# Guidelines for Incorporating Smart Building Technologies in the Design Brief

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## Abstract

*To minimize the cost impact of providing smart building technologies, they should be incorporated into the design of new buildings from the beginning since retrofitting these systems into an existing building is far more expensive and disruptive than simply getting it right the first time. This paper introduces guidelines for incorporating smart building technologies in the design brief in order to provide greater opportunities to integrate and consolidate different building system functions into fewer independent systems, which can reduce overall complexity*.

## 1. Introduction

Smart buildings apply technologies to improve the building environment and functionality for occupants while controlling costs. Improving end user security, comfort and accessibility all help user productivity and comfort levels. Building owners and facility managers want to provide this functionality while reducing cost by utilizing smart technologies that make this possible. An efficient integrated system enables a modern, comprehensive access and security system to operate effectively and exchange information with other building systems. Fully integrated functionality will include the ability to open doors, notify responsible staff of unwanted intrusions and ensure that lighting, fire and other building management systems are informed of staff that arrive or depart the building. This information can then be used to manage the local environment and the resulting energy usage. Life safety systems, notably fire systems, are heavily regulated by stringent code requirements. These requirements do not however prevent the information from a fire system being provided to other systems. This opportunity can be exploited to open doors and illuminate a building when fire alarms are received. Transducers (detectors) can measure many building parameters, e.g., vibration, strain and moisture, to continually monitor the building's infrastructure condition. To integrate these systems and exchange information effectively, a ubiquitous and reliable communications infrastructure is needed. Integration considerations may be addressed through standards and conventions, or manufacturers' protocols. Since proprietary solutions permeate the industry, total inter-working is currently unattainable. The future will require full interoperability, with information exchanged among all systems. There is an opportunity for technologies that translate protocols and conventions so that systems are fully interoperable [1].

To minimize the cost impact of providing smart-building capabilities, they should be incorporated into the design of new facilities from the beginning since retrofitting these systems into an existing building is far more expensive and disruptive than simply getting it right the first time. Starting early affords greater opportunities to integrate and consolidate different building system functions into fewer independent systems, which can reduce overall complexity. Smart-building infrastructure is least expensive when it is planned from the earliest phases of the design process. Costs for retrofitting buildings to include smart-building infrastructure, or for changing construction documents for a new building late in the design phase, are quite prohibitive. Architectural design for conventional buildings is generally not intended to accommodate a structured cabling system or raised access floors. Therefore, adding intelligence to an existing building is quite costly from an architectural perspective. Further, changing out existing pneumatic controls in a building system can add exorbitant cost, whereas installation of a new full- direct digital controls (DDC) system has relatively low capital costs. Also, the high costs associated with premature replacement of cabling systems justify the installation of high-bandwidth systems in new buildings. Finally, the costs for integrating separately controlled building systems into one BAS can be quite high due to the need for communication gateways and revised software. Operating cost savings achieved through smart-building infrastructure more than make up for the incremental capital costs. Improved HVAC and lighting controls, along with smart metering technologies, can significantly reduce both energy and maintenance costs [2].

## 2. Benefits of smart building technologies

Smart 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 1.

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. Smart building technologies reduce the infrastructure space needs, e.g. fewer conduits, control systems and control locations, increasing the usable space. Effective implementation of smart 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 smart technologies. This produces a tangible and saleable improvement to the building, which is clearly attractive to any developer. The inherent intelligence in smart 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, smart 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.

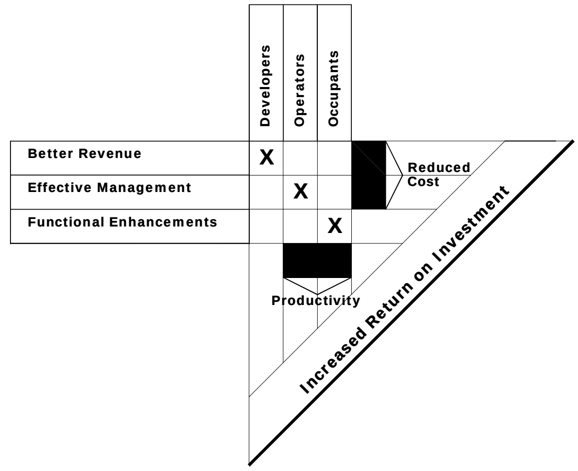


Figure 1. Benefits of smart building technologies for various stakeholders.

Building occupants perceive that features of smart 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 smart building technologies reduces the cost of operating staff. A well-equipped smart 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 [1].

