Integrating Intelligent Building Technologies: A Means for Fostering Sustainability

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Abstract
Intelligent Building technologies have a potential significant impact on sustainability issues (energy efficiency, due diligence, health and safety and indoor environment). It is widely recognized that intelligent building can improve the environmental and economic performance of buildings. Consequently, the promotion of intelligent buildings is regarded as means of fostering sustainability. Intelligent building technology encompasses sophisticated systems targeting various facets of building automation. Developing such an integration system of intelligent buildings technologies can significantly increase the energy efficiency of the building while also providing enhanced occupant comfort and cost effectiveness. Given the developments in information and communication technology and the increasing level of complexity of intelligent building systems, this paper introduces an integration system that facilitates improving the utilization of intelligent building technologies. The proposed system in this paper provides three indispensable sets of criteria by which successful integration of intelligent building technologies can be achieved. These measures are integration criteria for sub-system operation, best practices of sub-system business considerations, and interoperability criteria. Detailed and articulated measures for each set of these criteria are introduced. The paper explores the potential benefits of integrating intelligent building technologies as a useful means for fostering sustainability in buildings.

1. Introduction

The greatest challenge to the built environment professionals including architects, engineers and facility managers in the next decades will be the preservation of natural environment. Buildings greatly affect the environment and produce a large proportion of green house gas emissions. Intelligent Building technologies have a potential significant impact on sustainability issues (energy efficiency, due diligence, health and safety and indoor environment). It is widely recognized that intelligent building can improve the environmental and economic performance of buildings. Consequently, the promotion of intelligent buildings is regarded as means of fostering sustainability. The interrelationship between intelligent buildings and sustainability includes achieving integrated design, individual comfort control, indoor environmental quality, energy efficiency, automatic climate response and advanced controls.

The construction industry is moving into intelligent building design and development, and analyzing the impact this will have in terms of building sustainability and long-term business value. Therefore, the key players in building and construction industry are being pressed to deliver more efficiency, productivity, safety, and performance from both the current and planned projects. On top of this, they are getting additional pressure to deliver sustainable buildings. There is an expectation that intelligent building technology as one of the methods that they will be using to deliver on these needs. Intelligent building technology encompasses sophisticated systems targeting various facets of building automation. With construction investment around the world currently pushing the industry towards even bolder and more complex building solutions, the means by which a building's sustainable qualities and overall functionality can be assessed becomes an important driver in determining return on investment.

Installing various intelligent and Hi-Tech equipments in a building is no guarantee that a building will be intelligent or the benefits of intelligent buildings will be achieved. The unification and coordination of all buildings' management functions will provide a comprehensive system. Thus the step to an integration system will yield considerable benefits at relatively tiny cost. The benefits of developing an integration system of intelligent building technologies include: cost reduction and management control (capital saving, efficient building management); staff comfort, security, safety and most importantly flexibility. Hence, there will be a specific capital savings in new building situations where equipments and cabling are shared, and where the integration is planned at the design stage. However, significant cost savings come later, where the system will be in operation (Lees, 1994).

Currently high-tech buildings are having increasing amount of automated systems installed to increase their reactiveness, function, and to improve aspects of usability and control in the environment. Considering that most building users spend a large part of their life in buildings, then it seems only fitting that buildings should be as flexible and complimentary as possible. Gaining access to one's workplace intelligent facilities should be an automatic event for the area's owner/occupant but prohibit other people access. Although conceptually simple, the infrastructure required for such a system necessitates, at minimum, integration between sensor development, vision and recognition, task user profile and user interfaces within distributed systems. Therefore, developing a clear strategy and guidelines of an integration system of cost-effective hi-tech intelligent buildings is imperative and paramount.

This paper addresses the concept of intelligent buildings and its associated technologies along with the importance and necessity of improving the utilization of intelligent building technologies by successful integration. An integration system aimed at achieving this goal is proposed and its components and measures are articulated. The potential benefits of integrating intelligent building technologies as a useful means for fostering sustainability in buildings and target beneficiaries of the proposed system are identified in the remainder of this paper.

2. Intelligent buildings

The concept of intelligent buildings focuses on taking advantage of Information Technology (IT) to provide flexible, productive, and cost-effective environment for building occupants. The initial cost of developing intelligent buildings might appear expensive; however the total life-cycle cost for intelligent buildings is generally lower than the cost for conventional buildings. Hi-tech intelligent buildings stir cost savings to building tenants and owners. Today's "intelligent building technologies" support and operate various aspects of a building and its infrastructure, including lighting; heating, ventilation, and air-conditioning (HVAC); energy management; security; elevators; life-safety systems; communications; and building condition monitoring. The technologies used in these "wired" buildings seek to improve the building environment and functionality for the occupants while controlling costs. Improving end-user security, comfort, and accessibility all help productivity and user comfort levels. While no example of a wholly integrated building exists, integration is becoming more pervasive (Suttell, 2002).

