INTELLIGENT BUILDINGS AND ENERGY CONSERVATION: ECONOMY AND EFFICIENCY

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ABSTRACT

Fossil fuel reserve is limited and present indications show that if current rates of energy consumption continue, the world will face energy starvation sometime during the 21st Century, added to that the thoughtless exploitation of these fuels which caused devastating environmental pollution. All together proves that there is no alternative to the widespread application of energy conserving techniques. A breakdown of national energy consumption into various sectors indicates that 35% of the total energy is required for building use. This would involve realization of optimum internal environmental conditions and provision of modern services (i.e., elevators, escalators, telecommunication and automation systems). An appropriate approach to deal with the sophisticated demands of modern buildings, specially of public building type, for example offices and shopping centers, is the utilization of intelligent buildings. The main function here is to monitor, record, analyze, critically examine, redirect and control energy flow through different systems so that energy is utilized with maximum efficiency.
This research is concerned with surveying the intelligent buildings concept and features. Cultural considerations of applying such systems in developing countries with special reference to Egypt are examined. A process of cost and benefit criteria is suggested to be used by the investor to evaluate the feasibility of the intelligent building application.

Keywords: Intelligent Buildings, Energy management, Running cost, Economic analysis.

INTRODUCTION

Energy conservation and energy efficiency, both have a major role to play in meeting the needs of global energy demand, regarding Carbon dioxide 2 emission in the atmosphere, and combating the danger of global warming. It is a well known fact that 8 countries have 81% of the world crude oil reserves, 6 countries have 70% of all natural gas reserves and 8 countries have 89% of all coal reserves [1]. It is also well established now that global warming is happening and according to the three centers in the world (Princeton, USA, Hamburg, Germany and IPCC, London, UK) who assessed this phenomenon, the temperature rise during the last 70 years is 1.75 °C. The increase of CO_2 since 1760 is 20%. Rain has increased by 15% and the sea level has increased by 10.5 cm during the last 100 years. Unless drastic measures are taken, all these phenomena are going to change the climate as well as the terrain of many countries. The recent Kyoto meeting, December 1997, emphasized the importance of limiting CO_2 emissions, and accordingly one should conclude that energy efficiency installations penetration into the energy market would be much faster than was expected few years ago.

Buildings use energy, which accounts for 35-50% of total energy use and would be responsible for around 50% of all CO_2 emissions [2]. This illustrates the need to view the building as a system. Energy loads need to be examined and quantified so as to be able to identify how best to provide the energy required and how to reduce the demand as much as possible.

With the recent advance in technology, modern design approach can help in controlling the energy output of buildings while facilitating the introduction of extra luxurious services while, architects can influence new building design fairly easily, it is well recognized that the vast majority of the building stock is existing. The importance of additional automated systems that can be installed into the existing buildings to improve their energy performance is thus perceived.

INTELLIGENT BUILDINGS AS AN APPROPRIATE APPROACH

Conventional buildings can no longer meet user's need in a world hitting for systematic information services provided through advanced computer technology. Intelligent buildings now contribute to office productivity, which has grown immensely since the introduction of office automation techniques. Since 1983, intelligent buildings have become increasingly popular.

Intelligent or smart buildings represent an activity that is the result of the joining of several fields involved in building design and construction such as, interior and exterior architecture, computer and telecommunication technologies, ergonomics (design for human use), human factors, building construction, building Heating, Ventilating and Air-conditioning (HVAC) technologies, building security, and all the connected mechanical and electrical services. Motives of intelligent buildings may range from commercial concerns to genuine interest in creating ergonomic and useful working environments that favor creativity, increased productivity, a maximum degree of safety and rigorous control over the use of all forms of energy, and offer a wide range of services and conveniences, as well as being aesthetically pleasing.

Definition

An intelligent building is a single or a complex of buildings which offers a consistent set of facilities to both the building managers and to the occupants.