## 3. Challenges for successful implementation of smart building technologies

Challenges for successful implementation of smart 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.

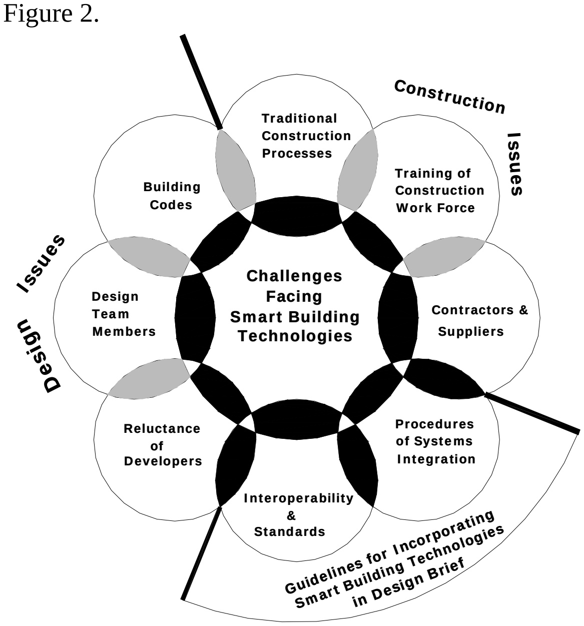


Figure 2. Challenges facing the successful implementation of smart building technologies.

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 smart 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 smart 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 a smart building. Furthermore, building codes require substantial update to facilitate the implementation of smart 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 smart building technologies.

The development of procedures required in implementing an integrated smart building system, and the lack of proven interoperability and universally accepted standards are major challenges in achieving successful implementation of smart building technologies. This paper attempts to overcome this latter difficulty by introducing guidelines for infrastructure requirements of smart building technologies and guidelines for incorporating smart building technologies in the design brief as presented in the following two sections respectively.

## 4. Guidelines for infrastructure requirements of smart building technologies

The building services are integrated under one building automation system (BAS) platform. For efficient integration, layout of building services and the distribution network of their associated components is a must. Since information exchange between various building systems to the central BAS system happens via a network of cables, it is also essential to lay the cabling in a structured manner. The basic considerations that a designer should keep in mind while planning the building services are as follows:

(a) Building Structure: A simple modular approach towards the building structural system best suites the needs of a smart building. A modular layout of structural elements allows greater flexibility for the distribution of heat, ventilation and air condition (HVAC) and lighting service duct work. Various structural modules can be clustered and served by a single horizontal duct which is vertically connected through a shaft. The vertical shaft could be centrally located or can be planned on one of the building edges. This arrangement allows ease of future expansion by multiplying the modules along with the vertical services hub.

(b) Equipment Room: The components of the various services such as HVAC, boilers, water tanks etc. can be located in their conventional locations i.e. in the basement or on the roof. However, the BAS needs to be located in an appropriate floor since it requires a controlled environment. Sized as any other services room, the equipment room should be air-conditioned with appropriate lighting.

(c) Vertical Riser: The vertical organization of building services could be in the form of a central vertical service hub. However, it is recommended to separate the structured cabling connecting the BAS from the rest of building systems' services. The BAS cabling and communication for the backbone subsystem could be housed in a well accessible riser that is ventilated. An enclosure housing the administration subsystem could be attached to this riser at every floor allowing easy circulation of horizontal cabling as a horizontal subsystem.

(d) Horizontal Distribution of Services: For efficient and flexible distribution of building services components such as HVAC and lighting conduits, and the BAS cabling, a raised floor system will best suite a smart building. The raised floor is often referred to as Under-Floor Air Distribution (UFAD) system that is adaptive, flexible, and environmentally efficient distribution system. Concurrently, an optimum modular layout of BAS and coverage area subsystem can be achieved. A combination of a raised floor and a lowered ceiling system could be used with the HVAC system occupying the conventional location in the ceiling. However, such solution does not prove to be beneficial enough. When UFAD system is employed solely for cable management, this necessitates installing conventional ceiling-based air distribution system. The result is that floor to ceiling heights, space planning, and future maintenance are restricted. Alternatively, integrating mechanical and electrical infrastructure within a single under-floor plenum, readily accessible and adjustable via the raised access floor system, offers advantages at all stages in a building's life cycle, from planning to construction to occupancy. This will work efficiently with vertical wiring that runs from the main equipment room to satellite rooms or closets serving each floor/zone and horizontal modular cabling installed within a raised floor system handling transmissions between these closets and each individual workstation.

