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PAPER TITLE (Intelligent Architecture as an approach for apply the Technological Development in Attaining the Objectives of Sustainable Architecture)

PAPER SUBTITLE (Intelligent Architecture between Technology and Environment)

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ABSTRACT:
At the beginning of the eighties, amalgamation occurred between artificial intelligence and information technology in building sciences. The fruit of this amalgamation was the appearance of intelligent buildings. A short time ago, technologies of intelligent buildings was taken to mean the use of computer technologies, means of communication and knowledge in the integration of the building systems. This is due to the fact that the technology part is considered an essential part in architectural intelligence. However, some other concepts complementary to the technical orientation have appeared. The concepts of sustainability and response to individual requirements have been added. Thus, the concept of intelligent buildings exceeded the stage of automated buildings to effective and responsive buildings that is friendly to the environment and cost effective in energy consumption.
This investigational study aims at achieving two main objectives:
- *Proving the possibility of exploiting and using advanced technology for achieving environmental objectives in the fields of rationalizing the consumption of energy and the conservation of the environment to attain the values of sustainable buildings. This is achieved through studying the integral and comprehensive image of intelligent architecture with its two technical and environmental sides.*
- *Reaching an access for the evaluation of the performance of intelligent buildings, through which a method can be invented for evaluating the performance of intelligent buildings.*

The value of the study lies in its clarification of the role of intelligent architecture in the conservation of the environment, achieving the values of sustainable buildings and proving the possibility of integration between the digital revolution architecture and the environmental architectures.
The study followed the analytical approach in the theoretical study. It also followed the descriptive approach, and the comparative analytical approach in studying and analyzing the local and international case studies.
The study ends with introducing the most important findings of the study. It is a full summary clarifying the main points of the study. One of the most important findings of this research is that intelligent architecture is one of the most effective architectural trends for creating a sustainable and responsive environment through achieving the integration between technological and the environmental systems. As well as, the study has reached an access for evaluating the performance of intelligent buildings.

Keywords:
(Intelligent Architecture, Sustainable Architecture, intelligent building features, assessment of intelligent buildings).

1. INTRODUCTION:

With the beginning of the twentieth century, divisions, conflict and struggle increased between the patrons of technological advancement and the patrons of environmental conservation. There was a call for environment friendly buildings. So many trends regarding environmental buildings appeared. But all trends concentrated on taking care of the environment, the usage of renewable energy and reducing the consumption of energy through the use of natural means as well as disregarding the application of technological advancement for achieving these goals. However, the civilization we see and live today has become part of man's life and his indispensable fate. The solution to face the bad effects of technology on the environment cannot be achieved by the separation of one from the other, by applying technology excessively, disregarding its effects on the environment or by limiting its usage and going back to the past with regional architecture, like the call to vernacular architecture. If they have any conflict with the environment is not due to the nature of technology but due to its wrong application and excessive use, disregarding any environmental or human considerations. In an age that depends on electronic computers, satellite communication systems and information exchange networks, it is not acceptable to use construction technology that depends only on conventional means. The solution lies in the good utilization of this technology to attain man's convenience without harming the environment.

Hence, it was necessary to think of a new architectural trend, capable of utilizing the latest scientific inventions in the field of information technology and communications. This new trend should, at the same time, conserve the environment and rationalize energy consumption in buildings. This was the beginning of the 'intelligent architecture' as a practical model for the possibility of reconciliation between technology and environment.

2. Intelligent Architecture and Sustainable Architecture: two sides of the same coin

> Sustainable architecture is the architecture that sustains the environmental balance through relying on ecological construction systems and recycled materials to reduce the exhaustion of the natural resources. It meets the needs of the present generation without compromising the ability of the future generations to meet their own needs.

As for the intelligent building, it is defined as:

> *"The building which is capable of comprising the most recent of the present and future technological means that enables it to perceive what is going on inside and outside it, and plan for taking its decisions on time, concerning the most effective methods for creating a responsive and sustainable environment that enhances the effectiveness of its occupants, with the least possible costs, all through the lifetime of the building.*"

According to this definition, it is clear that realizing a sustainable environment is one of the objectives of intelligent architecture. It is not this definition alone. Studying the different definitions that have appeared about intelligent architecture since the nineties, we find that they imply the principle of sustainability. This is clear in "Ting & So" definition: *"A smart building is the one that should aim to meet present and future user's requirements* ", also in the website of "intelligent buildings group" that define intelligent building as: "*An intelligent building provides a sustainable, responsive, effective & supportive environment within which individuals and organizations can achieve their objectives"*.

Hence, it is clear that intelligent architecture and sustainable architecture are two sides of the same coin. Both of them Endeavour to achieve the same goal, namely preserving the environment and supporting justice of consumption among present and future generations. This goal, of course, is achieved through different approaches; sustainable architecture uses environmental and ecological systems - figures (1) & (2) - whereas intelligent architecture achieves the goals of sustainable architecture by realizing integration between technological and environmental systems.