To the building managers, an integrated set of management, control maintenance, and building communication facilities that allow efficient and cost effective environmental control, security surveillance, alarm monitoring and communications, both inside the building and out to municipal authorities (police, fire stations, and hospitals), all together present the final destination. To the occupants in the workplace, an environment ergonomically designed to increase productivity and encourage creativity and in residences and hotels, environments that will foster comfort and a "humanizing" atmosphere as well as providing sophisticated computer and telecommunication services with the facilities to realize these environments would be the ultimate. The design could extend from a macro-level encompassing the building and its internal and external spaces to a micro-level involving furniture, workplace, and residential equipment, local atmosphere and lighting control [3].

Intelligent Building Concerns

The objectives of intelligent buildings concept can be summarized in what follows. First to ensure satisfaction and convenience for people working or living in them. Second to have an overall automatic control system that enables the officials in charge of minimizing the building running cost while offering the best possible internal conditions.

The third objective of intelligent buildings is to serve as a locus for receiving and transmitting information and support management efficiency as a way of realization of building administration..

The fourth objective lies in fast, flexible and economical responses to changing sociological environments, diverse and complicated office work, and active business strategies [4].

Components of Intelligent Building System

As mentioned before, intelligent buildings have an expected goal-oriented behavior, namely: to increase worker comfort, productivity, creativity, security, and to control energy resources so as to minimize costs and maximize individual comfort, while facilitating overall building management and permitting building owners to realize profits. As a result, intelligent buildings, have a number of distinct interacting subsystems and components:

- A computer and telecommunication system.
- An alarm/security system.
- An energy regulatory system called Energy Management Control System (EMCS) with the purpose of managing energy resources to minimize cost and create a healthy, comfortable working or living environment with the following services;

Basic service: control of HVAC.

Advanced service: conservation of electrical consumption through HVAC control and electrical/mechanical devices control (elevators, escalators, etc.), and /or micro-climate control: air-conditioning, lighting and solar energy regulation.

- Electrical and communications wiring infrastructure.
- A command and control center.
- An electrical power supply system, usually guaranteeing continuous Uninterrupted Power Supply (UPS).
- A utilities system (water, sewerage and drainage).

Intelligent buildings are both "high tech" as well as "high reputable buildings", having a very high degree of system integration and flexibility. Global considerations implied in the design of intelligent buildings are: architecture (interior and exterior), aesthetics, space utilization, local supporting environment, internal wiring scheme and hardwire versus software elements and human factors such as privacy, reduced noise levels, comfort (lighting and micro-climate control), safety (fire, smoke), security and convenient communications (human-machine interfaces). An example for intelligent building system concept is shown in Figure 1 [5].