The incorporation of intelligent technology into facilities and infrastructure can assist installation personnel. Recent advances in sensor, electronic, communications, computer, and information technologies offer the possibility of intelligent buildings that have the capability of monitoring, assessing, and responding to some types of conditions. Such facilities are referred to as intelligent, or high-tech. In general, an intelligent building system incorporates three fundamental features (as illustrated in Figure 1), that are performed autonomously: Detection: sensing or detecting changes in the environment; Analysis: intelligently analyzing signals and data to assess the situation and to determine an appropriate response; and Response: executing an appropriate response.

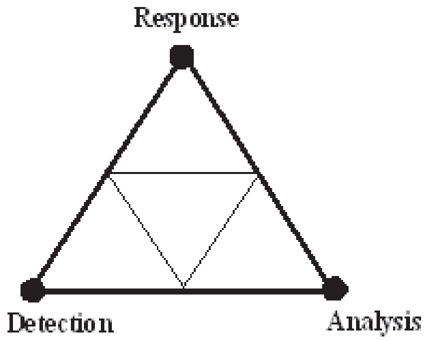

Figure 1. Fundamental features of a intelligent building system.

Various studies (Drewer and Gann, 1994; Kim, 1996; So and Wong, 2002; Ltd. Synetrix, 2004) have addressed the concept and technologies of intelligent buildings from different dimensions. An intelligent building can be viewed as one that provides a productive and cost-effective environment through optimization of its four basic components: structure, system, service, management, and the interrelationship between them. Intelligent buildings encompass technology of microprocessors that operate and control building systems HVAC, power, vertical transportation, fire and life safety and security (Ltd. Synetrix, 2004). The building systems rely on a network of sophisticated telecommunication systems. Intelligent building technologies include networking, audio-visual systems, raised floors, intelligent cards, occupants' amenity, building automation and energy efficiency (Kim, 1996). In essence, the components of an intelligent building must include building management system for real time control, utility functions, energy efficiency/energy management, security and life safety systems and computer/internet integration. There are four factors that should be considered in designing intelligent buildings including people, environment, technology and possible change (Mawson, 1994). These factors will help to guide the design and implementation of intelligent building technologies.

An intelligent building is viewed as an entity made from many individual intelligent objects. These intelligent building objects or technologies can be either fixed or mobile and can be broken down into the following categories

(Walsh et al, 2000).

• Fixed elements: These are items which do not have computational or processing ability but will have state which can be ascertained using sensors. For instance, doors and widows that can be open or shut; lights that can be switched on or off or dimmed, thermostat controls and even rooms themselves, etc.

• Mobile elements: It is not necessary to install processors to everything that can move. For instance, certain furniture and fittings do not need such processors, e.g. chairs and disks can be brought from one room to the other while adding a magnetic tag with a particular signature will allow tracking these types of elements throughout the premises.

• Fixed computing elements: This set of elements comprises of objects which have processing ability but with no method of moving such as printers, computer terminals, coffee machines, photocopier, air conditioners, smoke detectors, fire alarm, security sensors and cameras, etc.

• Mobile computing elements: These objects exhibit the properties of fixed computing entities but also have the freedom of movement such as mobile communications, intelligent wheelchairs, mobile personal computers, task specific robots.

The concept of intelligent buildings is more than incorporating an individual or a set of intelligent components into a building. Intelligent buildings also include the efficient management and utilizations of building spaces and resources. Furthermore, developing intelligent buildings involves enhancing the building systems' capabilities to be responsive, intelligent and autonomous for a better and productive environment.

3. Challenges for successful implementation of intelligent building technologies

Challenges for successful implementation of intelligent building technologies arise from many diverse considerations that can be clustered into three groups: (a) design issues that include: reluctance of building developers, design team members, and building codes; (b) construction issues that involve: traditional construction processes, training of construction work force, and contractors and suppliers; and (c) guidelines including procedures of systems integration, inter operability and standards, as graphically depicted in Figure 2.