Fig.1 use a curvy paper tunnel supported by a matrix of recycled paper tubes to construct the "Japan pavilion" in "Hanover" exhibition in Germany (http://www.designboom.com/history/ban_expo.html)


Fig.2 "Peninsula" house is a good model for sustainable architecture as has used wood and glass in its construction to make integration between the building and environment
(http://archrecord.construction.com/projects/residential/archives/0304godsell.asp)

3. Sustainability is one of smart buildings features:

Through studying and observing the numerous views and definitions that have appeared about the “intelligent building”, since intelligent buildings first came into being during the eighties, up till now, it has been possible to determine the features of the intelligent building. These can be classified into three main groups - figure (3) - that form together the access through which we can realize the values of intelligent architecture and give the architectural product the characteristic of smartness. These features are as follows:

- <u>Automation</u>: The building’s ability of auto- control in its functions, without the least human interference, through programming its control systems.
- <u>Responsiveness</u>: The building’s ability to meet the needs and requirements of its occupants, and respond to the changes in its internal and external environment.
- <u>Sustainability</u>: meets the needs of the present generation without compromising the ability of the future generations to meet their own needs.

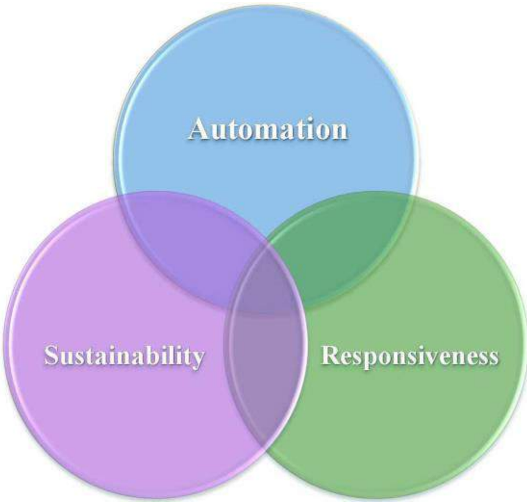


Fig.3 Intelligent Building Features

Through reviewing the chronological development of intelligent building, since their first appearance in the eighties up till now, we find that these three main features are the chief determiners of each generation. We find that in the definitions which were issued in the early eighties, the main feature that determined the smartness of buildings was the "automation". That is why this generation of architecture was called "Automated Buildings." Since the mid-eighties, the notion of building intelligence began to take an additional dimension which is "Responsiveness". That is why the buildings of that time were called "Responsive Buildings." In the early nineties, the concept of intelligent building started to take the meaning recognized now, with the addition of the last side of this triangle that is the feature of "sustainability". This generation of intelligent buildings has been called 'effective buildings', because its most important principle is taking care of the environment and using the environmental systems to realize the principle of sustainability and compatibility with the environment.

4. The role of Intelligent Architecture in attaining the objectives of Sustainable Architecture:

The first determiners of sustainable architecture are its compatibility with its environment and preservation of resources, whether natural, man-made. All these must be amalgamated with the successful technical shape that encourages individuals and society to preserve them, respect them, use them correctly, and maintain them. Some of the most important principles of sustainable architecture are:

- The limited consumption of non-renewable resources, and using highly efficient natural resources such as renewable energy, water and land.
- Creating healthy environment by devising low-poison resources.
- Designing buildings that are more responsive to the environment.
- Coherence with the environment and comprehending natural processes.
- Communication with nature.
- Recycling of waste materials.

Intelligent architecture has been able to attain these objectives by using communication and information technology. By achieving integration among communication systems and building-management systems (which include environmental control systems, safety and security systems and electrical network management systems) as shown in figure (4). It has been possible to create an intelligent architectural product that is compatible with its surrounding environment.