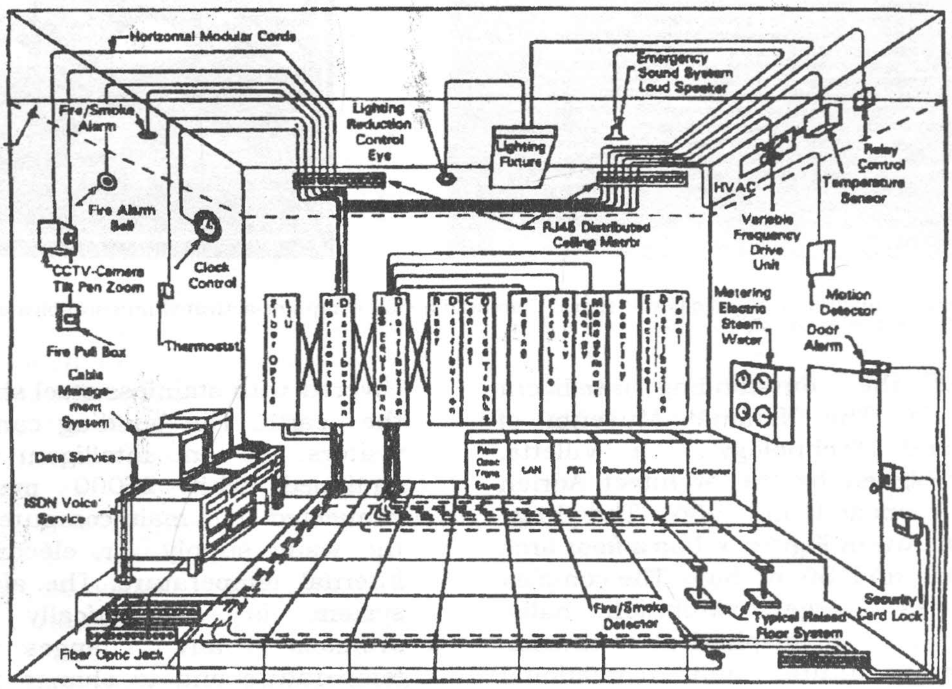


Figure1 Components of intelligent buiding system.

Running Cost

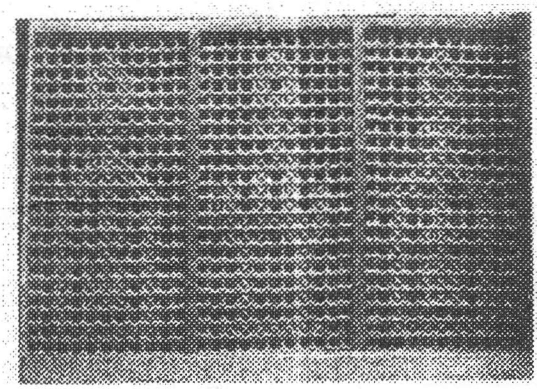
One of the main objectives of intelligent buildings is to cut down running cost through the following aspects:

- The system precisely regulates air-conditioning by switching the Value Added Network (VAN) on and off in each building section. Similarly, rental conference rooms are air conditioned automatically just prior to reserved conferences.
- Card control system guarantees tenants security and free access around the clock, to detect when the tenant leaves and switch off the air-condition and lights if tenant forgets to do so. It also controls the on/off switches for lighting in the utility area.
- Remote controlled switching allows one to change the lighting distribution within the open office plan. Panel terminal installed in each section allows each worker to control lighting and air-conditioning.
- Computer terminals allow each tenant to communicate with building management to change lighting layout.

EXAMPLES

Full intelligent buildings that manage the problem of internal environment through the control of both external envelope and internal energy resources are explored as follows:

The "Institut Du Monde Arabe" in Paris, 1987, shown in Figure 2 is a well established example for a building that harmonizes with natural environment and accordingly presents an energy efficient building. Jean Nouvel, utilized on the outside of the building, aluminum, glass and concrete that welded together to create a building with a fantastic level of technological expertise. It is equipped with a High Tech control system altering the size and shape of the diaphragms, creating different lighting conditions and offering protection from the sun [6].



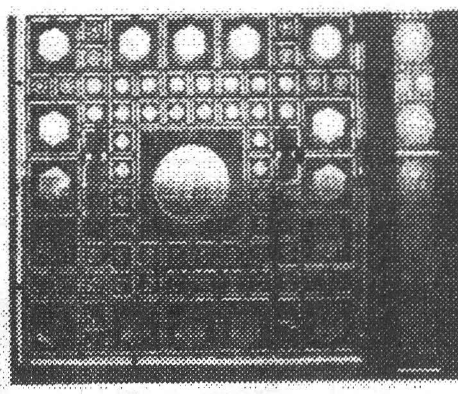


Figure 2 Wooden mushrabbiya in medieval Islamic Cairo and a steel computer-activated mushrabbiya at the "Institut du Monde Arabe in paris", 1987 [7]

