is used in-house and the results are a relative comparison of the prior and improved performance of the building, whereas in the second case the intelligence of the building can be quantitatively rated against other buildings. The scope of the work was to develop an applicable tool for improvement of the performance of intelligent buildings and has resulted in a tool for overcoming promoting the effective operation of intelligent buildings whilst also allowing a qualitative comparison between different buildings.

3. TOOL DEVELOPMENT

The matrix tool constitutes the development of an existing assessment methodology regarding the effective use of IT (information technology) for energy management in buildings (Sutherland, 1995). The methodology has been developed and extended to encompass the concept of an intelligent building as one which not only incorporates so called SMART technologies, but also one in which these technologies are utilized smartly (Mulligan et al., 1996).

Five global performance indicators (GPIs) are specified and used, each of these consisting of five specific performance indicators (SPIs) which belong to one of five spheres of influence. The adopted GPIs and SPIs are:

Built Environment, consisting of the SPIs (a) Comfort and productivity; (b) Individual control of local environment; (c) Health and safety; (d) Energy consumption and environmental impacts; (e) Integration with the surrounding ecological systems.

Responsiveness: (a) Awareness; (b) Automatic response to changes in the surroundings; (c) Performance under emergencies; (d) Decision-making; (e) Flexible usage.

Functionality: (a) Reporting system; (b) Building Management System (BMS); (c) Maintenance; (d) Facility Management (FM); (e) Easy-of-use through design;

Economic issues: (a) Investment; (b) Energy supply; (c) Resources; (d) Cost centres; (e) Budget.

Suitability: (a) Special use; (b) IT connectivity; (c) Location; (d) Internal corporate organisation; (e) Internal flow and operational planning.

The SPIs, and in turn the GPIs, are in affected by a number of influencing factors, or in effect, spheres of influence. Five spheres of influence have been identified:

People, i.e. do the occupants feel comfortable and are they productive in the building, how well do they understand their relationship with the building, etc.

Systems, i.e. does the system provide facilities for individuals, are the building and its systems well integrated with the surroundings, etc.

Critical, i.e. what measures are there to ensure the safety and health of people staying in and around the building, facilities equipped to handle emergencies, etc.

Processes, i.e. the means of adopting and enforcing energy management policies within the organization, the technical competence of the building operators in dealing with any relevant change, etc.

Design, i.e. design considerations and decisions on the integration of the building and its systems with the surroundings, etc.

Each of the five GPIs are influenced by the five spheres of influence. Their interactions are considered in the Matrix Tool. In accordance with the above description a checklist has been developed for walk-through survey of intelligent buildings Each of the performance indicators has a value ranging from 0 to 5, with 5 indicating the best and 0 indicating the worst. The overall assessment scheme which results in the building IQ is shown in Figure 1.

The value of IQ specifies the "intelligence" of a building under the "Matool". The maximum value of IQ is 125. The performance indicators can be weighted in accordance with a detailed mechanism which would allow the use of the methodology for certification purposes, but the methodology can also be applied qualitatively for improvement of the performance of a particular building. In this instance the weighting factors are each set as unity.

The rating of the intelligent building is accordingly specified as follows:

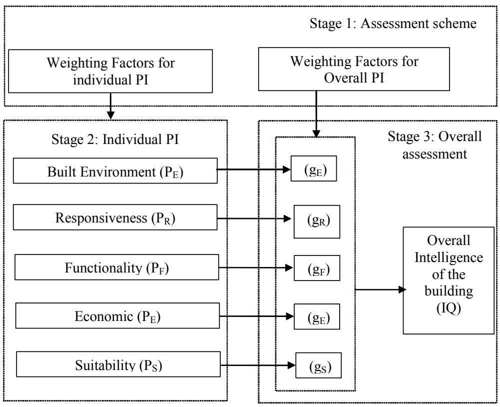

Figure 1: Stages of the assessment methodology.

Bad: <50

Good: 50 ~80

Very Good: 80 ~100

Excellent: 100~125

4. METHODOLOGY APPLICATION

An example of the application of the methodology is indicated in Figure 2. The figure indicates the impact of each of the spheres of influence on the intelligence of the building and figuratively highlights the areas which should be addressed in order to improve the performance of the building.

For example, consideration of the results of application of the methodology (Fig. 2) indicates the following:

- People play a very positive role in Built Environment, Economy and Responsiveness. However, in terms of Suitability and Functionality, there is a substantial potential for improvement, concerning the regular recommissioning of the system, training of occupants, better organisation of documentation and provision of improved facilities for the elderly and disabled persons.
- Systems has been rated very highly for Built Environment, Suitability, Economy and Functionality. However, Systems poses a barrier to Responsiveness. Areas to improve upon include: regularly commissioning the BMS and making use of variable utility tariff.
- Considerations on Critical issues have limited impacts on Responsiveness and Built Environment but significantly reduce the performance related to Suitability, Economy, and Functionality. Things to improve include: improving maintenance of the building systems, contracting out the survey of energy consuming devices and waste treatment to the specialists. Nothing can be done for the location.
- Process has caused some declination on each of the five performances. This suggests that the performance of this building can be significantly improved through adopting a better energy policy, training facility managers, setting up more efficient decision-

ting up more efficient decision-making system, and better communication among relevant departments or divisions. Things to improve include: carrying out regular inspection on the energy system, training the facility managers so that they can make better decisions on the management of the building systems, and improving the infrastructure of energy management with the organization.