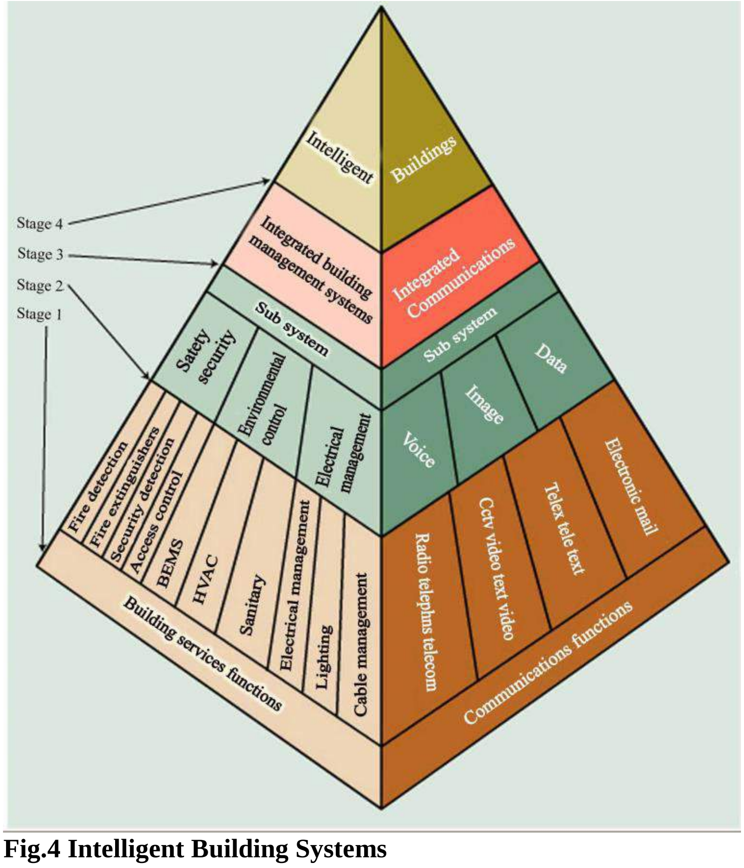


Fig.4 Intelligent Building Systems
(I & I limited_proplan, " Intelligent & Integrated Infrastructures in Buildings – Business Overview ", www.proplan.co.ok.)

The building research establishment (BRE) office building, known as "the Environmental Building" is considered one of the best example of using technology to attain the objectives of sustainable architecture. The building management system (BMS)* has an important role in enhancing the efficiency of the internal environment of BRE building. The BMS system used to control ventilation systems, heating, window shadings and lights.

Daylight in the building is maximized with large areas of glazing on the north and south facades, giving daylight factors of over 2% across the 13.5m floor plate, the south façade is protected by rotating glass louvers designed to cut out all direct sun to the interior, whilst still letting in considerable diffuse skylight, figure (5). The translucent glass louvers span in bays between the ventilation towers, and programmed to intercept the sun during the hours it can penetrate the south façade, figure (6). When it is dull, they park above horizontal, becoming light shelves. The motorized louvers are adjusted by the BMS every 15 minutes. The upper windows throughout the building can be opened by the BMS at night to induce cooling of the thermal mass. Regarding artificial lighting in BRE building, a fully integrated lighting system has been installed that automatically compensates for daylight levels and occupancy. Each bank of luminaries is fitted with two sensors that act as occupancy sensors, light-level sensors, figure (7). Integral sensors measure internal light levels and movement, dimming the lamps (100% to 0%) if there is sufficient daylighting, or switching them off if a room is unoccupied. The sensors also have an infrared receiver, which allows users to control light levels by means of a hand-held controller.

Fig.7 lighting system is fitted with two sensors (occupancy sensors & light-level sensors)

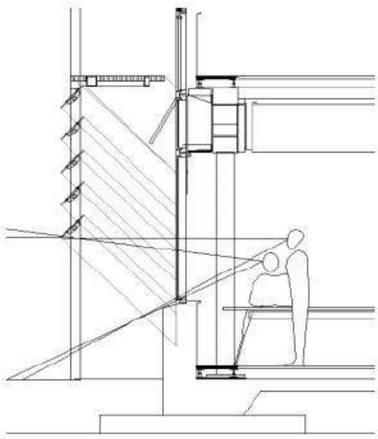


Fig.6 glass louvers doesn't obstruct the views of occupants

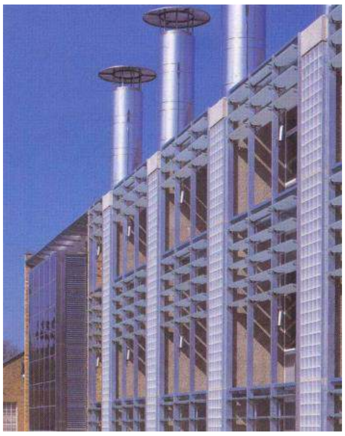


Fig.5 rotating glass louvers in the south façade

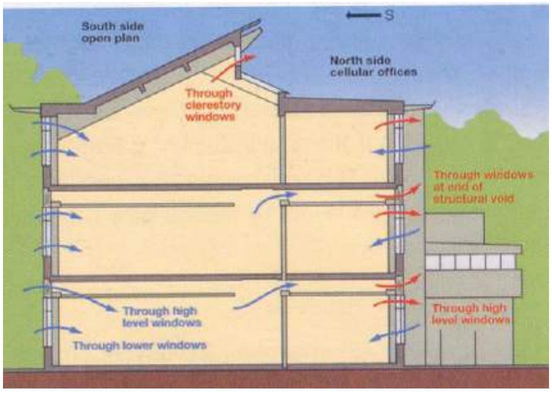
(Wingginton, M & Harris, J. (2002), " Intelligent Skins ", p.78,79)
(www.caa.uidaho.eduarch504ukgreenarchCaseStudiesbre2.pdf)

Regarding ventilation system, there are both high-level hopper windows controlled by BMS and low-level operable windows for user control. During the day, ventilation is controlled on temperature sensors in the main office areas and by CO2 levels in the main seminar room. The south façade has five ventilation towers that allow BRE to investigate solar contribution to the stack effect. The second floor, which rises to 5m at its apex, is different in that it is not connected to the ventilation towers, but instead has a split-pitch roof with automatically controlled north-facing clerestory windows; they provide additional daylight and a route for air to leave by natural buoyancy or wind forces, figure (8).