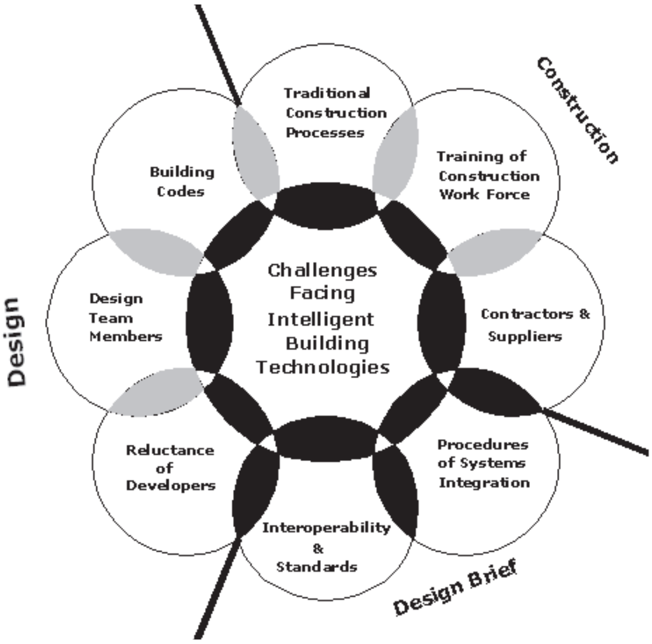

Figure 2. Challenges facing the successful implementation of intelligent building technologies.

Low initial costs are attractive to developers, while the operators and occupants are more interested in long term operational costs. The reluctance of developers to incorporate intelligent building technologies is due to the perception of increased initial cost and concern over unproven technologies. With regard to design team members, there is a difficulty in achieving an agreement on the approach required for incorporating intelligent building technologies among the design team members. There is also a challenge for the architect to select engineers and contractors qualified to undertake the consolidated activities needed to design and implement an intelligent building. Furthermore, building codes require substantial update to facilitate the implementation of intelligent building technologies. Construction challenges include: the unwillingness to change from the traditional construction process arrangement, where each of the specialized construction trades completes its task independently of all others; the inability of suppliers to depend on each other for system data inputs due to proprietary protocols that cannot communicate with each other; the lack of contractors with the knowledge and experience to undertake a project where total integration is the goal; and the need for extensive training of a broad spectrum of the construction work force in the implementation and use of intelligent building technologies. The development of integration criteria for subsystem operation and best practices of subsystem business considerations of intelligent building technologies, and interoperability and universally accepted standards are major challenges in achieving successful implementation of intelligent building technologies.

4. Integration of intelligent building technologies

Building a single integrated system to accommodate security, life safety, HVAC and other systems is the goal of many building designers and architects, but is being frustrated by the multiplicity of separate proprietary systems. What is needed is an integration system (instead of one complete system) in terms of procedures, policies, standards and measures, which govern the interfaces with all of the varied products that go into the building. This integration system would provide process and strategies to accommodate all building systems such as access control, environmental control, fire alarm and emergency control. It would guide the provision for a full array of sensors that would alert the central focal point of changing conditions, providing the information needed for proactive rather than reactive response when changes pose a threat to people and/or property. Developing such an integration system of intelligent buildings technologies can significantly increase the energy efficiency of the building while also providing enhanced occupant comfort and cost effectiveness. Considering this integration system at the conceptual design stage affords greater opportunities to integrate and consolidate different building system functions into fewer independent systems, which can reduce overall complexity. Introducing an integration system of intelligent building technologies at the early stages of the design process (pre-design and schematic) with a reasonable design effort would be very effective in providing better opportunities to implement const-effective energy savings buildings. On the other hand, substantial design effort at the construction documentation and construction stages will have little impact in providing const-effective energy savings buildings as graphically illustrated in Figure 3.

The integration system helps in identifying a clear set of desired outcomes and objectives for each of the four basic components of intelligent buildings: structure, system, service and management and the interrelationship between them, in order to enhance the building systems' capabilities to be responsive, intelligent and autonomous for a better and productive and cost-effective environment. The integration system will result in the lowest net present value while the value of the integration system will increase with the advancement of information technology wherein information will be a competitive advantage. The set of guidelines that helped in the development of the proposed approach of an integration system to improve the utilization of intelligent building technologies include ensuring the integration system to be:

- informative
- modifiable and flexible
- comfort and service-oriented
- economic
- based on correct fundamental hi-tech solutions