One of the outstanding intelligent buildings is "The National Museum of Science and Technology", La Villette, France, designed by the architect Adrien Fainsilber, opened in 1986. The huge building shown in Figure 3, has a floor area of 59000 m^2 and 50 m high. The complex accommodates, large exhibition halls, libraries, a hemispherical cinema, planetarium, cultural and recreational facilities. The sphere diameter is 34 m and covered with stainless steel shell to look like the earth. The building can serve 15000 visitors. As an intelligent building, it is equipped with 25000 metallic sensors connected to a main computer that controls the water supply, air, electric power, and internal temperature. The air conditioning system is automatically operated to overcome any changes in internal temperature and to change 2 million m^3 of air flow/hour. A complete floor is devoted to operate the intelligent building system. To insure the safety regulations, fifteen water supply points are distributed around the building to automatically rush water if the temperature exceeds 68 °C. The number of visitors is counted by photocells not to exceed the maximum capacity. Four thousand smoke detectors can predict and locate any smoke source for fire protection. The building is also equipped by Uninterrupted Power Supply system (UPS) with a capacity of 6000 kW. The main exhibition hall 100 m length and 40 m high is equipped by two computer operated rotating domes to collect, reflect and control the intensity and color of daylight through the building depth. This building is a good example of applying advanced high technology to completely control a huge project [8].

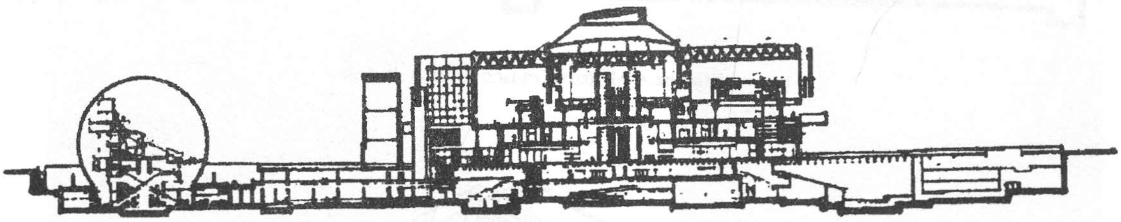


Figure 3 The National Museum for Science and Technology, La Villette, France.

Shinjuku L Tower in Japan, is another example for an intelligent office building. The Shinjuku L Tower is furnished with the following intelligent subsystems:

- Zoning accordance to thermal load: The office is divided into zones, light, middle and heavy, according to its thermal load. The light zone occupies most of the area (minimum thermal load of Office automation (OA) equipment-20 W/m°). The middle zone has workstation with (maximum thermal load of OA equipment - 65 W/m^2). The heavy zone is the Central Processing Unit (CPU) zone (maximum thermal load of OA equipment - 500 W/m^2).
- Three-way duct air conditioning system- it is provided to supply cold and warm air. Air conditioning can be sent only to the rooms that are used.
- Temperature detachable thermostat-this thermostat can be easily attached and removed to adapt to any future changes in the interior layout.
- Odor control system- it is combined with the air conditioning system to enhance the office and commercial facilities by means of specially blended natural fragrances.
- Information systems and security card system are also included.

The previous three examples reviewed the concept of fully automated intelligent buildings. Another important approach that could suit the upgrading of energy performance of existing buildings to minimize the running cost; is the automated movable external envelopes. This approach is implemented to manage the thermal environment in the following examples:

In Milton Keynes Energy house, Architects, Robin Spence and Glenn Howells implemented the end walls and roof with three layers of glass, with insulating louvers in a sealed cavity as shown in Figure 4. The louvers operate in three modes: in hot weather they cut out sunlight, but let in daylight; during the night they turn flat to prevent heat loss; and in cold weather, they let in much light as possible to heat the building up. In hot periods, heat pumps draw excess heat from the sealed cavity in the glass box to transfer it to underground water tanks which in the best conditions can store enough energy for 24 hours to provide a night heating.

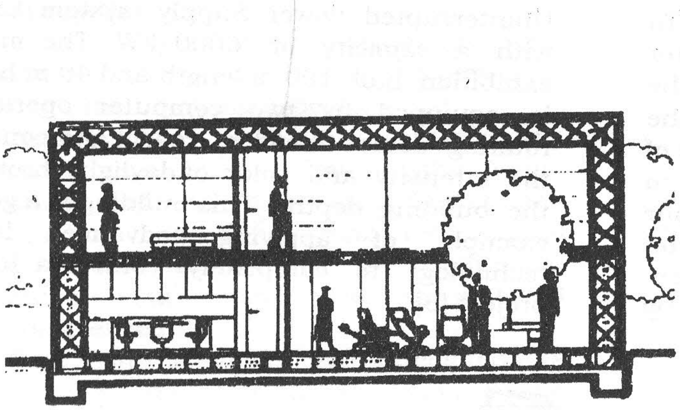


Figure 4 Milton Keynes energy house.