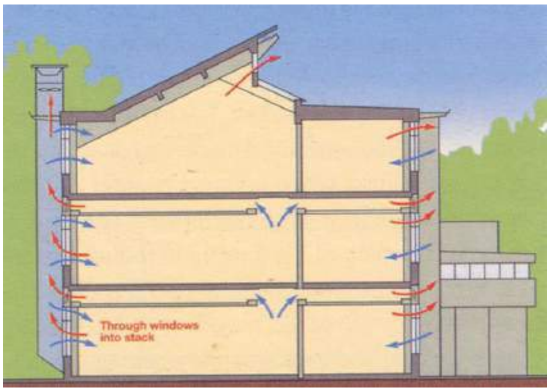
* BMS is the central processing unit, receiving all of the information from the various sensors outstations, and determining the appropriate control response to the actuating elements. An "intelligent" BMS is able to monitor weather changes and control and monitor the operation of both passive and active environmental systems to ensure the most efficient use of energy (Wigginton, M & Harris, J, "Intelligent Skins").

All controls for BMS go through a common network provided by a LON network∗. The computer algorithm used to control the degree, and period of automatic window opening, relies on the sensing of internal temperature. The control algorithm for the louvers is determined by the calculated sun angle. The whole system provides for 5-minute data logging over an extended period. On receiving a single, a message packet' is sent on the LON network to be picked up by the BMS and translated as a command to move the relevant window, switch the lights, or adjust the bank of glass louvers. The BMS also collects weather data from a rooftop station that measures wind and outside air temperature. Other standard energy-saving techniques are also employed by the BMS. Smart materials are used to saving energy, The south-facing wall of the seminar rooms is clad with a 47m2 array of photovoltaic (PV) cells, produced a peak output of 1.5kW, figure (9).

The building has been assessed by one of the methods of evaluating the environmental performance of buildings, which is called (BREEAM). It has got 39 out of 42 credits (92.8%). It has also been assessed by using two methods of evaluating the performance of intelligent buildings. The first was Matrix Tool (Matool) method that is issued by "Building Research Establishment – BRE" in UK, It has got 98.6 out of 125 (78.9%). and the second was "Intelligent Building Index" (IBI) method that is issued by "Asian Institute of Intelligent Buildings" (AIIB) in China, It has got (82%).Percentages in the two methods showed that it is an “excellent building” with a high level of intelligence.



Cross ventilation system that used at windy summer's day



Stack ventilation system that used at hot summer's day

Fig.8 natural ventilation systems that used in BRE building

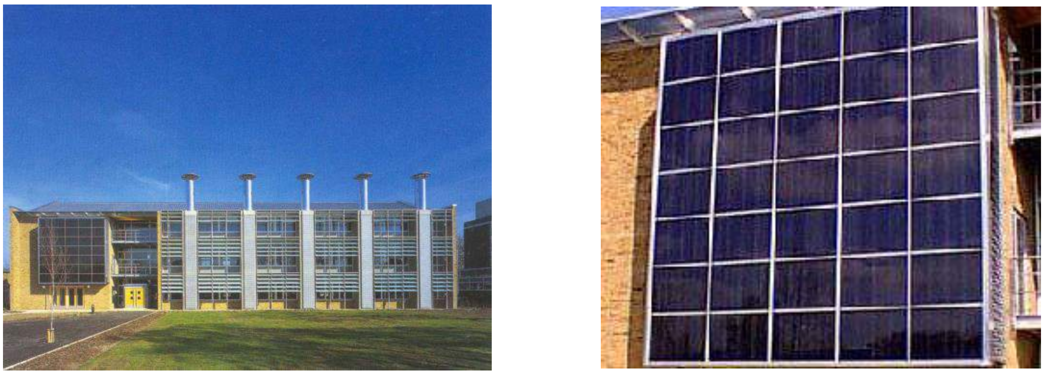


Fig.9 photovoltaic (PV) cells that produced a peak output of 1.5kW
(http://projects.bre.co.ukenvbuildenvirbui.pdf)

∗ LonWorks is a networking platform specifically created to address the needs of control applications. The platform is built on a protocol created by Echelon Corporation for networking devices over media such as twisted pair, power lines, fiber optics, and RF. It is used for the automation of various functions within buildings such as lighting and HVAC; see Intelligent building (http://en.wikipedia.org/wiki/LonWorks)

5. Sustainability in assessing the performance of intelligent buildings:

Due to the importance of environmental considerations, and to attain compatibility with the environment and sustainability in the concept of intelligent building, "Asian Institute of Intelligent Buildings" (AIIB) defined a set of environmental standards to assess the intelligent building. All these standards aim at attaining three main objectives: promoting environment and ensuring its fine quality, meeting the needs of the user, and attaining the principles of the sustainable building. This method has been called "Intelligent Building Index" (The IBI). It categorized into ten indices based on the ten Quality Environment Modules, each of which contain a long list of elements that may be service, technologies or passive items, totally 378 elements, figure (10).