- Design considerations were carefully taken for each of the five issues. This is in agreement to the fact that this building was designed to achieve the highest BREEAM scores (Baldwin et al., 1998).

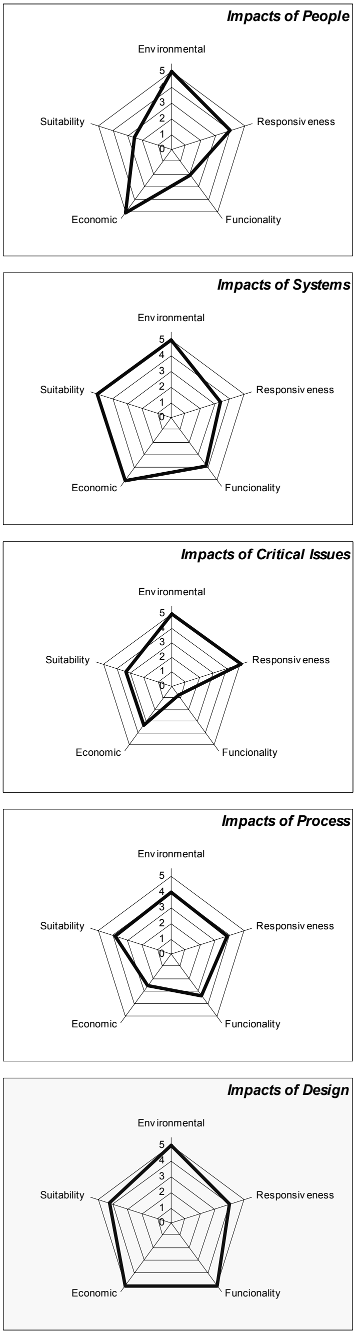

Figure 2: Impact of Spheres of Influence.

Summing up, System and Design have achieved very high credits. Process has got a low score, meaning that overall there is a potential for improvement through adapting better energy management. There is also significant potential for improvement through training occupants and facility managers.

Overall, this building has achieved a score of 98.6 out of a maximum 125. This suggests that this building is approaches excellence in utilising intelligent building technologies.

5. RESULTS AND CONCLUSIONS

A methodology for assessment of building intelligence is presented. The methodology incorporates the individual factors included in the definition of an intelligent building. The application of the methodology is presented as an example. The developed tool can be implemented voluntarily within an organization in order to improve operation of the building and to heighten the operational IQ. The methodology can also form the basis of an intelligent building certification scheme, requiring the development of strict classification and grading rules to account for the difficulty in evaluation of the individual parameters that constitute an intelligent building and their relative weighting.

ACKNOWLEDGEMENTS

The work was carried out in the framework of the SMART Accelerate project (4.1031/Z/02-094) consisted of Technical University of Crete (Greece), National Kapodestrian University of Athens (Greece), TECHEM (Germany), ENEA (Italy), University of La Rochelle (France) and Building Research Establishment (UK). The project was funded by the SAVE programme,

DG Energy and Transport, European Commission.

REFERENCES

Baldwin, R., A.Yates, N. Howard and S. Rao, 1998. BREEAM 98 for offices, An environmental assessment method for office buildings, BR 350, ISBN 1 86081 2384.

EIBG - European Intelligent Building Group, 1999. Directory of Intelligent Buildings.

Intelligent Buildings Institute Intelligent Buildings Definition, IBI, 1998. Washington DC.

Levermore, G.J., 2000. Building Energy Management Systems, Applications to Low-Energy HVAC and Natural Ventilation Control, E&FN SPON.

Mulligan, H., S. Platt, J. Goulding and G. Sutherland, 1996. The Climate Responsive Building, the Facilities Manager and Information Technology, Proceedings, 4th International Conference on Solar Energy in Architecture and Urban Planning, Berlin, 26-29 Mar., pp 233-236.

Robathan D.P., 1994. The future of intelligent buildings. In: D. Boyd, Editor, University of Central England, Henley on Thames Intelligent Buildings, Alfred Waller in association with Unicom, London, pp. 259–265.

Sutherland, G., 1995. The Effective Use of Information Technology for Energy Management in Buildings, Proceedings of the 2nd SAVE Conference on Means and Strategies to Influence Energy Related Behaviour in Europe, Amsterdam, 30 Nov. – 1 Dec., pp 63-65.

Wigginton, M. and J. Harris, 2002. Intelligent Skin., Architectural Press, Oxford, UK.