(e) HVAC, Lighting and other conduit network: the UFAD system makes use of raised floors to provide an accessible and adjustable HVAC network that shares its distribution space with a cable management network, thus reducing the problems of accommodating each of them separately. There are various benefits associated with integrating occupant-controlled infrastructure within one accessible zone, potentially reducing the initial cost of air distribution systems. For instance, the floor plenum will be utilized for cable management purposes and thus its cost will not be considered solely as HVAC expense. Such integration also simplifies the job of the architect that is traditionally faced to reconcile numerous grids of components in a building ranging from HVAC grilles to desk units. The most significant advantage of this integration becomes apparent with high level of coordination and compatibility of various systems' networks that drastically reduce the costly downtime of building systems. The flexibility of an integrated under-floor plenum allows the layout of floor diffusers and cable outlets to be determined once furniture configurations have been decided upon. The removal, insertion, and relocation of a floor diffuser is a simple process involving the removal of carpet tiles and a floor panel using a suction grip, or similar tools and the laying down of an alternative panel and corresponding carpet tile. Integrating the distribution of conditioned air and voice, power, and data within the under-floor plenum optimizes the use of floor area and minimizes the depth of plenum needed for the drop ceiling. In some cases ceiling plenums can be eliminated altogether when an alternative means of removing return air from the space is provided, such as return grilles located at a high level on internal walls. Architecturally, this provides a greater opportunity to utilize the ceiling plane for creative lighting effects that are either natural or artificial in addition to other space-enhancing devices. Architects and occupants will also have more freedom in terms of planning the workplace without the restriction of locating ceiling grilles.

## 5. Guidelines for incorporating smart building technologies in the design brief

The proposed guidelines for incorporating smart building technologies in the design brief articulate specific considerations that should be thoroughly taken into account by the design team members at the very early stages of the design process of buildings. These guidelines are targeting the following smart building systems: building automation system, network system, lighting systems, HVAC system, fire protection system, and security services. For each of these systems specific guidelines are outlined along the benefits attained by adhering to these guidelines as shown in Table 1.

Table 1. Guidelines for incorporating smart building technologies in the design brief.

| Smart Building Technologies | Guidelines for incorporating smart building technologies in the design brief | Potential benefits |
|---:|---|---|
| **Building Automation System (BAS)** | • Integrate all building systems easily without the need of external gateway<br>▪ Usage of single cabling infrastructure supporting building services control singles<br>▪ System uses distributed data acquisition and control technology supporting a multilayered system architecture in setting up multiple monitoring and control centers | • Enhanced productivity<br>• Cost and Energy efficiency |
| | • Multiple control PC based graphical workstation functioning remotely via an internal or/and world wide network | • User comfort<br>• Ease of use |
| | • Modular system with convenient access, flexible application, easy instillation and expansion capabilities<br>▪ Integrated building safety, asset protection and safety modules<br>▪ Integrated tracking and monitoring of physical assets and personal<br>▪ Web based technology, user interface, controllers, IP convergence and wireless building technology controls | • Cost and energy efficiency<br>• Enhanced productivity |
| **Network System** | • Two network protocols namely LonWorks and BACnet networks dominate the commercial intelligent building market. Both networks efficiently integrate building services like HVAC, security, access control, fire safety, vertical transportation, maintenance, waste management and lighting system.<br>• These two technology standards have gained wide acceptance and application. However, comparing market presence, greater market acceptance for LonWorks technology over BACnet is noticed. This implies a greater demand for LonWorks products and an active community of manufacturers and system integrators. | • Ease of use<br>• User comfort<br>• Enhanced productivity<br>• Cost and energy efficiency |
| **Lighting System** | • Creation of task specific lighting situation and zone specific general lighting | • User comfort<br>• Enhanced productivity |
| | • Better Lighting Control<br>▪ Usage of dimmers for:<br>• Architectural dimming<br>• Day light harvesting dimming<br>• Pre set time-event controlled dimming<br>▪ Occupancy sensing<br>▪ Motion Detection<br>▪ Thermal image detection sensors<br>▪ Low voltage sensing mechanism<br>▪ Photocell detection of lighting levels for both external and internal areas<br>▪ Control of external shading devices<br>▪ Digital lighting controller<br>• Remote/on-site access<br>▪ Low voltage switches and control breakers<br>▪ Power outlet controls | • Cost and Energy efficiency<br>• User comfort |
| | • Energy management mechanism | • Cost and Energy efficiency |
| | • Usage of existing wiring structure (in case of retrofit projects) | • Cost effective |
| | • User friendly control panel with graphical user interface | • User comfort |
| **HVAC System** | • Selection of appropriate module and equipment components | • Cost and energy |