(IBI) Method has numerous advantages that make it the best method, up till now, of assessing the performance of intelligent buildings:

- A comprehensive method for all aspects of assessing intelligent buildings, which have never been tackled by other methods of assessment: technology, environment, architecture, culture, management, economy and working efficiency.
- Paying attention to the environmental aspect, conserving energy and environment, and realizing the principles of sustainable buildings in all modules of their assessment.
- Using the property of Cobb-Douglas utility function**, which makes possible the omission of any inapplicable element to a certain building, without affecting the final mark of assessment.
- The method's validity for all types of buildings with different functions, as the functional differences between the various types of buildings is observed in its calculation.

Despite the above-mentioned advantages of IBI method, and despite its being the best current method for assessment intelligent buildings, its is not the most accurate. This is due to the following reasons:

- The three main features ought to be found in any smart building are not clearly present in the "Intelligent Building Index" method (IBI), while they are randomly present in some evaluation elements where we find that intelligence features exist with a percentage of 37% only in the modules of assessment the "IBI" method.
- Many elements do not express the modules of assessment. Let's take the feature of "sustainability" for example. Despite the presence of a complete module especially assigned for its evaluation- the first standard "The Green Index" which is assigned for the evaluation of the features of the green building which are present in the building, and for the extent to which the building is compatible with the environment- this module includes many elements that concern with the evaluation of the lifts and escalators systems, the lavatories, the sanitary equipment, the disposal of wastes and the efficiency of the drainage net, despite the presence of other modules assigned for the assessment of these elements.
- The outcomes of calculation by IBI method are non- unique. As there are elements that rely on the personal estimation of the auditor. This leads to differences in the final results of the assessment process according to the dissimilarity of auditors even when they evaluate the same building.

** In economics, the Cobb–Douglas functional form of production functions is widely used to represent the relationship of an output to inputs. It was proposed by Knut Wicksell, and tested against statistical evidence by Charles Cobb and Paul Douglas in 1900–1928. (http://en.wikipedia.org/wiki/Cobb%E2%80%93Douglas)

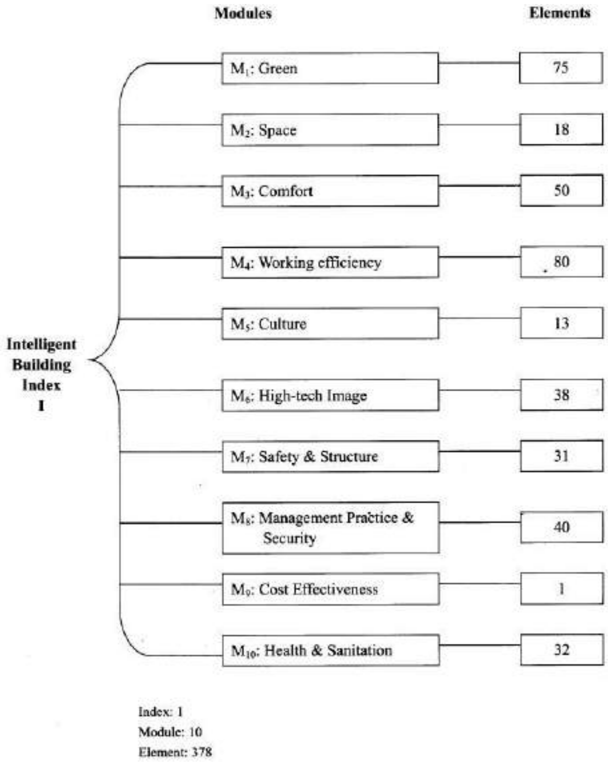


Fig.10 Intelligent Building Index (IBI) method to assess intelligent buildings
(Leonard, C & et al.(2005), " Intelligent Building Index ", p.4)

Thus, it is clear that there is not an ideal method for assessment an intelligent building, and that the access to the assessment of the performance of intelligent buildings is through the previously mentioned three features of intelligence. These features can be deduced through a set of designing functions and tools which, if available, indicate the features of the building's intelligence, and which- in turn- could constitute an approach as a system for intelligent building assessment (Intelligent Building Features), as is shown in figure (11).

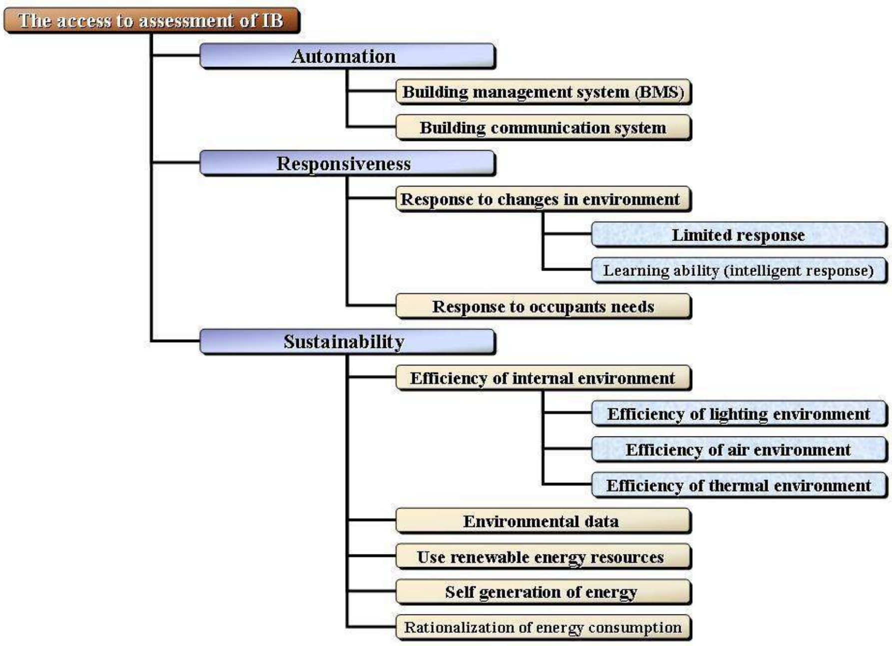
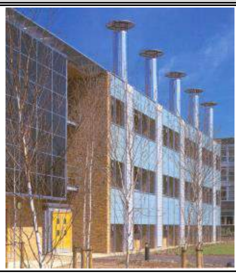