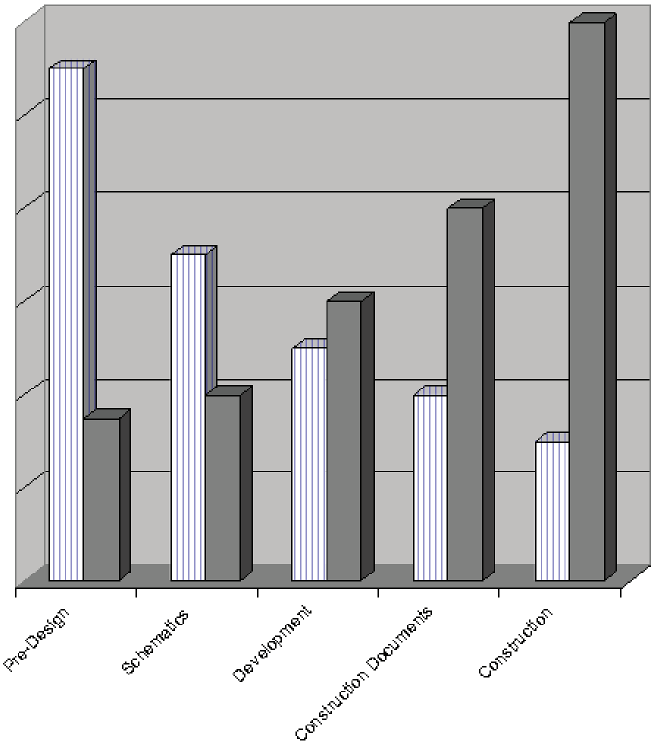

Figure 3. The relationship between opportunities to implement cost-effective energy savings buildings (light-shaded columns) and levels of design effort (dark-shaded columns) across the various stages of design process (after: www.energystar.gov).

5. Communication and interoperability of intelligent building technologies

Incompatibilities and limited opportunities for the integration of building automation and control systems among products of different vendors have frustrated real estate developers, building owners, operators, consultants, and system integrators (Fisher, 1996). Even though there has been a substantial progress on the interoperability of Building Automation and Control System (BACS), proprietary protocols still dominate the current BACS market even today (Frost, 2002). Recently, a comprehensive Intelligent Building system was developed (Wang et al, 2004) in which the sub-systems are integrated into a single Ethernet backbone. Users can supervise and monitor the entire intelligent building system via the management software. Interoperation over different sub-systems could be achieved. For instance, the HVAC system will stop and the relevant image of the space can pop-up when a fire alarm arises. Lighting is turned on automatically when an authorized person intends to enter the laboratory identified by the access control panel. The digital CCTV camera can be turned to monitor the delegated locations and start to record the event when a person intends to access the laboratory or if the door is open. However, every sub-system has different protocols in this intelligent building system. Therefore, gateways are needed to realize the conversion of protocols to achieve the total integration of the sub-systems.

Nowadays, the rapid development of information technologies offers new possible methods and solutions to overcome these difficulties. BACS network can be divided into three levels: management level, automation level and field level (Kranz, 2001). One can achieve integration and interoperation at all three levels starting from the bottom (field level) or achieve integration and interoperation at a high level. This provides two possible ways to solve the problems in interoperation and integration. First is to employ the same communication protocol in all the three levels. Second is to employ standard protocols at the upper level (e.g. management level) to avoid handling the difference of the lower level protocols directly (Wang et al, 2004). There are few potential candidates likely to be the future unified BACS communication protocols for all the three levels, such as BACnet, European Installation Bus Object Interface Specification (EIB-ObIS), LonTalk plus LonMark. They are all object-oriented protocols or have extension of object-oriented technology (Craton and Robin, 2002).

Intelligent building technologies have evolved over the past decades from the mixture of pneumatic controls, relays, sensors, and actuators of the past to the direct digital controls of the present. Many manufacturers had developed their own protocol to enable their devices to communicate with each other. Even unique systems within a building, such as boiler controls, chillers, variable speed drives, fire panels, and security systems, developed their own protocols until the typical building became a tower of babble. In many buildings interoperability means that the front-end controls for the various systems in the building all terminate in the same room. While protocols such as LonWorks and BACnet have come a long way toward the goal of interoperability, many of the devices and systems desired by today's building operators and integrators do not utilize these open system protocols to interface to building automation systems. Therefore, it would have been perfect if all devices used a common communication protocol, but the reality is that with large number of legacy devices worldwide, plus many different protocols available today, a single common protocol is not usually a choice. Also, for most devices, there is usually only one protocol output available. Thus, even if the integrator does select BACnet as the primary protocol, there will be many individual devices that will use a proprietary protocol – LonWorks, Metasys, Modbus, or something else. The only practical way to bring information from these other devices is via a protocol gateway. A gateway system can seamlessly integrate systems together.

For instance, when interfacing a fire panel using a proprietary protocol to a control system using Modbus TCP, the gateway should appear like a fire panel node to any device on the fire network and appear as a Modbus node to any Modbus system. A gateway can link a serial device to other serial systems or to Ethernet. Hence, interoperability is a necessity for an integrator's need to share data between devices and enjoy unified control. Using gateways enables the integrator to bring in legacy devices and enable interoperability between diverse systems (Ferree, 2002). Therefore, clearly there is a need to develop means that ensure intelligent building technologies work together to provide owners with interoperable solutions, and benefit end-users with reduced project risk and easier implementation .