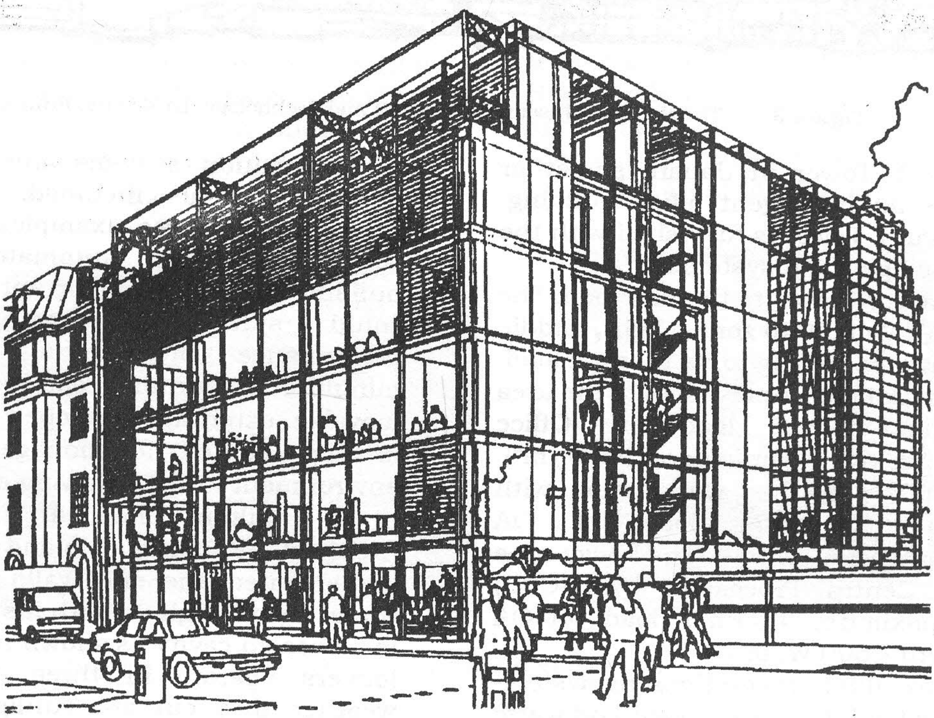


Figure 5 A commercial and residential building, London

Example for a commercial and residential building in London's Euston Road, shown in Figure 5 The architects, Spence & Webster proposed a building on a three-sided site. They designed an atrium, which is daylit from the top and from the west side. The roof of the office and the atrium is double and single skins of flat silicone glass panels, with automatically variable highly insulated sun control louvers which can alter light levels from 87.5% of daylight to total blackout. The same system is used on the north elevation, with a wide air space to reduce noise penetration. The movable louvers have other uses besides controlling the emissivity of heat and prevention of excessive insolation. In both the north wall and the roof of the office part, it is utilized to reflect light from the sky into the building. In the north wall, it reflect daylight onto the ceilings, where it complements the output of lower openings; in the roof. It can also work to capture the low rays of winter sun and reflect them into the interior [9].

A unique example of automatically controlled umbrellas designed by, Rash Associates, are implemented in Saudi Arabia to shade outdoor large areas. A solar powered anemometer automatically causes the umbrellas to open in hot climate or fold if wind speed destabilizes them as shown in Figure 6 [10].