Fig.11 the proposed approach to assessment of the performance of intelligent buildings
(Badr, M. (2010). Intelligent Architecture As an Approach for apply the Technological Development in the Environmental Control and Energy Efficiency in Buildings , p.405)

Through conduct a comparative analysis study where drawn between the (IBI) method and the previously proposed approach (Intelligent Building Features) on a number of international and local Egyptian buildings uses as models – figure (12) - to demonstrate the ability of developing more suitable intelligent building method. Also to be acquainted with the reactions of the Egyptian architecture regarding the massive development and progress in architecture at the international level; the local influence of such progress and development; and how responsive is the local experience to the idea of 'intelligent buildings'.

International Buildings Models			
			
Headquarters of Gotz (1993 – 1995) Owner-occupied office building Wuzburg – Germany	**The environmental Building (BRE) (1994 – 1996) B1 office building Hertfordshire- UK**	**SUVA Insurance Company (1988 – 1993) office building Basel – Switzerland**	**Stadttor (City Gate) (1991 – 1997) Speculative office development Düsseldorf – Germany**

Local Buildings Models		
		
Vodafone building (2004) Office building Smart Village – Cairo – Egypt	**Alexandria Library (1995-2002) Public library Alexandria – Egypt**	**Humanitarian and Social Sciences College (HUSS) - AUC (2002-2007) – Cairo – Egypt**

Fig.12 the international and local building models that used in comparative analysis study
(Wingginton, M & Harris, J. (2002), " Intelligent Skins ", p.97,79,137,65)
(http://commons.wikimedia.orgwikiCategoryBibliotheca_Alexandrina)

The study as is shown in table (1) and figure (13) & (14), led to the following findings:

- All international and local models have the first feature of intelligent buildings, which is "automation". This proves that this is an essential feature in all intelligent buildings.
- All international models concern themselves with the feature of sustainability, while local models obviously lack this feature. This eventually affects its grade of evaluation, and leads to a clear discrepancy in the results of evaluation between the local models and their international counterparts. The "HUSS" building in "AUC" in Egypt is an exception in this respect because those responsible for executing this project were keen on applying the concepts of environmental and sustainable architecture in the university buildings.
- The study showed, without the least doubt, the Egyptian architects' and practitioners' lack of awareness concerning the right concept of the intelligent building. All local

study cases pay attention to the first feature of building intelligence, which is “automation,” whereas they do not pay the same attention to the other two features, responsiveness and sustainability. This shows the Egyptian architect’s wrong belief that an intelligent building is the building that comprises only the latest means of information and communication technology.

- The study showed that the Egyptian architecture is lagging behind its international counterparts with respect to the rationalization of energy in the buildings.
- The study confirmed that the factor of “the rationalization of energy consumption” is one of the most important factors that affect the level of building intelligence. The relation between a building intelligence and the rate of its energy consumption is an adverse relation, as is shown in figure (15). This means that the more the building consumes energy, the lower its level of intelligence will be.
- The study showed some shortage in the IBI assessment program regarding the evaluation of the performance of intelligent buildings in general. It also showed its invalidity for evaluating the local buildings in particular. This is clear from the considerable incompatibility and inconsistency between the final results of building evaluation through intelligence features, and IBI method in determining the level of the building intelligence. Comparison shows that local study cases get comparatively higher ratios of intelligence, compared to features of intelligence available in them, and compared to their international counterparts.