6.Proposed integration system of intelligent building technologies

It is important to distinguish between the proposed integration system and an integrated computerized system that oversees and controls building operations, generally energy and life safety. Although the potential exists to integrate all facilities management activities into one monstrous system, practical and economic considerations discourage this. What is more likely is an interface among the various systems - HVAC, lighting, fire, and security - enabling essential communications. Owners resist putting all their eggs in one basket but rather they want competitive bids from a number of qualified suppliers. Although total integrated computerized system remains as practically out of reach in the immediate future, there have been giant strides toward it in facilities energy management systems.

The proposed integration system helps in identifying a clear set of desired outcomes and objectives for each of the four basic components of intelligent buildings: structure, system, service and management and the interrelationship between them which will form the basis for guiding the interface and managing the interactions among the various systems in intelligent buildings (Reffat, 2007). The proposed integration system aims to outline the infrastructure that will handle the interactions which will occur through various scenarios of building usage. The integration system is a process by which multiple elements and components and seemingly unrelated aspects are integrated in a manner that permits synergistic benefits to be realized. The goal is to achieve high performance and multiple benefits at a lower cost than the total for all the components combined. This process often includes integrating intelligent and sustainable design strategies into conventional design criteria for building form, function, performance, and cost. The process for developing the integration system to improve the utilization of intelligent building technologies included:

- Analyzing requirements of intelligent building technologies

- Evaluating alternative implementations
- Developing integration plans and criteria
- Evaluating the utility of the proposed integration system.

In the proposed integration system as depicted in Figure 4, intelligent building technologies are categorized into two categories: (a) primary systems that include intelligent technologies for building automation, information communication network, fire protection, heat ventilation and air condition, and security; and (b) secondary systems that include intelligent technologies for electrical, vertical transportation, lighting, interior layout, and building façade. In order to achieve a successful integration for these intelligent building technologies to improve its utilization, the proposed integration system provides three indispensable sets of criteria by which successful integration of intelligent building technologies can be achieved: integration criteria for sub-system operation, best practices of sub-system business considerations, and interoperability criteria as articulated in Tables 1, 2, and 3 respectively. Tables 1 and 2 have been adapted from the best practices guide for evaluating intelligent building technologies (Wacks, 2002).

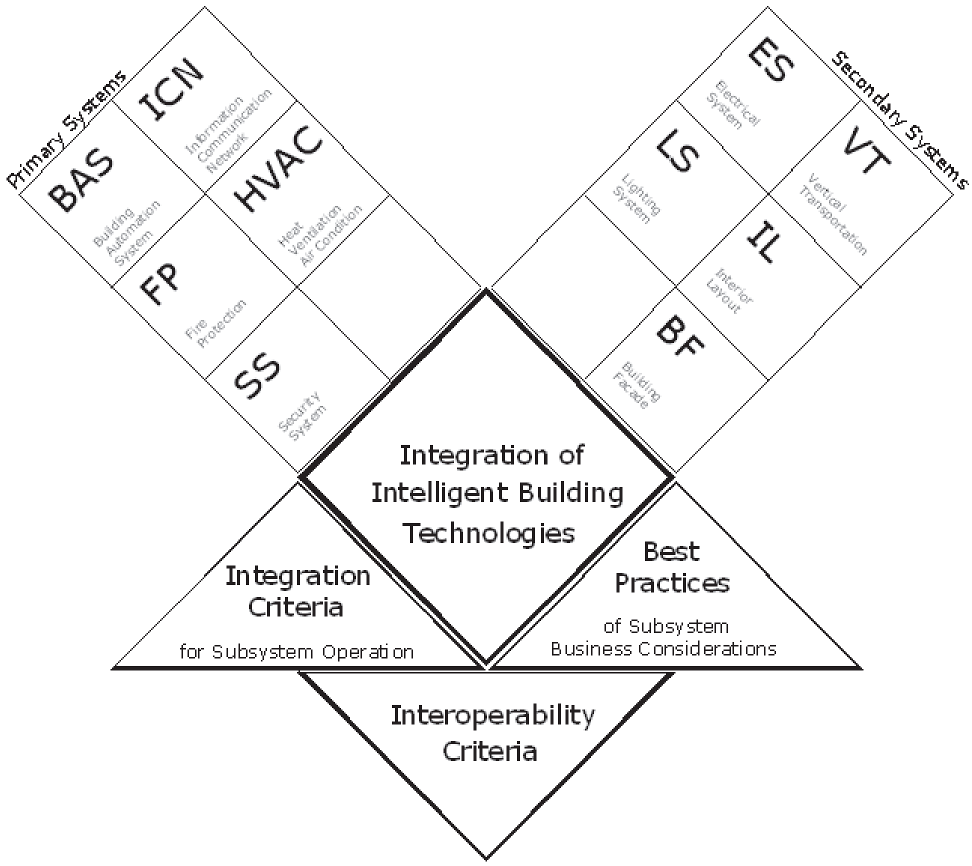

Figure 4. Proposed integration system with three sets of criteria for improving the utilization of intelligent building technologies.