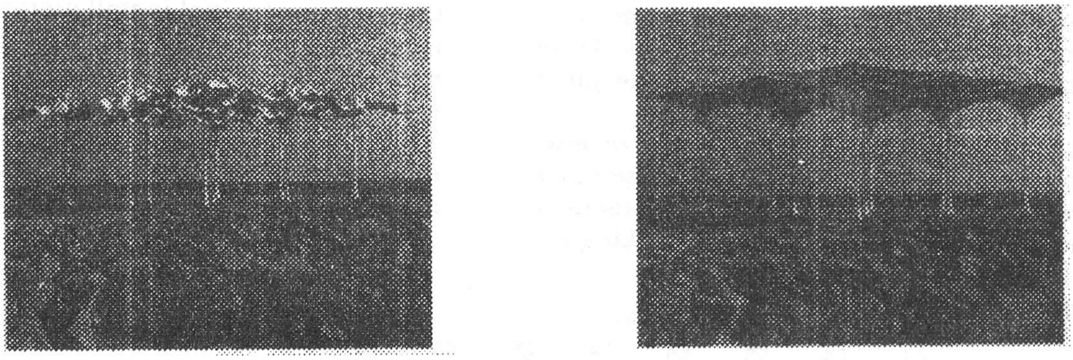


Figure 6 Automatically controlled umbrellas in Saudi Arabia.

ECONOMIC ANALYSIS OF INTELLIGENT BUILDINGS

Four methods are available as decision techniques in economic analysis. These methods are "Costs-in-Use", "Cost-Effective Analysis", "Discount Cash Flow" and "Cost-Benefit Analysis".

Costs-In-Use

The technique of costs-in-use is concerned with means and not with ends. It is concerned with the choice of means to a given end and with the problem of obtaining the best value for money for the resources spent. While the technique has been primarily developed to provide a means of comparing building designs and planning alternatives, it is clearly applicable to any comparison of alternative means to a given end. In this technique sometimes, the differences can not be quantified. Factors such as appearance, comfort, convenience and atmosphere can generally be subjective. It is difficult to measure likes and dislikes of building users but it is often possible to guess whether the investor would be willing to spend a given sum of money to reach a reputable output.

Cost-Effective Analysis

Cost-effective analysis is another technique which is concerned with comparing different means to reach the same end. This technique has been developed in the field of weapon industry analysis. It is concerned with obtaining the best performance for the least cost.

Discount Cash Flow

Discount cash flow is a technique developed for use in the business sector for comparing alternative investment projects. In business sector, the scarce factor is usually the fixed capital, and it is the returns on capital which the business man wishes to maximize. The individual investor is not concerned with producing what the community requires but only what the market indicates it requires. Maximizing the returns on capital is therefore a valid criteria for the individual investor. The application of this criterion involves comparing the returns on capital from alternative investment possibilities. The most accurate method is to discount the flow of expenditures and revenues at the rate of interest at which the sum of the discounted values of the surpluses exactly equals the discounted values of the capital expenditures.

Cost-Benefit Analysis

This concept is more appropriate to public or social projects, where it is necessary to evaluate not only the revenues which accrues directly to a project, but also all the side effects, which increase the revenues to other projects and which increase welfare and satisfactions even if no corresponding payments are made. Thus values or benefits are quantified in the same way as in the cost-in-use technique.

As a result of the previous review, "Discount Cash Flow" method is the most appropriate for the subject of a practical economic analysis and decision making for different alternatives of intelligent building systems, and for comparing conventional buildings and intelligent buildings systems in a developing country with restricted financial resources. When applying the "Discount Cash Flow" method, an Intelligent Building System is recommended if the present worth value of annual savings exceeds the present worth value of total cost. Cost of an intelligent system is composed of initial installation cost, annual running cost and single payment cost like intermittent upgrading or replacements as shown in Figure 7. As explained by P.A. Stone [11], economic behavior of a system is influenced by time period (n) and (i) interest rate.