Accordingly, it has been realized that the feature of sustainability has an important role to play in raising the level of building intelligence. The fact that the international models pay more attention to the third feature (sustainability) than local models do, made the ratio of intelligence of the international buildings higher than that of the local ones. Although the ratio of the first and second features – automation and responsiveness – is higher than that of the feature of sustainability in both "Vodafone" building and "Alexandria Library" building, this has not made these buildings intelligent buildings. On the other hand, the promotion of the feature of sustainability in the "HUSS" building in the AUC in Egypt has made it an ‘acceptable intelligent building’

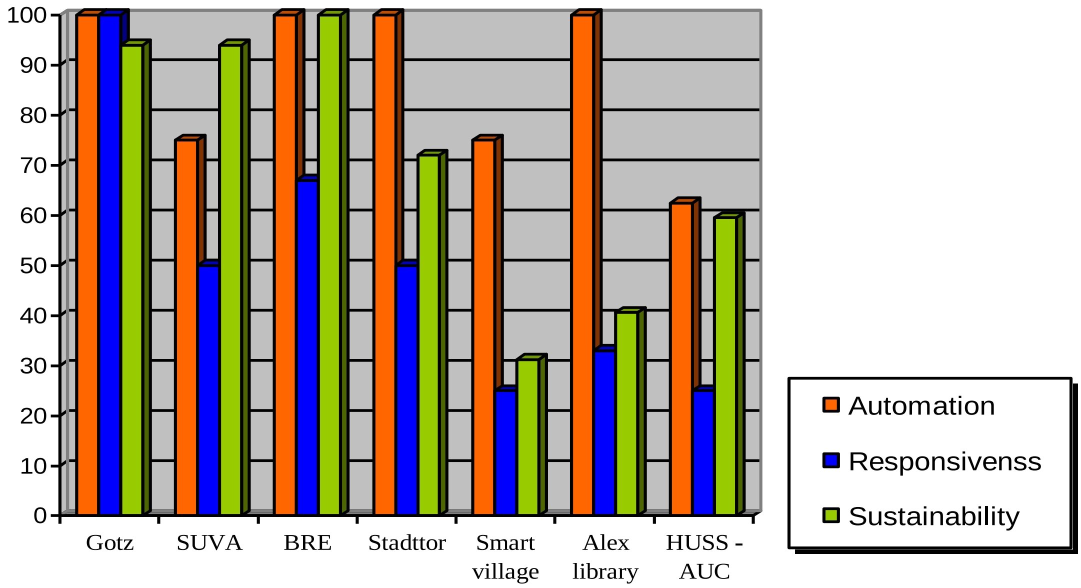


Fig.13 Bar chart demonstrate the assessment of the international and local building models by the proposed approach (Intelligent Building Features)
(Badr, M. (2010). Intelligent Architecture As an Approach for apply the Technological Development in the Environmental Control and Energy Efficiency in Buildings , p.404)

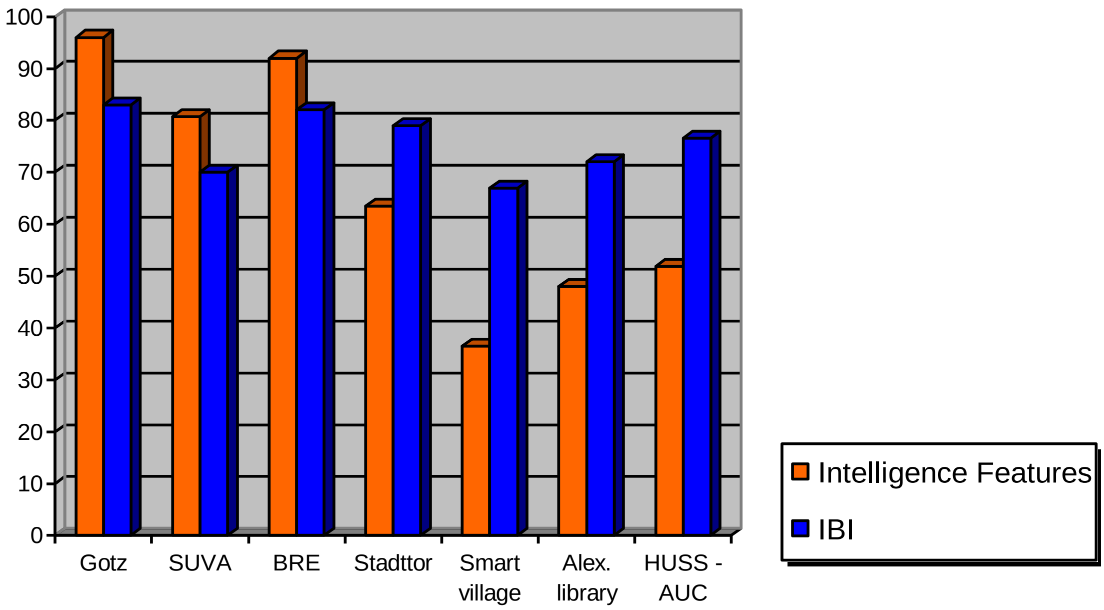


Fig.14 bar chart demonstrate the deference between the assessment by the proposed approach (Intelligent Building Features) and the "Intelligent Building Index" (IBI) method

(Badr, M. (2010). Intelligent Architecture As an Approach for apply the Technological Development in the Environmental Control and Energy Efficiency in Buildings , p.404)