Table 1. Integration Criteria for Subsystem Operation of Intelligent Building Technologies (adapted from Wacks, 2002).

Integration Criteria	Integration Measures
Interaction with other subsystems	• BAS functions • Legacy systems • Network access • Remote access from offsite • Observable and controllable parameters • List of interoperable systems • Diagnosis and repair
BAS equipment	• User interface • Interface between device and network • Communications media • Interconnection among building networks • Power supplies for communications • Communications tools • Building facilities to accommodate network equipment
BAS features	• Network structure • Network access • Network control • Network security • Network configuration • Network capacity • Network bandwidth • Network performance • Error control
BAS management issues	• Network configuration • Network expansion • Network reconfiguration • Network security • Network management integration
System management issues	• Network enabling and disabling • Network configuration • Network commissioning during construction • Network commissioning for tenants • Network provisioning and reconfiguration • Network upgrades • System maintenance • System usage accounting • Operator interface conveniences
Communications protocol issues	• Formal communications protocol • Protocol obsolescence • Internet protocols • Communications protocol conformance

Application layer features	• Application language • Data management • Application language extensions • Application message transfer • Addressing of devices on the network
Lower layer features	• Message security • Session security • Transport layer functions Network layer functions • Data link layer functions • Physical layer

Table 2. Best Practices of Subsystem Business Considerations of Intelligent Building Technologies (adapted from Wacks, 2002).

Integration Criteria	Integration Measures
Subsystem manufacturer	• Manufacturers experience in developing networked subsystems • Participation in trade associations developing standards and practices for building automation • Size of manufacturer market share that is based on proprietary subsystems • Is the manufacturer willing to interoperate with products and components from other manufacturers, including competitors? • Is the manufacturer willing to adapt catalog products to specific requirements of a building installation? • Does the manufacturer participate on national and international standards bodies? • Code modifications • What procedures are in place for the manufacturer to notify users of bugs, fixes, and subsystem updates? • Is the manufacturer willing to provide references to subsystem buyers • Does the manufacturer have experience dealing with electrical and mechanical contractors? • Does the manufacturer have experience in dealing with networking contractors? • Is the manufacturer willing to help sell the benefits of the networked subsystem to tenants? • Is the manufacturer willing to allow building managers or third-party developers to alter the subsystem operation as needed for the building environment? • Can the manufacturer provide names of third-party developers for custom changes in the subsystem? • Are there alternate suppliers of the subsystem technology for a compe titive evaluation, or if the chosen manufacturer were to fail or discontinue support?
Documentation	• Availability of a non-technical summary to help make a business case for the networked subsystem • Appropriate documentation for installers, operators, maintenance personnel, and tenants • Is the manufacturer willing to provide additional details to adapt to building environment?

Integration Criteria	Integration Measures
Cost / benefit issues	• Purchase cost of subsystem with basic communications capabilities • Cost for any installation personnel required • Cost for any tools required for installation and for maintenance • Cost of a systems integrator, responsible for organizing subsystems into a cohesive system via the communications network • Possible cost reduction in building construction because of less space required for raceways and spaces using shared network media or wireless-network solutions • Possible churn-cost reduction from the use of plug-and-play technology and reduction in technological obsolescence by facilitating the easy and economical introduction of new technologies, or replacement of dated technologies • Cost for any inspection and certification of proper and safe operation required by a governmental agency • Costs to building operators for management and maintenance of the subsystem, including any training costs • Cost to outsource or hire facilities operators to run and maintain networked subsystems • Any licensing fees, royalties, or metered operating costs (per use charges) • Costs to tenants to learn and operate networked subsystems • Possibility of offsetting operating costs with revenues from tenants • Benefit of increased employee satisfaction and comfort • Benefit of improved organizational productivity • Cost of expanding the communications network interface • Life cycle costs, considering all the costs listed above • Warranty costs and provisions • Costs of specific contractual provisions for network operation and maintenance shared among manufacturers and third-parties • Impact of network subsystems on liability insurance cost • Benefits of higher market rents sustainable by an intelligent building compared to a conventional building • Benefits of additional income from possible fees for intelligent building services offered by the building management to the tenants • Benefits of lower tenant-turnover because the building services can be adapted to changes in tenants' needs
Training availability	• Installers • Building managers to run the networked subsystems • Maintenance personnel • Tenants • A provision for ongoing training as a requirement of an organization's learning plan for those involved with operations, maintenance, and related aspects of the subsystems
Industry education	• Educational materials for architects, building engineers, and consultants so they can plan networked subsystems • Education for building owners and managers on ancillary services using networked subsystems that can be offered to tenants for revenue beyond the lease • Education of construction companies to install building structural sensors properly during construction for a subsystem to monitor the building structure • Education materials for unions to support the installation of networked subsystems • Education materials for the insurance industry describing the impact of networked subsystems on insurable risks, such as fire and life safety.