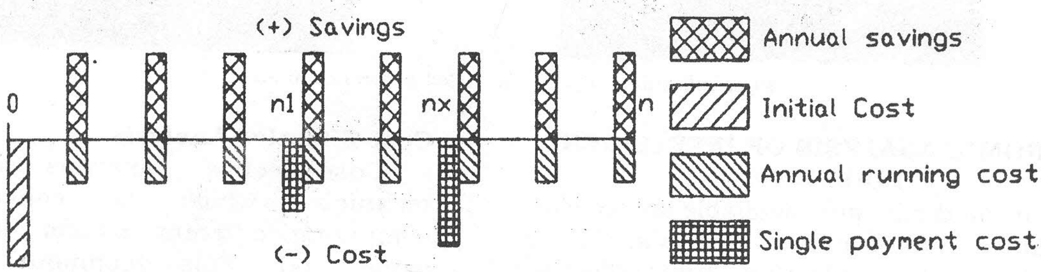


Figure 7 Cash flow of an intelligent building system

Present worth value of savings =

$$\frac{1-\left(\frac{1}{1+i}\right)^{n}}{i} \; x \text{ equal annual savings} \qquad (1)$$

Present worth value of cost = initial cost +

$$\frac{1-\left(\frac{1}{1+i}\right)^{n}}{i} - x \text{ equal annual running cost} + \Sigma$$

present value of single payment cost (2)

Present worth value of a single payment cost

$$= \frac{1}{(1+i)^{nx}} \text{ x single payment} \qquad (3)$$

Accept project if:
Present worth value of savings is greater than the Present worth value of cost.

CONCLUSION

Architects have always been known as generalists, able to assimilate a wide variety of information and convert it into a final design solution. The intelligent building challenges this ability. The architect should use analysis, cross comparison, synthesis leading to choices that have a basis in fact rather than fashion. Within the content of Intelligent Building attributes are a must:

- Awareness of the energy implications of design concept, material choices, energy cost, and their pollution potential.
- Awareness of new technologies and reviewing the literature beyond it.
- Reading or rereading the indigenous solutions by the visionaries of the age, leading to design with nature and energy conservation (The Insitut du Monde Arabe is an inspiring example).

A view point of multiple rather than singular realities and meanings, more in tune with the future.

- The Discount Cash Flow method is a suitable approach to reach a decision, concerning the Intelligent Building application.

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المبانى الذكية والحفاظ على الطاقة: الاقتصاد والكفاءة

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ملخص البحث

نعلم جميعا أن مصادر الطاقة المستخرجة من باطن الأرض محدودة و إذا استمرت معدلات استهلاك الطاقة الحالية فان العالم سيعاني من نقص حاد للطاقة مع قدوم القرن الحادى و العشرين، علاوة على ذلك فان الاستهلاك الغير واعي لهذه المصادر قد سبب تلوث بيئى مدمر . و تشير هذه الدلائل انه لا بديل أو غنى عن استخدام واسع لتكنولوجيا الحفاظ على الطاقة .

نظرا لان ٣٠ % من الاستهلاك المحلى للطاقة يوجه إلي المباني و ذلك لتوفير بيئة حرارية داخلية مناسبة و تشغيل المصاعد و عناصر الاتصال الرأسي و الاتصالات و أنظمة التحكم ، فهذه الدلالة تشير بوضوح إلي أن الاتجاه المناسب للتعامل مع المطالب المعقدة للمباني الحديثة خاصة المباني العامة مثل المكاتب و المراكز التجارية هو المباني الذكية. و الوظيفة

الأساسية للنظم الخاصة بالذكاء الصناعي هى مراقبة، و تسجيل، و تحليل، واعادة توجيه الطاقة للأنظمة المختلفة لتحقيق أعلى كفاءة لاستخدام الطاقة.

و يهتم هذا البحث باستعراض التصورات المختلفة للمباني الذكية مع وضع المؤثرات الثقافية عند تطبيق هذه النظم فى البلدان النامية مثل مصر فى الاعتبار – وقد تم فى هذا البحث تقديم أسلوب للتحليل الاقتصادي للتكلفة و العائد حتى يتمكن المستثمرون من تقديم الجدوى الاقتصادية لتطبيق مبدأ المبنى الذكى .