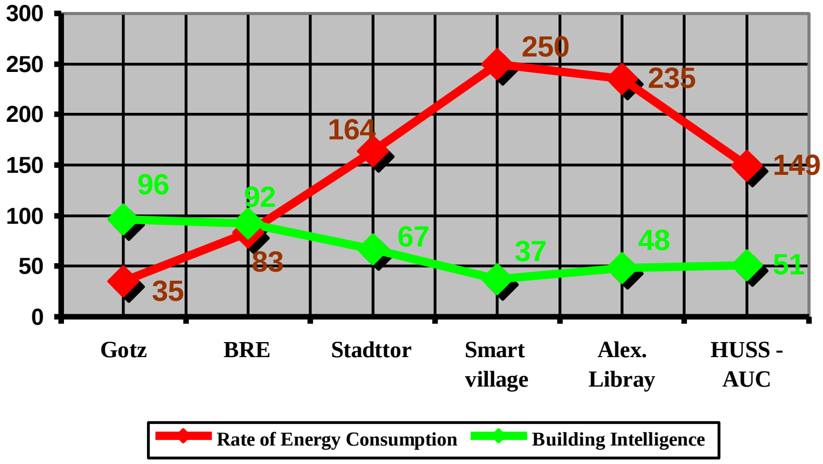


Fig.15 schematic chart demonstrate the adverse relation between a building intelligence and the rate of its energy consumption

(Badr, M. (2010). Intelligent Architecture As an Approach for apply the Technological Development in the Environmental Control and Energy Efficiency in Buildings , p.405)

Table 1. comparative study between local and international models

(Badr, M. (2010). Intelligent Architecture As an Approach for apply the Technological Development in the Environmental Control and Energy Efficiency in Buildings)

Assessment methods / Case studies				International models				Local models		
				Gotz	SUVA	BRE	city gate	Smart village	Alex. Library	HUSS - AUC
Proposed approach (intelligent building features)	Automation	BMS		●	●	●	●	⊙	●	◒
		Building communication system & office automation		●	⊙	●	●	●	●	●
	Responsive	Repose to changes in environment	Limited response	●	●	●	●	◒	●	◒
			Learning ability	●	○	○	○	○	○	○
		Response to users needs		●	⊙	●	⊙	⊙	⊙	⊙
	Sustainability	Efficiency of internal environment		●	●	●	●	⊙	⊙	●
		Environmental data		●	●	●	●	◒	⊙	◒
		Self generation of energy		●	●	●	●	◒	◒	⊙
		Use renewable energy resources		⊙	●	●	○	○	○	⊙
		Rationalization of energy consumption		●	⊙	●	○	○	○	⊙
Final evaluation by intelligence features				96%	81%	92%	67%	37%	48%	51%
Intelligent building index (IBI)	M1	Green Index		94%	97%	93%	71%	65%	68%	85%
	M2	Space Index		92%	70%	72%	72%	57%	58%	77%
	M3	Comfort Index		81%	61%	91%	85%	58%	70%	85%
	M4	Working Efficiency Index		79%	72%	81%	78%	68%	66%	76%
	M5	Culture Index		80%	60%	70%	91%	85%	89%	78%
	M6	High-tech image Index		78%	64%	83%	78%	66%	68%	66%
	M7	Safety and Structure Index		87%	80%	85%	68%	68%	89%	81%
	M8	Management Practice and Security Index		92%	80%	86%	82%	69%	75%	68%
	M9	Cost Effectiveness Index		This module had been neglected						
	M10	Health and Sanitation Index		73%	87%	80%	80%	77%	70%	81%
Final evaluation by IBI method				83%	72%	82%	78%	67%	71%	77%

6. Conclusion

The study ends with introducing the most important findings and recommendations of the study. It is a full summary clarifying the main points of the study.

6.1 General Findings and Outcomes

- Intelligent architecture is one of the most effective architectural trends for creating a sustainable and responsive environment through achieving the integration between technological and the environmental systems.
- The solution to face the passive effect of technology is not reached by the separation of one from the other but the solution lies in reaching an architecture which is able to apply and absorb advanced technology without doing any harm to the environment. On the contrary, it should be in harmony with the environment.

- There is no method up till now that can be considered a model evaluation method for intelligent buildings.
- Evaluating the performance of intelligent buildings can be accessed through the three smart features: automation, responsiveness and compatibility with environment & sustainability. By means of these features, the values of intelligent architecture can be achieved and architectural products can be described as 'intelligent'.

6.2 Recommendations:

- The work of raising awareness for architects and practitioners in Egypt with modern technologies generally and with right concept of intelligent architecture, in particular, and to clarify the role of intelligent architecture in achieving the goals of environmental architecture and the preservation of the environment.
- The inclusion of the field of intelligent architecture trend and its visions within the curriculum for universities and engineering scientific institutions in the two stages of what undergraduate and after graduation. As well put new decisions and approaches about the technology of intelligent architecture and its role in achieving the objectives of environmental architecture, where play that a major role in creating a generation of architects familiar with these new technologies and all what is new in international architecture.
- Try to take advantage of the international experience in this field, so that we can benefit from the previous experiences and start from where the others ended.
- The establishment of institutes and research centers specialized in research and building sciences prepared code specialized in intelligent buildings. Moreover, to try to develop what has been studied in the research and drafting the integral and comprehensive vision of intelligent architecture and turn it into a programme or a method to assess the performance of intelligent buildings in line with local reality.

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