Table 3. Interoperability Criteria for Building Systems.

Interoperability Criteria	Interoperability Measures
Function & Standards	• System requirements • Compliance with standards • Application functionality • Dynamic behavior
Operation	• Data elements (types & access) • Node connectivity • Protocols • Information flow / latency • Interpretation • Information utilization
Business Process	• Milestone performance • Productivity • Personnel

7. Potential Benefits of Integrating Intelligent Building Technologies to foster Sustainability

Intelligent building technologies can be substantially beneficial to the various stakeholders including developers and owners, operators and facility managers, and occupants. These benefits can be either functionally desirable or costly effective. Cost effectiveness benefits primarily developers, owners, operators, and facility managers. On the other hand, functional enhancements are mainly enjoyed by occupants. If functional enhancements in the form of, flexibility, reliability, security, and occupants> comfort can be achieved with reduced costs and increased productivity, this will result in increasing return on investment as graphically illustrated in Figure 5.

Developers are concerned with the total cost of ownership of the building, recognizing that higher initial costs are clearly justified if the result is an appropriate payback through reduced operating costs and/or increased building value. Nevertheless, developers generally seek to meet the market’s requirements, with minimum investment. Intelligent building technologies reduce the infrastructure space needs, e.g. fewer conduits, control systems and control locations, increasing the usable space. Effective implementation of intelligent building technologies can be operated with fewer operational staff, using these capabilities to monitor conditions and resolve problems more effectively. At the same time, occupants value the improved services and environment in buildings equipped with intelligent technologies. This produces a tangible and saleable improvement to the building, which is clearly attractive to any developer. The inherent intelligence in intelligent building technologies allows building owners and operators to transfer some building control to the occupants and to improve services accessibility for the end user and facilitate security management. All of these changes provide operational efficiencies and the opportunity for increased revenue. Therefore, intelligent building technologies provide owners and operators with greater operational flexibility, e.g., the ability to operate several buildings from one control centre, improving effectiveness while reducing cost (Reffat and Hamid, 2007).

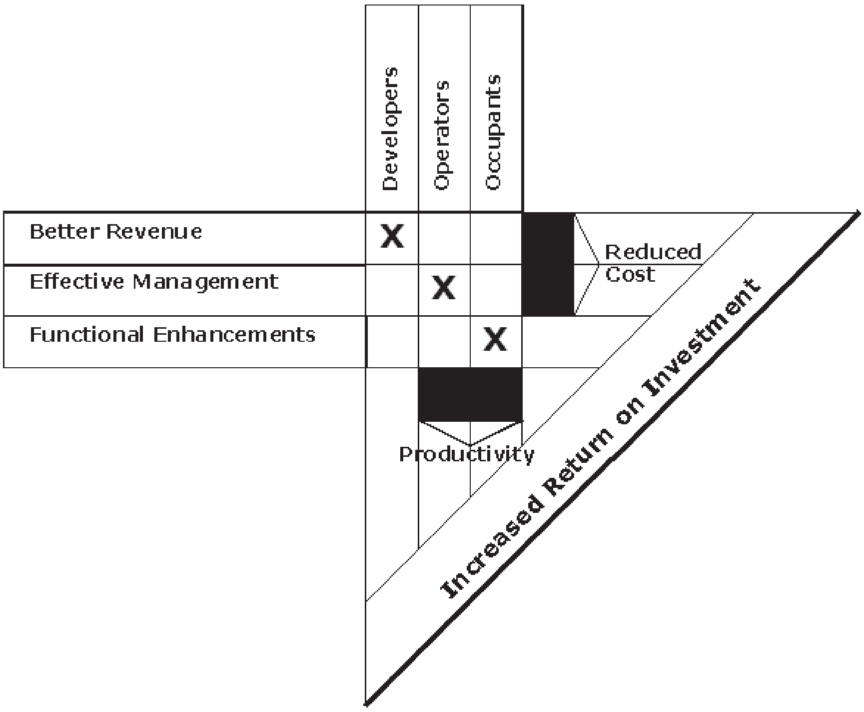

Figure 5. Benefits of intelligent building technologies for various stakeholders.