| | | |
|---|---|---|
| | to suite building needs (major components like chillers, fans, air/water circulation network) | efficiency<br>• User comfort |
| | • Usage of intelligent controls<br>• Centralized control of HVAC equipment components<br>▪ Remotely accessible system<br>▪ Graphical user interface | • Cost and energy efficiency<br>• User comfort |
| | • Sensor based adaptive micro-climate control<br>▪ Occupancy sensors based on motion detection and/or thermal imaging<br>▪ Humidity sensors to correct humidity levels<br>▪ Air velocity flow sensors<br>▪ Water/air warning/leak detection sensors<br>▪ Indoor air quality monitoring sensors | • User comfort<br>• Enhance productivity<br>• Energy efficiency |
| | • Efficient building envelope design to contain heat gain/loss | • Cost and energy efficiency |
| | • Intelligent Air-handling unit controller<br>▪ Provide individual environmental control to users and work stations zones | • User comfort<br>• Enhance productivity |
| | • Energy monitoring mechanism | • Cost and energy efficiency |
| | • HVAC system diagnostic and maintenance agent | • Cost and energy efficiency |
| **Fire Protection** | • Efficient fire protection zoning design and instillation of zone wise isolation mechanism | • User comfort<br>• Safe environment |
| | • Early fire detection<br>▪ Usage of optical smoke detectors<br>▪ Manual and integral sensitivity testing/alarm verification<br>▪ Pre-active fire detection and control mechanism<br>▪ Air sampling based smoke detection<br>▪ Remote fire detection sensors | • User comfort<br>• Safe environment<br>• Asset safety |
| | • Early warning and notification<br>▪ Visual and vocal emergency alarm system<br>▪ Paging, call-up and graphic display mechanism<br>▪ Quick activation of emergency protocols and zonal isolation on notification including power breakage | • User safety and comfort |
| | • Efficient fire suppression<br>▪ Thermal imaging based sensors<br>▪ Quick response mechanism<br>▪ Clean agent fire suppression, Carbon Dioxide fire suppression<br>▪ Water mist and adaptive water spread sprinkler | • Safe environment<br>• Asset safety |
| | • Intelligent central fire protection panel<br>▪ Graphical user interface with remote access facility<br>▪ Ease of programming, maintenance and operation | • Safe environment<br>• Asset safety |
| **Security services** | • Wired and wireless security sensors<br>▪ Magnetic and laser sensors<br>▪ Motion detectors<br>▪ Glass-break detectors<br>▪ Key chain transmitters<br>▪ Window/door transmitters<br>▪ Personal panic button | • User safety<br>• Asset safety |
| | • Access management<br>▪ Password certification system<br>▪ Smart card access mechanism<br>▪ Security mode swapping, day/night modes<br>▪ Finger print, palm reading based system<br>▪ Identification based access to building facilities and controls including initialization of user defined pre-set conditions such as environmental control selection, etc. | • User comfort<br>• Asset safety |

| | | |
|---|---|---|
| | ▪ Network based instant access changes to doors and alarm points<br>▪ Report event triggered activities via alarms, visual devices, call-ups, pager massages, video clip storage | |
| | • Surveillance system<br>▪ CCTV monitoring equipment allocated in sensitive locations and access points<br>▪ Storage and retrieval of visual monitoring protocol via network with satellite uplink facility | • Asset safety |

## 6. Conclusion

New technologies provide both opportunities and challenges. Building systems can now be managed using automation, with less dependence on humans. Smart building technologies will promote the integration of control systems that enhance building and end-user functionalities. Market drivers of smart building technologies include the owner and operator's desire to achieve a competitive advantage through more cost-effective and featured locations and the occupant's need for space that is comfortable, secure, versatile and productive.

Some of the challenges for achieving successful implementation of smart building technologies include the development of procedures required in implementing an integrated smart building system, and the lack of proven interoperability and universally accepted standards. This paper has attempted to overcome such challenges by introducing guidelines for infrastructure requirements of smart building technologies and guidelines for incorporating smart building technologies in the design brief. These guidelines articulate specific considerations that should be thoroughly taken into account by the design team members at the very early stages of the design process of buildings. At the same time, the guidelines for incorporating smart building technologies aim at increasing the level of awareness of design team members at the early stages of the design process on various dimensions that should be investigated in order to achieve successful implementation of smart building technologies. The guidelines have targeted certain smart building systems including: building automation system, network system, lighting systems, HVAC system, fire protection system, and security services.

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