Building occupants perceive that features of intelligent building technologies bring enhanced value. These premium features focus on two areas. One addresses a more comfortable environment (HVAC, lighting, access and security) and the other relates to services that will improve efficiency and effectiveness. Enhancements of comfortable environments include improved air quality and self managed temperature through enhanced HVAC, on demand lighting and higher quality security that includes parking and elevators and common areas as well as the personal space. Enhanced efficiency and effectiveness requires an infrastructure that provides a broadband, accessible communications facility that gives ready access control by end-users to a comprehensive suite of communication services. Automation achieved through intelligent building technologies reduces the cost of operating staff. A well-equipped intelligent building enables operators to exchange information in real time with occupants. Security arrangements can be integrated between operators and occupants, e.g. visitors can be approved for access to the building, to specific authorized areas in real time, and their location and progress can be monitored by the operator and the occupant. The result is a building that is regarded as superior, desirable and, therefore, more valuable. Occupants will enjoy the benefits of such an upgraded facility and are expected to be more productive (Clements-Croome, 2004).

8. Discussion

Intelligent-building technology is expected to enable multiple structures to automatically respond to adverse weather conditions, energy shortages, nearby fires, or local crime events. Intelligent-building systems actively exchange information to provide a productive environment for occupants at the lowest possible cost. Wireless networks and enterprise- information-technology cabling permit building systems to share data without new wiring. Low-power, low-data-rate wireless networks give intelligent-building systems distributed-sensor nodes to optimize control algorithms. XML and Web-services technology provide a common communications channel between incompatible, automatic building systems (Webb, 2006).

Intelligent building technologies encompass sophisticated systems targeting various facets of building automation. Given the developments in information and communication technology and the increasing level of complexity of intelligent building systems, the paper argues the case to introduce an integration system that facilitates improving the utilization of intelligent building technologies. The proposed system provides three indispensable sets of criteria by which successful integration of intelligent building technologies can be achieved. These measures are integration criteria for sub-system operation, best practices of sub-system business considerations, and interoperability criteria. Detailed and articulated measures for each set of these criteria have been introduced.

Building designers and property managers can substantially boost the efficiency of their real-estate portfolios by appropriately and successfully utilizing intelligent building technologies. Intelligent-building technologies seek to enhance the building environment for occupants while controlling costs. These systems are designed to improve end user security, control, and accessibility, with the aim of increasing worker productivity and user comfort levels (King, 2006). The successful and seamless integration of intelligent building technology will result in providing both the building operator and occupant with an environment that is flexible, effective, comfortable, and secure. By using the proposed integration system to improve the utilization of intelligent building technologies, building operators can enjoy an integrated system within which they can control a network of disparate building automation systems that are interoperable and simplify management, conserve energy, reduce costs and provide security. It is hoped that the proposed system will be used as a quality measure by which a successful integration of intelligent building technologies can be in the reach of building designers, engineers and property managers at various stages of the building life cycle from design, construction, operation and maintenance.

Acknowledgement

The author would like to acknowledge and thank the support of KFUPM for funding this research through the SABIC / Fast Track Research Project.

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دمج تقنيات المبانى الذكية كوسيلة لتعزيزالإستدامة بالمبانى

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ملخص

تمثـل تقنيـات المبانـى الذكية فرصة لتعزيـز الإستدامة بالمبانى من خلال تحقيـق كفاءة إستخدام الطاقـة، المرونة، الدقة، الأمان، وتحقيق الراحة للمستخدمين مع زيادة الإنتاجية وتقليل تكلفة الصيانة والتشغيل. لذا يعتبر التوظيف الفعال للتقنيات الذكية بالمبانى وسيلة هامة لتعزيز الإستدامة بالمبانى. وحيث أن تقنيات المبانى الذكية تتناول نظم عديدة ومتشابكة لمكونات وأنظمـة المبانـى، فإنه يعد من الضـرورة بمكان تطوير نظام الإندمـاج لتقنيات المبانى الذكية ليمثل القاعـدة فى إدارة سبل التعامـل والتفاعـل بين التقنيات الذكية المتنوعـة للمبانى. ويشتمل نظام الإندماج المقترح فى هـذه الورقة البحثية على ثلاثة معايـير جوهريـة لتحقيق الإندمـاج الناجح وهى: معايير الإندمـاج لتشغيل مكونات الإنظمة الجزئيـة، أفضل الممارسات فى الإعتبارات العملية لمكونات الإنظمة الجزئية، ومعايير التشغيل المتبادل. تتناول الورقة البحثية بالتفصيل هذه المعايير الثلاثة ودور كل منهـا فـى تحقيق الإندماج لتقنيات المبانى الذكية. وتستعرض الورقة أيضاً معوقات التوظيف الناجح لتقنيات المبانى الذكيـة. وتوضح الورقة البحثية كذلك المكاسب المختلفة الناتجة عـن تحقيق الإندماج لتقنيات المبانى الذكية ودورها كوسيلة وآداة هامة فى تعزيزودعم الإستدامة بالمبانى.